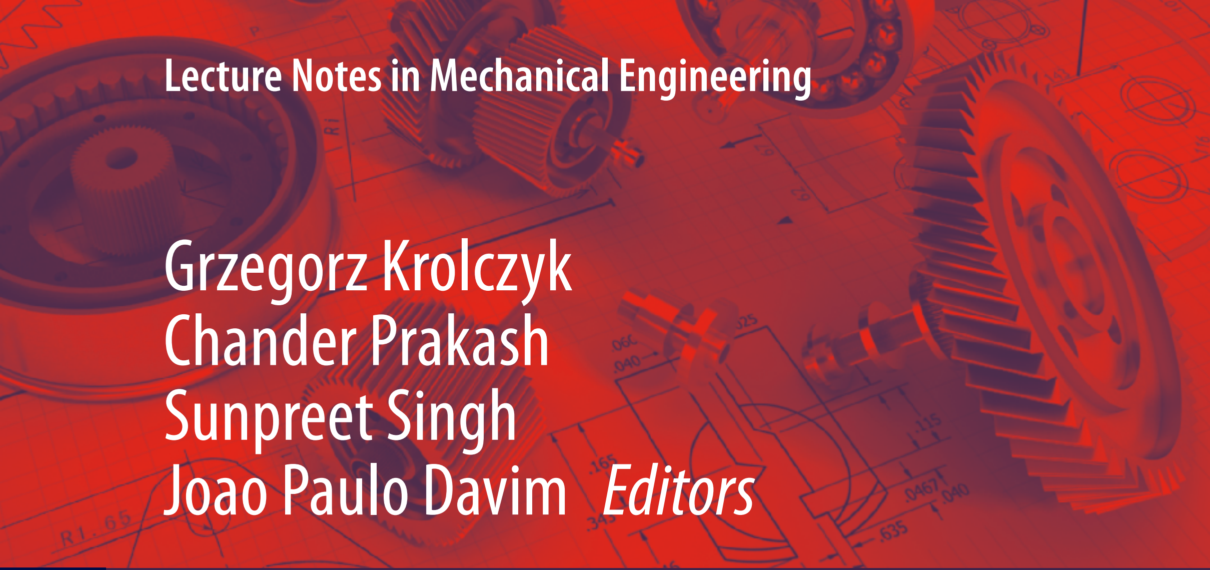

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Grzegorz Krolczyk
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Advances in Intelligent Manufacturing

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Editors

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Preface

The book entitled *Advances in Intelligent Manufacturing*, by Springer aims to present the comprehensive and broad-spectrum picture of the state-of-the-art research, development, and commercial perspective of various discoveries conducted in the real-world of intelligent manufacturing. The book focuses on optimizing manufacturing resources, improving business value and safety, and reducing waste—both on the floor and in back-office operations. It highlights the applications of the latest manufacturing execution system (MES), intelligent devices, machine-to-machine communication, and data analysis for the production lines and facilities. This book will be useful to manufacturers of finished goods and of subassemblies in the automotive, agriculture, and construction equipment sector. It will also provide solutions to make production strategies exceptional and can be a useful reference for beginners, researchers, and professionals interested in intelligent manufacturing technologies.

Opole, Poland	Grzegorz Krolczyk
Phagwara, India	Chander Prakash
Singapore, Singapore	Sunpreet Singh
Aveiro, Portugal	Joao Paulo Davim

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Six Sigma Methodology and Implementation in Indian Context: A Review-Based Study

Mahipal Singh, Rajeev Rathi, Dinesh Khanduja, Gurpreet Singh Phull, and Mahender Singh Kaswan

1 Introduction

In the present era, every organization is focusing on quality, productivity, lower cost, and customer delight to sustain in the competitive market. The industrial managers have clearly understood that, if they want to sustain in this competitive environment, there is a huge need to achieve continuous improvement in terms of quality and service of the product. Various quality improvement strategies like Total Quality Management (TQM), Statistical Quality Control (SQC), Zero defects, Six Sigma, etc., were adopted by industries for sustainable improvement [1]. Among these strategies, Six Sigma is cited as an emerging, most effective continuous improvement strategy because it focuses on the reduction in variation [2–4]. Six Sigma is a prominent strategy, which recognizes and eliminate defects, breakdown or faults, reduce cycle time, increase quality and reliability, decrease unit cost in systems by concentrating on parameters that are having great importance of success [5, 6]. Six Sigma is fluctuating from different quality improvement tools because of the systematic and rigorous structure of implementation, truth-based selections, and control commit to guarantee current quality control in an exceeding method.

The initiation of Six Sigma as an improvement tool was carried out by Motorola in 1980 in their business and it was fully adopted in 1988 [7]. After 1990, many other companies like Honeywell, GE, Sony, Caterpillar, etc. also have employed Six Sigma strategy for improving quality and service of products and reaching up to customers' expectations and got benefits like cost saving per units production as shown in Table 1 [8, 9].

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Table 1 Six Sigma implementation: gains

Company	Year	Gains
Motorola	1986	Reduced the manufacturing cost of $1.4 billion from 1987 to 1994
GE	1995	Annual benefit of $2.5 billion
Honeywell	1998	Reduced the time required to introduce fresh products 16% and reduced manufacturing cost by $1 million
Ford	2000	Saved $1.5 billion money in 2001–2003
Wipro	1997	After adopting Six Sigma, Wipro completed 91% project on time
TISCO	1998	Minimized inadequacies in design, imperfect product
Mumbai Dabbawala	1987	Reduced error and found only one error in every 8 million
Pfizer	1999	5–10% defect reduced in medicines preparation

In recent years, due to the popularity of Six Sigma worldwide, small-scale industries' interest is also increased to know the facts about Six Sigma and its methodology to implement in their projects. The authors observed that most of the articles on Six Sigma present a direct implementation of Six Sigma and their results. But still, the literature lacks to present how to apply Six Sigma? What are the best methodologies and tools for each phase? Keeping this point at the frontier, the main motive of the current study is to present Six Sigma key concepts, methodology, and implementation. Moreover, the area of future research direction is summarized.

2 Six Sigma: Approach

Business excellence can be achieved by having quality in every process and product of the company by meeting the customer's expectations and all other stakeholders. This objective can be achieved if all processes are managed efficiently to minimize waste and reduce variations [10]. So for this purpose, various approaches have been implemented such as TQM, TPM, Kaizen, Lean manufacturing, Six Sigma, Zero defect, etc. [11]. Six Sigma has some overlap with all these approaches to achieve business excellence [12]. Six Sigma is a statistically based approach that improves procedures that seek to decrease flaws by recognizing and excluding the sources of business process discrepancy. Six Sigma word specifies three elements such as measure, target, and philosophy. Six Sigma measures how far from perfection a method deviates, targets to achieve 3.4 billion defects per opportunities and a business philosophy focussing on reducing costs by reducing variability in process and product [13]. Six Sigma methodologies offer the methods and instruments for enhancing capacity and decrease any process flaws. The word level of Six Sigma implies 3.4 deficiencies per million possibilities (DPMO) or a 99.999660% achievement rate [14]. Defect level is measured in terms of parts per million (PPM) or defects per

Table 2 Sigma value and equivalent yield

Sigma value	**DPMO**	**Yield %**
1	691,462	30.85
2	308,537	69.164
3	66,807	93.39
4	6210	99.38
5	233	99.9767
6	3.4	99.9996

million opportunities (DPMO). Table 2 shows the DPMO as a function of the Sigma level [15].

In statistics, Sigma (σ) is the Greek letter, which is the standard deviation. Standard deviation means variability from mean. Sigma calculates the difference between a given process and perfection. If the value of Sigma is increased, then performance will be better [16, 17]. Six Sigma measures the quality that strives for near perfection. The area under σ, 2σ, 3σ, 4σ, 5σ, and 6σ are given Fig. 1. Under 3σ limits, the percentage of conformance is 99.73% and 66,807 parts per million defects. To accomplish 6σ, a process must not provide more than 3.4 DPMO, i.e., area under curve is 99.99966%. The value of the standard deviation in 6σ is lesser than the 3σ.

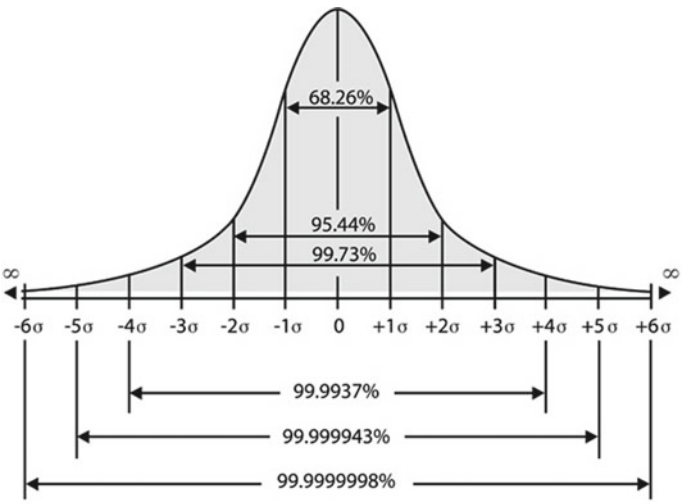

Fig. 1 Six Sigma: statistically [20]

3 Six Sigma: Methodology

This section illustrates the approach used in any company to incorporate Six Sigma. The fundamental goal of the Six Sigma technique is to introduce a measurement framework that focuses on process improvement and variance reduction in the execution of specific projects [18]. At any association, Six Sigma aims to analyze the excellence that attempts for near perfection and reduce the variation in process [19]. In the typical approach used in Six Sigma, the actual problem is converted into a statistical problem and estimates the relation between input and output variables and finally converted into practical solution using two methodologies as discussed in the following sections [20].

3.1 DMAIC Methodology

The cycle of Define–Measure–Analyze–Improve–Control (DMAIC) is the methodology used to effectively implement the Six Sigma strategy for any project. Edward Deming created it and is helpful for enhancing business processes to decrease defects [21]. Perhaps the DMAIC cycle is best considered as a more detailed and prescriptive version of the well-known Plan–Do–Study–Act cycle by Deming. Figure 2 shows the steps of the DMAIC process. DMAIC relates to a data-driven cycle of enhancement used to improve, optimize, and stabilize current products, processes, or services [22]. The DMAIC enhancement cycle is the key methodology for driving Six Sigma initiatives. DMAIC's every step was studied as follows:

Define. This phase is very crucial for every project because it is very necessary to select the right job or process for improvement. For fruitful employment of Six Sigma, right project selections are very important for any business organization. So, the define phase is completed different steps as follows [23]:

- Formulate the process mapping to identify where the origin of problem is.
- Carry out process input, output, and several controls of the procedures.
- Construct a chart which shows the responsibility of each employee for project, resources of project.
- Identify the internal and external customers and justified how this problem related to customers' pleasure.

Measure. In the measure phase, the main objectives are to estimate the present procedure presentation and recognize the potential input factors which are thought to affect the output. The main key point needs to be considered in this phase are the following [24]:

- Determine the process yield and DPMO of the current process.
- Compare the current process with the benchmarking process in terms of performance.

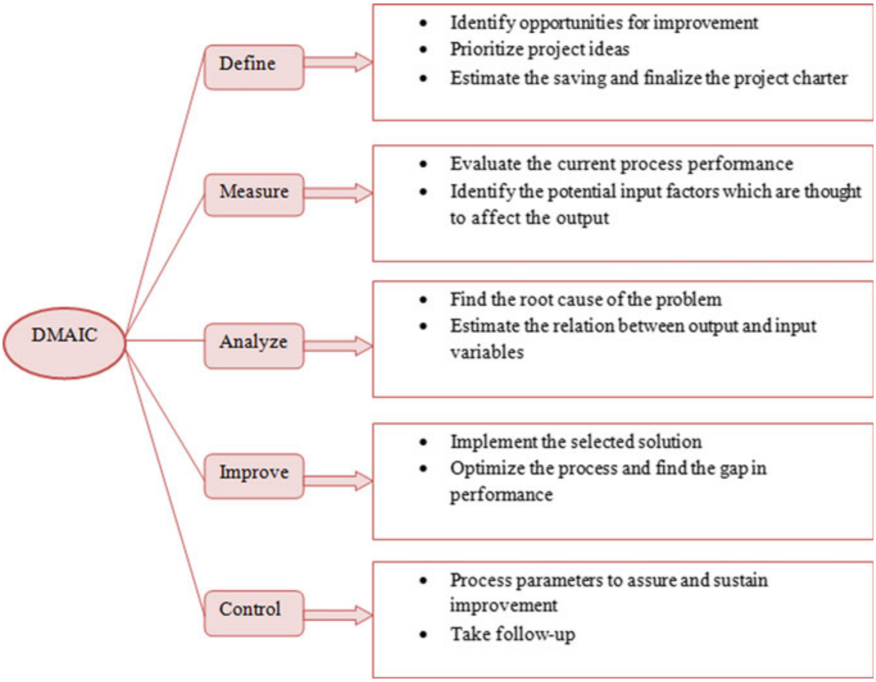

Fig. 2 DMAIC methodology

- Identify strengths and weaknesses and regulate the gaps for development.

Analyze. In this phase, the relation between input and output factors is characterized. Some important points need to be considered in this phase are as follows [25]:

- Analyze the collected data and understand the nature of data.
- Determine the root cause of the problem in the process.
- Understand the variability of the root cause of the problem and prioritize them for further investigation.

Improve. Improvement measures are chosen and enforced on the basis of the analysis stage findings. Usually, optimization is necessary to get the best out of the process. Some key points are necessary for this phase [26]:

- To analyze the effect of every solution using a criteria decision matrix. Those solutions which have a great effect on consumer happiness and bottom-line saving of organization are needs to be examined and recommend for implementation in the organization.
- Find risk associated with potential solutions.
- Validate improvement by calculating Sigma level of process.

Control. Once the solution is implemented and validated, it is essential to ensure that improvement is sustainable. In this phase, there are need to focus on the following steps [27]:

- Develop new procedures and standards for long-term gain.
- Determine process capability using various charts.
- Verify benefits and cost saving.

During the implementation of DMAIC methodology, it becomes necessary to know about the suitable tool used for each phase of DMAIC.

In the current era, there are significant numbers of quality improvement tools available, so the selection of appropriate tools for a specific phase is not an easy task. Tools are basic instruments and necessary ingredients of a process for the success of a project [28].

As a consequence, it is essential to highlight which instruments in which stage can be more efficient. Therefore, it is essential to understand how, when, and what instruments are to be used in procedures of issue solving or improvement [29]. The selection of the right tool for the right phase becomes very important for the researcher and practitioner. The authors have complied literature related to the tools used for Six Sigma employment in several businesses. Table 3 represents the suitable tools for every stage of the DMAIC Six Sigma approach [30].

3.2 DFSS Methodology

Strategy for Six Sigma (DFSS) is an organized approach to designing, designing, optimizing, and certifying the capability of a fresh product design or manufacturing process. It meets the demands of the client and can generate the products at the quality point of Six Sigma. DFSS is more suitable than DMAIC because it is implemented early in the design of the product [31]. A more suitable roadmap of the DFSS approach was introduced to design new components and improve quality, i.e., IDOV (Identify, Design, Optimize, Validate) and the same approach was implemented in the automotive industry to improve the engineering design [32]. A suitable approach DMADV (Define–Measure–Analyze–Design–Verify/Validate) has been implemented to accomplish professional quality and to meet consumer expectations [33]. The steps of DMADV roadmap are listed in Fig. 3.

The key success of DFSS methodology is the right selection of tools for the right phase. So the authors have listed various tools according to their significance for the right phase of the DMADV cycle. These tools have been collected from exhaustive literature as evident in Table 4 [34–36].

Table 3 DMAIC tools

Tools	D	M	A	I	C
Chart					
PERT, Gantt chart	✓				
Pareto analysis	✓				
Process mapping		✓			
Value stream mapping		✓		✓	
FMEA		✓	✓		✓
Cause and effect matrix		✓	✓		
MSA		✓			✓
Process capability		✓	✓	✓	
Exploratory data analysis	✓	✓	✓	✓	
Life data analysis		✓		✓	
Multi-vari analysis			✓		
Hypothesis testing			✓	✓	
Confidence intervals			✓	✓	
Power and sample size			✓	✓	
ANOVA		✓	✓	✓	
Correlation and regression			✓		
Multiple regression			✓	✓	
DOE			✓	✓	
Response surface methods				✓	
Evolutionary operation				✓	
SPC	✓	✓		✓	✓
Production part approval process					✓
Control plan, documentation					✓
Prioritization matrix				✓	
AHP			✓		
Brainstorming	✓		✓	✓	
Kanban					✓
Poka-yoke					✓
Variable control chart					✓
Attribute control chart					✓
5 Why 5 How			✓		✓
Affinity diagram			✓		
SIPOC	✓		✓		

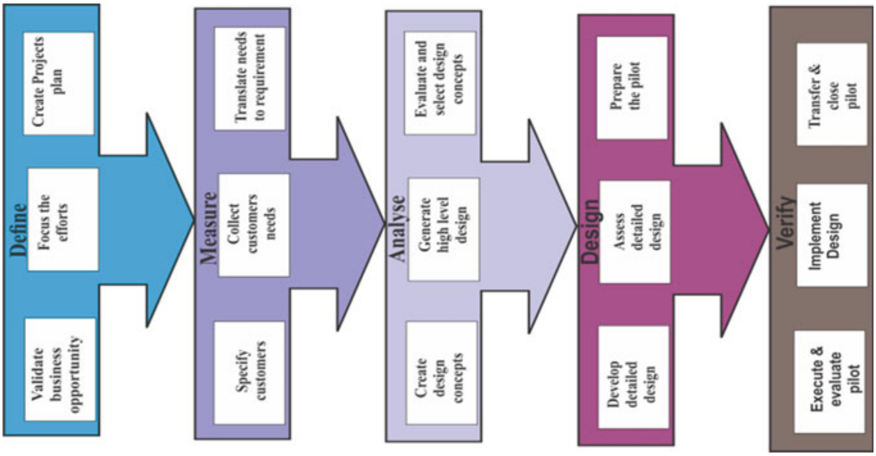

Fig. 3 Roadmap of DMADV approach

Table 4 DFSS tools

Tools	Define	Measure	Analyze	Design	Validate
Business planning	✓				
Market analysis, survey	✓				
Charter and teaming	✓				
KJ analysis		✓			
Kano model		✓			
QFD		✓			
APQP phase gates	✓	✓			
Developing and validating measurement system for CTQs		✓			
Design scorecard		✓			
Critical parameter management			✓		
P-diagram			✓		
Design Review			✓		
Triz FMEA			✓	✓	✓
Reliability engineering			✓		
Creating detailed design				✓	✓
Design analysis				✓	✓
Robust design				✓	✓
Tolerance analysis				✓	✓
DFX				✓	✓

4 Employment of Six Sigma in Indian Context

In this section, the authors discover various trends of Six Sigma and profits of fruitful implementation of Six Sigma in various organizations in India. Various case studies related to the employment of Six Sigma in Indian manufacturing atmosphere have been downloaded from the reputed database and read one by one with full attention. The summarized results of the study have been described in Table 5.

Most researchers and practitioners used DMAIC methodology during the implementation of Six Sigma rather than DFSS. Actually, DMAIC methodology mainly focuses on process improvement, but DFSS focuses on design or redesign the product in any manufacturing organization [35–39]. In this paper, the authors have presented many case studies in which Six Sigma has been implemented successfully for improvement in enterprises. There are many success factors acting behind the successful implementation of the Six Sigma approach in any project. The authors have pointed out the top ten enablers from the literature and evident in Table 6.

5 Result and Discussion

The present paper is focused on the Six Sigma approach, methodology, and successful implementation in the Indian manufacturing environment. Six Sigma is a logical business strategy that has approach to identify and eliminate the failure or defects of any product and process [40–42]. The basic concept of Six Sigma is based on 3.4 defects per million opportunities (DPMO) or a success rate of 99.999660%. Six Sigma is based on two methodologies as DMAIC and DFSS as shown in Figs. 2 and 3. DMAIC methodology is used to reduce the variation in existing processes or products using steps as define–measure–analyze–improve–control, but DFSS methodology is applied for reducing defect by redesigning the product using steps define–measure–analyze–design–verify [43, 44]. For completing all steps of DMAIC and DFSS, various tools are used as elaborated in Tables 2 and 3, respectively. The selection of tools for a particular phase is based on the nature of process and product. It becomes very necessary to select the right tool for the right step for the right project for the successful implementation of Six Sigma. Six Sigma has been successfully implemented in manufacturing as well as service sectors of developed countries like Japan, USA, UK, etc. But the main focus of this paper is to present the implementation of Six Sigma in the manufacturing sector of developing countries like India. The manufacturing sectors of India are still facing challenges in the successful implementation of Six Sigma [57]. Many researchers and practitioners have tried to implement Six Sigma in the manufacturing sector of India and up to some extent, they got successes also. So the author summarizes the results of the successful implementation of Six Sigma in the Indian manufacturing sector as shown in Table 4. For successful implementation of Six Sigma, various factors have been identified which plays a lead role in Six Sigma implementation. From Table 5, it can be decided that if any

Table 5 Six Sigma implementation in Indian context

Author, Year	Sector	Remarks
Gandhi et al. [45]	Casting Industry	In this study, Six Sigma has been implemented for reducing rejection rate of the cylinder block in casting and investigation reveals that defects occurring due to blowholes has been reduced from 28,111 to 9708 PPM, which saves INR 1,256,640 annually
Raman and Basavaraj [46]	Capacitor Manufacturing Industry	This research work identifies the root causes of defects in the capacitor during manufacturing in the northern Indian manufacturing industry using DMAIC and found that OTR are main causes of rejections and further solutions have been given to overcome them
Srinivas and Sreedharan [47]	Automotive Indian Industries	In this study, the root causes of failure of automotive components in the spare distribution center have been found out using the DMAIC approach. The results of the current study present minor change in packing style of automotive component reduce the failure of components
Nupur et al. [48]	Garment Manufacturing Industry, India	This paper presents the application of DMAIC methodology to diminish defects in a cutting process of garment manufacturing industry and results shows that Sigma level increase from 3.1 to 4.7 for continuous improvement
Bhowmik et al. [28]	Manufacturing Industry, India	In this research, Six Sigma synergy and constraint theory were introduced to reduce the production system flaws. System re-engineering raises manufacturing limitations and enhances product quality by decreasing flaws
Rathi et al. [26]	Indian Automotive Sector, India	This article gives a method for best Six Sigma project with fuzzy logic for enhancement in an Indian automotive industry using the VIKOR method
Desai and Prajapati [49]	Plastic Parts Manufacturing Unit, India	DMAIC approach is used to improve the quality of the product by improving the injection molding process. The results show that critical factors like contamination, short molding, flash, and injection point are reduced. It saved the annual cost of INR 10.80 lacs
Rathi et al. [23]	Indian Automotive sector, India	Best Six Sigma project is selected to improve an Indian automotive sector by combining MADM with fuzzy logic

(continued)

Table 5 (continued)

Author, Year	Sector	Remarks
Rathi et al. [5]	Automotive Sector, India	It presents an approach used for the right selection of Six Sigma project using fuzzy logic based TOPSIS method. The findings indicate that for better enhancement, the Shox machine shop is the best Six Sigma project
Rathi et al. [6]	Automotive Sector, India	This article uses the fuzzy logic based AHP technique to investigate a framework used to select capacity waste variables in an Indian automotive industry. Results indicate that conveyor malfunction in the CLG segment is the most critical factor responsible for power waste responsible for capacity waste in CLG section
Malek and Desai [50]	Die Casting Manufacturing plant, India	In this paper, DMAIC methodology was implemented for reducing rejection in the pressure die casting process. Results show that the sigma level increased from 3.1 to 3.7 by reducing the rejection rate from 15.50% to 4.47% which is 71.2% improvement and save up to INR 1,827,402 annually
Sekhon et al. [3]	Forging Unit Ludhiana, India	This paper presents Six Sigma methodology was used to detect forging defects and results show that 83% defects were due to cracks, scaling, and low hardness
Singh and Kumar [51]	Small-Scale Industry, Haryana, India	In this paper, Six Sigma was used to improve production by reducing the rejection rate. The results show that the rejection rate of nozzle head of the hydraulic laser machine has decreased and the sigma level increased from 2.21 to 5.64. The main reason for rejection was nozzle hole diameter
Parsana and Desai [11]	Indian Manufacturing Unit, India	This paper presents the successful implementation of DMAIC methodology for reducing the variation in process of the Indian manufacturing environment
Kumara and Khanduja [15]	Small-Scale Industry, India	DMAIC methodology has been used in this document to decrease the rejection rate of the hydraulic jack pump headset by enhancing techniques and decreasing process mistakes. The results show that Sigma level increases from 2.21 to 5.64 and costs were saving 0.01929 million/annum
Desai et al. [52]	SME, India	This article introduces critical success factors in Indian sectors when implementing Six Sigma. Top management involvement was the most critical success factors noted down

(continued)

Table 5 (continued)

Author, Year	Sector	Remarks
Sambhe [53]	Indian Auto Ancillary unit, India	This case study presents various factors used in the successful implementation of Six Sigma. Here a medium-scale auto ancillary industry is considered for study which consists of 350–400 employees and Six Sigma was implemented to elevate toward the dream of excellence
Ganguly [37]	Rolling Mill, India	DMAIC methodology was used in the project in this paper to determine the CTQ features of the project The results are useful for any industry that needs to improve and utilize its resources in a better way
Goyat and Rai [36]	MSMEs, India	DMAIC methodology has been used in this paper to reduce the rate of rejection of bush by reducing inherent defects in the process. The result shows that the level of sigma increased from 1.40 to 5.46 by reducing process variations in bush diameter and saving Rs. 0.288 million per year
Soti et al. [54]	Aluminium Die Casting industry, India	In this study, the DMAIC methodology was implemented for improving quality and productivity. The result shows that the defect level of products reduced from 17.22 to 4.8%
Goyat [40]	Manufacturing Environment, India	This research paper presents enablers of Six Sigma and finding a relationship between them using ISM. In the results, 11 enablers investigated and ISM modeling represents the relation between them
Su and Chou [41]	Semiconductor Foundry, India	This research created a new strategy for creating a critical six sigma project and identifying priorities for these initiatives. This approach implemented in a semiconductor foundry industry and satisfactory results noted down
Desai [42]	Indian Small-Scale industry, India	In this study, DMAIC methodology implemented to improve core process in an Indian small-scale industry

Table 6 Enablers for successful Six Sigma implementation

SN	Enablers	References
1	Top management involvement	Banuelas et al. [44]
2	Understanding Six Sigma methodology	Banuelas et al. [44]
3	Utilization of the right tool for the right DMAIC phase	Banuelas et al. [44]
4	Linking of Six Sigma customers	Banuelas et al. [44]
5	Project prioritization and selection	Mishra and Rane [55]
6	Linking Six Sigma to supplier	Mishra and Rane [55]
7	Training	Mishra and Rane [55]
8	Organizational infrastructure	Silva et al. [56]
9	Proper communication	Silva et al. [56]
10	Culture change	Silva et al. [56]

organizations want to deploy Six Sigma successfully, they need to focus on these success factors.

6 Conclusion and Future Research Direction

The current study conducted related to various Indian industries, Six Sigma proved to be a true business strategy that gives a throughout improvement at the process level. It keeps in mind the specification of customers and impact in money-related terms. Six Sigma's implementation has led to important enhancement in organizations' efficiency. The sector should use it with the correct methodology and make efficient use of instruments and methods for the fruitful use of Six Sigma. Appropriate implementation of this company method can, therefore, prompt incredible advantages. In order to apply Six Sigma methodology to their units with better insight, this research paper will export manufacturing organizations. Despite these, it will help the organization to focus on success factors that are crucial for Six Sigma success. In the future research direction, practitioner and researchers may think if the personnel is trained with this methodology, it can be easily implemented and results will reflect at the bottom of the supply chain. Furthermore, the integration of Six Sigma with lean and green manufacturing can be implemented for business excellence.

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Evaluation of Work Posture Using Ergonomics in Indian Small-Scale Industry

Parveen Sharma, Rohit Sharma, and Soyal Mohammed

1 Introduction

Science and technology of ergonomics have been used since the era of World War II, this was the time when researchers framed progressive and new frameworks without taking into consideration the general inhabitants who might use them [2, 3]. This turned out to be certain frameworks by simple steps and items would need to be intended to consider numerous human and ecological components in the event that they are to be utilized securely and viably [5, 6, 33]. This attention to individuals' physical prerequisites brought about the order of ergonomics. A portion of the science that involves ergonomics incorporating biomechanics, building, anthropometry, physiology, science, brain science, and human science in it [7, 9, 10].

Amid World War II, the military and aviation programs turned ergonomics and human elements plan into the multidisciplinary science that it is today [12–15]. Amid World War II, the mind-boggling design of military flying machine cockpits, radar, and other hardware prompted administrator execution issues. Groups were framed from a few controls, including engineers, analysts, anthropologists, and physiologists. These groups were united to tackle the plan and execution issues [17, 18, 34]. This was the first multidisciplinary group to deal with tackling ergonomics issues in the workplace.

Ergonomics is the discipline of science which deals with taking consideration or relating the system with humans and integrates the theory principles, methods of design to enhance the performance of the system (IEA) [19, 20]. To boost human satisfaction and productivity, a systematic ergonomic approach is needed which allows reducing the risk factors that lead to musculoskeletal injuries. The work process can be improved by eliminating the barriers to maximize a safe working environment [21, 22]. The base of the expression "ergonomics" comes from the Greek "nomos",

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which means rule and "ergo" which means work [1, 24, 25]. One could suggest that ergonomics ought to create "rules" for a more forward-looking, imminent concept of design. Relating the corrective ergonomics with the prospective ergonomics, the idea is to take consideration of the profitability margins [28, 29]. Ergonomic typically handles the physical issues related to work environment by diminishing jumble between customer anthropometric and biomechanical parameters with a physical estimation of workplace, equipment, furniture [26, 30].

The term ergonomics can be defined in various ways, however, it is most normally alluded to as the investigation of work. The ergonomics procedure has advanced in the course of the past couple of hundred years to a multidisciplinary science that envelops ideas from material science, work physiology, anthropometry, biomechanics, human elements designing, and work association factors [3, 31, 35].

Health Ergonomics depends on the investigation of human life structures, physiology, pathology, and how the human body reacts to function. This information and experience base, of seeing how the body reacts and adjusts to the outstanding task at hand streamlines the evaluation of work limit of both solid and harmed specialists. The medicinal services professional can effectively apply the ideas of well-being ergonomics to successfully improve human execution, lessen human blunder, and exhaustion and limit musculoskeletal wounds [24].

1.1 Aspiration of Ergonomics

An ergonomics program uses the abilities of numerous orders, considering the brain research, medicinal, security, the board, and the workers or partners. The group cooperates to discriminate against the issue, organize the issue, assess the reason or purpose behind the issue, and select the best approach of the move to make to cure the issue. When these inquiries have been distinguished and assessed, ergonomic change strategies can be executed.

Nowadays, the act of ergonomics has two basics targets to improve work environment well-being, security, and work configuration issues. These are to

- prevent weariness and damage,
- enhance execution and efficiency.

So as to acquire these targets, changes should be made to the laborer work interface. The four fundamental strategies for change execution, or work alteration, used to improve or adjust the working environment are

- adjust the work procedure,
- modify the workplace
- modify the work the executives, and
- adjust the apparatuses.

At last, there is a chain of importance of favored methods for change in the workplace. Arranged by preference, the principal methods for change or work adjustment is through designing controls. Building controls include changing or substituting the work procedure or workplace. A case of building controls changes the genuine item or materials, or the size or shape or weight of the gear used to play out the work. The second change approach is authoritative controls that change the manner in which the work is overseen. This can mean changing the workplace or the administration of the work. Instances of regulatory controls are: including work revolution, changing rest work cycles, or changing the request or time of presentation to the work assignments issues [34]. The last strategy for control that ought to be executed is the utilization of individual defensive gear (PPE). PPE is utilized as a last line of the guard and just as a hindrance between the specialist and a specific work danger. Instances of PPEs in ergonomics include: utilization of gloves or defensive rigging, security goggles, gel embeds for steel toe boots. Sometimes, more than one of these methods might be utilized to unravel an ergonomic test.

Fruitful ergonomic projects are a progressing procedure. Risk must be measured or evaluated, high hazard or issue zones must be recognized, and changes should be actualized through a procedure of basic leadership. Development, after the work changes have been executed, is a fundamental segment of a fruitful program to remeasure hazard, guarantee that the alterations are proper and securely clung to, and decide whether further intercession is required.

1.2 Literature Review

The survey of the literature was carried out for conducting this study in the industry. Table 1 demonstrates a brief about the implemented techniques of ergonomics. Jones and Kumar [27] to separate the perception between 5 ergonomic hazard evaluation methods discovered reliant on quantitative associate measures and with a look at the point of confinement of the frameworks to satisfactorily depict 4 in risk occupations. Ansari and Sheik [1] examination presents the evaluation of the work position of professionals required with various exercises of small-scale industry. The assessment of position was done utilizing RULA and REBA. Assessment is done utilizing worksheets. The RULA procedure developed described that most of the specialists were under high peril levels and required quick change. The REBA framework confirmed that a group of the specialists were under lower levels and some under high hazard levels. Thusly it was considered that, there is a nonappearance of ergonomics care and awareness in small-scale associations. Hignett and McAtamney [23] determines about the phases of the REBA judgment and has conveyed to each about undeniable need. Kong et al. [32] supported common lower appendage assessment ergonomics inspiration, which was made for different agrarian assignments. 196 working positions were perused the ensured agrarian assignments to insist ALLA, a lower part body present in the assessment instrument, and a brief timeframe was later reviewed by 16 ergonomic experts.

Shah et al. (2013) conducted an evaluation by a procedural examination of body positions included. The exhaustion attracted with a specific errand was assessed

Table 1 REBA technique used by various researchers

Author details	Year	Tool used
Ansari & Sheikh	2014	REBA
Boulila et al. [4]	2018	REBA
Domingo et al. [13]	2015	REBA
Fazi et al. [16]	2017	REBA
Jones and Kumar [27]	2007	REBA
Kee and Karwowski	2015	REBA
Kong et al.	2017	REBA
Kulkarni & Devalkar	2018	REBA
Mali and Vyavahare	2015	REBA
McAtamney and Hignett	2000	REBA
Nafrizuan and Nafis	2018	REBA
Nam et al.	2017	REBA
Norhidayah et al.	2016	REBA
Ojha & Vinay	2018	REBA
Rafie et al.	2015	REBA
Raolji et al.	2018	REBA
Sahu et al.	2015	REBA
Shah et al.	2016	REBA
Singh, L. P.	2010	REBA
Wintachai & Charoenchai	2012	REBA

and as necessary changes in work technique for framework change were endorsed. These strategies helped in procedure refinement by perceiving practices causing high weakness. Kulkarni and Devalkar [36] identified with different undertakings on building headway. The principle point of examination is to value the stature of the ergonomics at different assignments in the headway business. Another motivation behind the examination is to locate the dimension of musculoskeletal issues and propose therapeutic measures for each errand having high hazard factor.

Ojha and Vinay [37] showed an examination of different working positions connected with the bike vehicle industry of SIDCUL, Pantnagar. The vehicle mechanical zones have an enormous part of in the Indian economy and it is the spot where work action examination is commonly dismissed. The subjects were offset with the Harvard organize stool test to pick their physical prosperity archive. Posture examination showed 111 bosses with a different arrangement of hiding away from bicycles were picked and surveyed the positions. Cimino et al. [8] propose a system for the powerful ergonomic outline of workstations inside mechanical plants. The technique in the context of various layout parameters and diverse execution gauges strengthens the course of action and the assessment of workstations to the degree of both the ergonomics and work systems.

In Das and Sengupta [11], for the course of action of a forefront workstation, ergonomics rules have appeared. In an authentic system circumstance, the execution of the proposals or rules needs arranging of the majority of the anthropometry with the diverse parts of the workstation. Satisfactory position, work stature, regular and most critical working territories, level space, and visual needs are agreed to the organized client masses. The framework for picking the workstation estimations and design has been cleared up.

The literature demonstrates that REBA technique is mostly used tool for handling the health related disorder on the shop floor.

1.3 Rapid Entire Body Assessment (REBA)

The ergonomic appraisal instrument uses an orderly method to assess the entire body postural MSD and dangers related to employment assignments. A single-page worksheet is used to assess required or chose body pose, powerful efforts, kind of development or activity, redundancy, and coupling. This tool was intended for simple use without requirement for a propelled degree in ergonomics or costly gear. We just need a worksheet and a pen.

On the other hand, we most likely should complete the process of perusing and examining this guide, and a clipboard would help too. By implementing the worksheet of REBA, the examiner will provide a score for every one of the accompanying body districts: elbows, shoulders, wrists, neck, trunk, back, lower arms, legs, and knees. After the information for every locale is gathered and scored, tables on the structure are then used to order the hazard factors, creating a solitary score that speaks to the dimension of MSD chance. Table 2 shows a list of levels. The evaluator ought to get ready for the appraisal by talking the laborer being assessed to pick up a comprehension of the activity assignments and requests, and watching the specialist's developments and stances amid a few work cycles.

Determination of the stances to be assessed ought to be founded on the following:

- The most troublesome stances and work undertakings (in view of the specialist meeting and starting perception),
- The stance continued for the longest time frame, or
- The stance where the most elevated power loads happen.

Table 2 Level of postural hazard

Tally	Level of the postural hazard
1	Negligible risk, no activities required
2–3	Little risk, alter may be required
4–7	Medium risk, further analysis required
8–10	Elevated risk, investigate and execute change
11+	Very elevated risk, execute change now

The REBA can be directed rapidly, so numerous positions and errands inside the work cycle as a rule is assessed without a critical time/exertion cost. When utilizing REBA, just the privilege or left side is surveyed at once. Subsequent to meeting and watching the specialist the evaluator can decide whether just a single arm ought to be assessed, or if an appraisal is required for the two sides.

REBA technique is also a framework or gadget in which the entire body evaluation is there. The body is divided into various sections, which are coded freely with reference to the improvement planes. Hignett and McAtamney [38] concluded that the headway of REBA expected to build up a postural examination structure sensitive to musculoskeletal perils in a diversity of endeavors. The whole body is isolated into fragments and coded dependent on the portion partition. Give a scoring system to muscle development brought about by static, dynamic, speedy changing, or shaky positions. A mirror matching is imperative in the treatment of weights anyway may not by and large be through the hands. The action level is given with an indication of criticalness. There is a prerequisite of irrelevant fittings like pen and paper system. Takala et al. [39] states that REBA was organized as a quick and straightforward observational postural examination gadget for whole body practices in social protection and other organization undertakings. The key idea of REBA resembles that of the rapid upper limb assessment (RULA) methodology: spots of individual body segments are viewed and postural scores increase when positions stray from the fair position.

2 Case Study Problem

The name of the industry is Chopra Industries Private Limited (CIPL) and situated in Ludhiana, Punjab, India. This industry is mostly centered around the assembling of the different bike car parts. The fundamental mission of the organization is that its focal objective is to be a model in the business through mastery improvement, thing structure, and collecting capability. They are focused on constant advance and update out development and place assets into HR to get vitality for flawlessness and the organization vision is to achieve such an unusual condition of significant worth and structure's adequacy that they are a trademark choice of their customers/accomplices for the things that they make. Ethical committee approval was taken to conduct an ergonomics study on the work posture of workers in this industry. History of CIPL: Chopra Industries Pvt. Ltd is a fundamental producer of sheet metal, adjusted parts, and social affairs for a broad number of clients in the vehicle division. The company has progressed by experienced administrators having over 30 years of contribution to the structure business. At present CIPL has three creator workplaces all arranged at Ludhiana (Punjab) and Haridwar (U.K.).

The parts of the silencer that this industry makes are: Silencer bend, STA inlets steel silencer bend pipes, Prism or loose golden and red silencer clamp, Silencer elbow, Silencer stud.

2.1 Steps of Rapid Entire Body Assessment (REBA)

Stage 1 Neck posture.
Stage 2 Trunk posture.
Stage 3 Legs posture.
Stage 4 Analyze the posture marks in the table.
Stage 5 Add load marks.

- If the load is less than 11 lbs then +0 will be awarded.
- If the load is between 11 and 22 lbs, then +1marks will be awarded.
- If the load is greater than 22 lbs, then +2 marks will be awarded.

Stage 6 (Adding of values obtained from previous two stages to obtain desire score A to find out the row in Table).
Stage 7 Upper Arm Posture.
Stage 8 Lower Arm Posture.
Stage 9 Wrist posture.
Stage 10 See the posture marks in Table by using the values from stages 7 to 9.
Stage 11 Add grip marks.

- Good—+0,
- Fair—+1,
- Poor—+2,
- Awkward (unacceptable)—+3.

Stage 12 For getting of a Score B we have to find a column in Table (add marks of 10 an 12 stages).
Stage 13 Activity Score (Range +1).

Figures 1 and 2 represent the basic stages of the REBA techniques along with various body positions.

3 Implementation of REBA Technique

Points to be considered while making the study:

(A) Study structure:

It is a descriptive cross-sectional examination done in Chopra Industry Private Limited (CIPL), Ludhiana, Punjab, India.

(B) Study zone:

The examination region is a mechanical region point in focal point 2 in the Ludhiana area of Punjab, India.

(C) Study population:

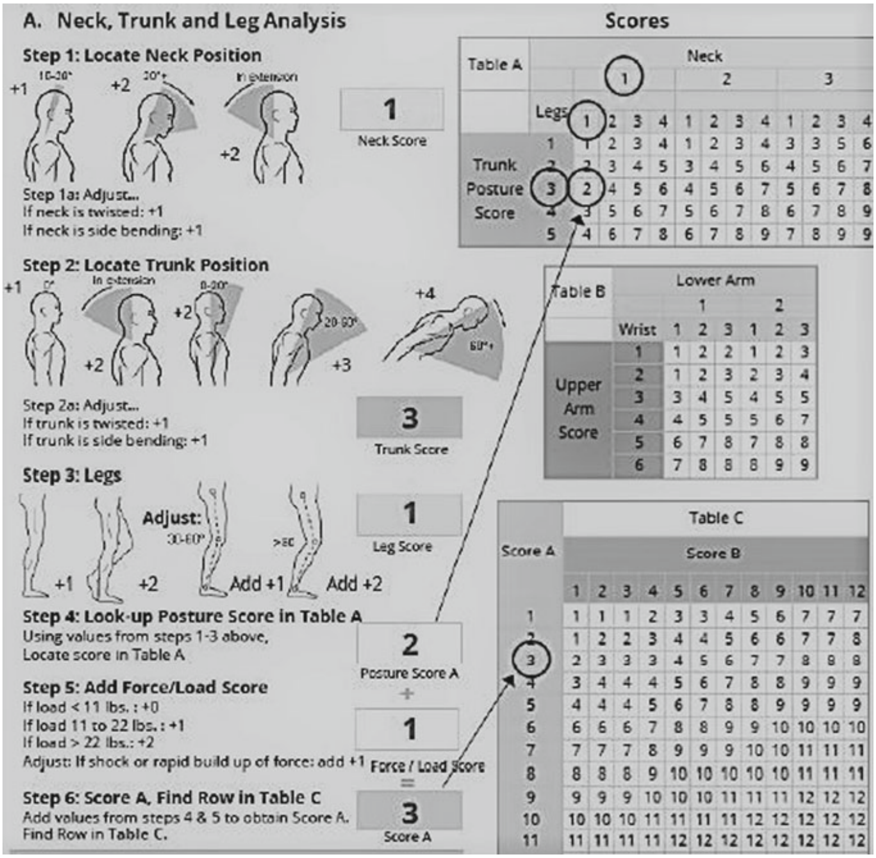


Fig. 1 Analysis of neck, trunk, and leg

The investigation populace incorporates some mechanical laborers in the examination region.

(D) Study period:

The study was conducted for a period of 1 month (April 2019–May 2019).

(E) Incorporation criteria:

In this investigation, the laborers having a place with the examination region and the individuals who were eager to take part were altogether incorporated into the examination. The specialists performing the task for a delayed timeframe for a normal of 5 days in seven days were just incorporated into the investigation.

(F) Avoidance criteria:

Workers who would not like to take part in the examination were avoided.

(G) Test measure:

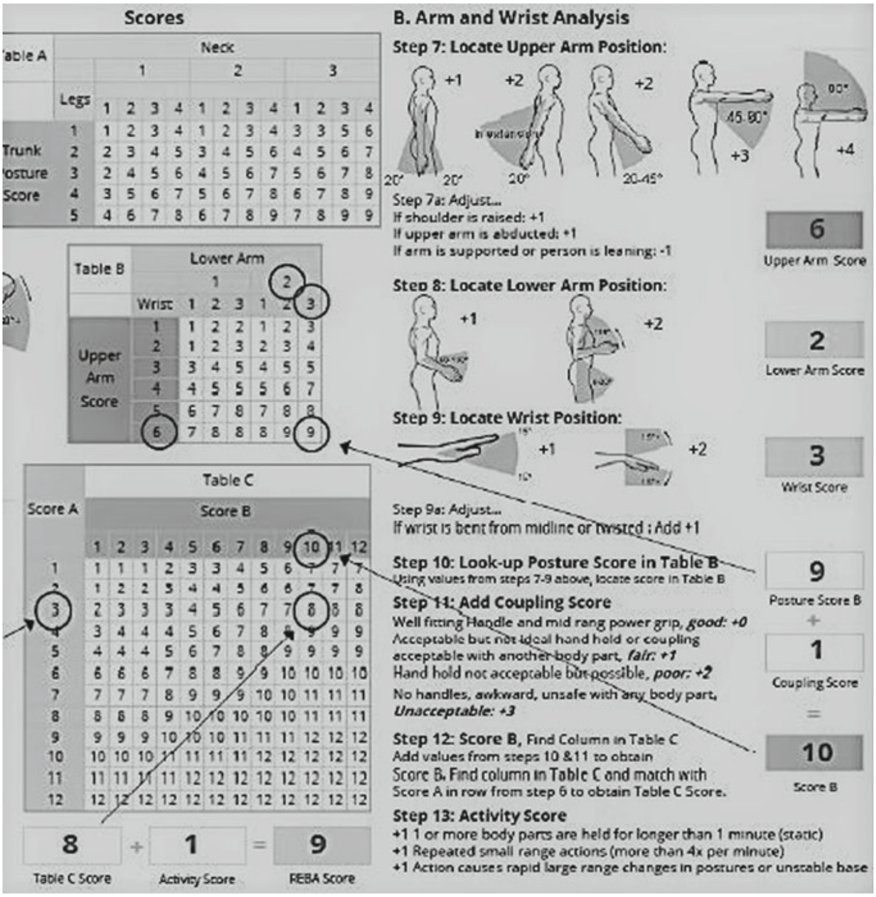


Fig. 2 Analysis of arm and wrist

According to the investigation objective, all-inclusive testing was utilized in the examination. The examination, for the most part, centers around the shop floor specialists, where the absolute populace of laborers is 70. 40 individuals were not accessible or not willing to take part, accordingly the last number of individuals partook in this investigation are 30. The members were obviously clarified about the reason for the investigation and its advantage.

(H) Study apparatus and information gathering:

A pretested organized poll is planned in connection to the investigation objective. The respondents were met, by making inquiries to the laborers in their nearby language. The poll comprises of data about neck, shoulders, elbows, wrists/hands, upper back, lower back, hips, knees, and lower legs/foot. The ordinariness of different torment side effects among the laborers while working is incorporated into the poll. And after that, the information changed over to some helpful data by placing it into a REBA system.

(I) Data Analysis:

The data was collected among the workers from various lines by clicking the still photographs and some videos then the data was entered in Microsoft Word and was analyzed.

(J) Informed consent:

The participants were briefed about the purpose of the study and informed consent was obtained prior to the data collection.

In Chopra Industry Private Limited (CIPL), we have selected the workers on the basis of their work. We have categorized the workers into three bases like

(a) Welding workers
(b) Pressing machines workers
(c) Pipe bending workers.

In the above categories, the stress is developing onto the parts of the body like—neck, trunk, legs, upper arm, lower arm, shoulders, and wrists. These workers are suffering from a lot of stress on their body parts. This industry basically manufactures the two-wheeler automotive parts and supply to the demanding automotive industry. All the workers are on a contract basis. Daily their duty starts from nine in the morning and lasts up to seven in the evening. The main disadvantage from my perspective is that they don't have chairs for sitting. They all work in the standing postures. But continuous standing postures of the workers are making their body in more stress.

The working environment in this particular industry is very noisy. All the machines working at the same time and they are creating a lot of noise. The managing director and the plant head have ordered to wear the earplugs to the worker's ears, but the workers are not doing the same as said by their heads.

So in these above workers, we will be implementing the REBA technique to give a check on them that how dangerous it can be to work, like in these unhealthy postures. And at the same time, we will be making them aware of the good postures, so that productivity can also increase in the industry.

In total, we have studied the postures of 31 workers in which there are 7 welding workers postures, 14 pressing machine workers, and 10 pipe bending workers. As we can see now, we will be implementing the REBA technique to the workers in the below section:

(a) **Welding worker**

The person on the shop floor doing the welding task has been demonstrated in Fig. 3, analysis of his body postures has been done. This analysis has been conducted on nearly about 30 workers but only one has been shown with an explanation.

Stages 1–3 Analysis of Neck, Trunk and Leg as shown in Fig. 4

Fig. 3 Welding person

In stage 1, a +2 score was utilized for the neck position (>20°) and +1 was included for the side twisting change (when seen from behind, the specialist was left side bowing) for an all-out score of +3.

In stage 2, a +2 score was utilized for the storage compartment position (in the expansion) and +1 was included for the turned minute, so the all-out trunk score is +3.

In stage 3, a +2 score was utilized for the legs.

In stage 4, we need to look into the stance score in the table. from the score of neck, trunk, and legs, we got an estimation of +6 in table A.

In stage 5, including the heap score we get +0 score in light of the fact that the heap on the specialists is under 11 lbs.

In stage 6, for score A we need to include the score of stage 4 and stage 5, at that point we see the table C. We get $6 + 0 = 6$, and we need to see table C and enclose at 6.

Stages 7–9 Analysis of Arm and Wrist as shown in Fig. 5

In stage 7, the correct upper arm is raised in an excess of 90° for a score of +4, a complete change of +1 is included in light of the fact that the shoulder is raised (+1) for an absolute score of +5.

In stage 8, a +2 score was utilized because of the arm position outside of the nonpartisan range.

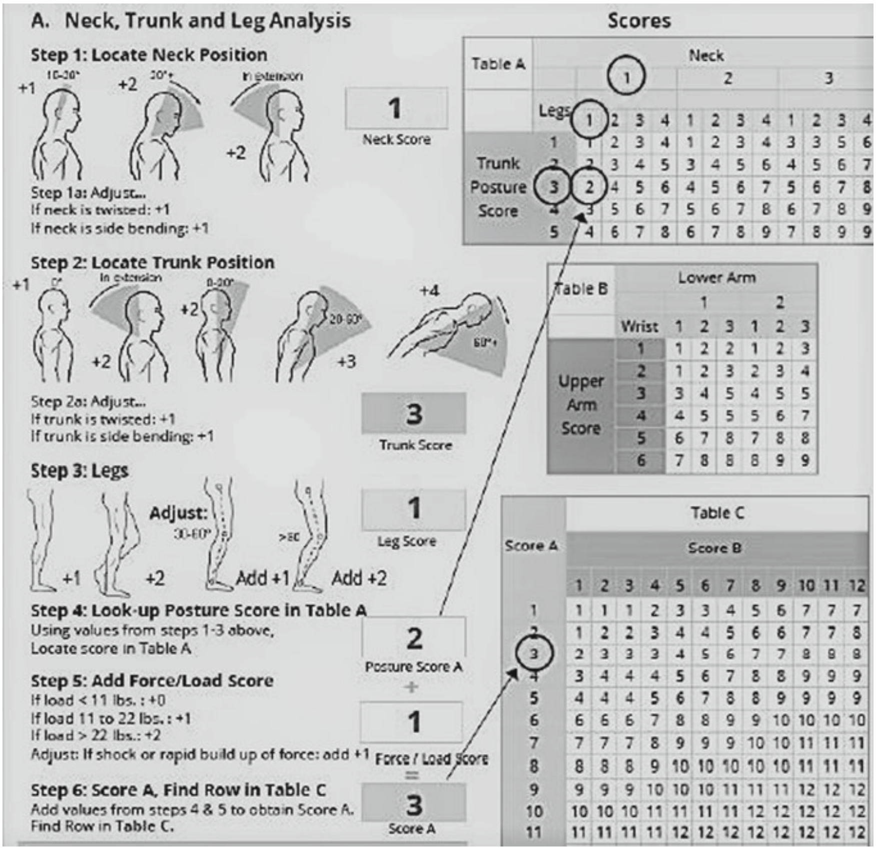


Fig. 4 Neck, trunk and leg analysis

In stage 9, the position score of +2.

In Stage 10, using esteems from stages 7–9, find the stance score for this progression in Table B. We get +7.

In Stage 11, add the coupling score. For this situation, the coupling is viewed as good (+0).

In Stage 12, firstly includes the qualities in stage 10 and stage 11 to acquire score B. Next, discover the segment in Table C, we get 7 + 0 = 7 and coordinate with Score from stage 6 to get Table C Score, we get 9.

In Stage 13, the activity score is +1 because of employment requiring little range activities (more than 4 × every moment). The Final REBA score can be calculated as Table C Score + Activity Score = 9 + 1 = 10.

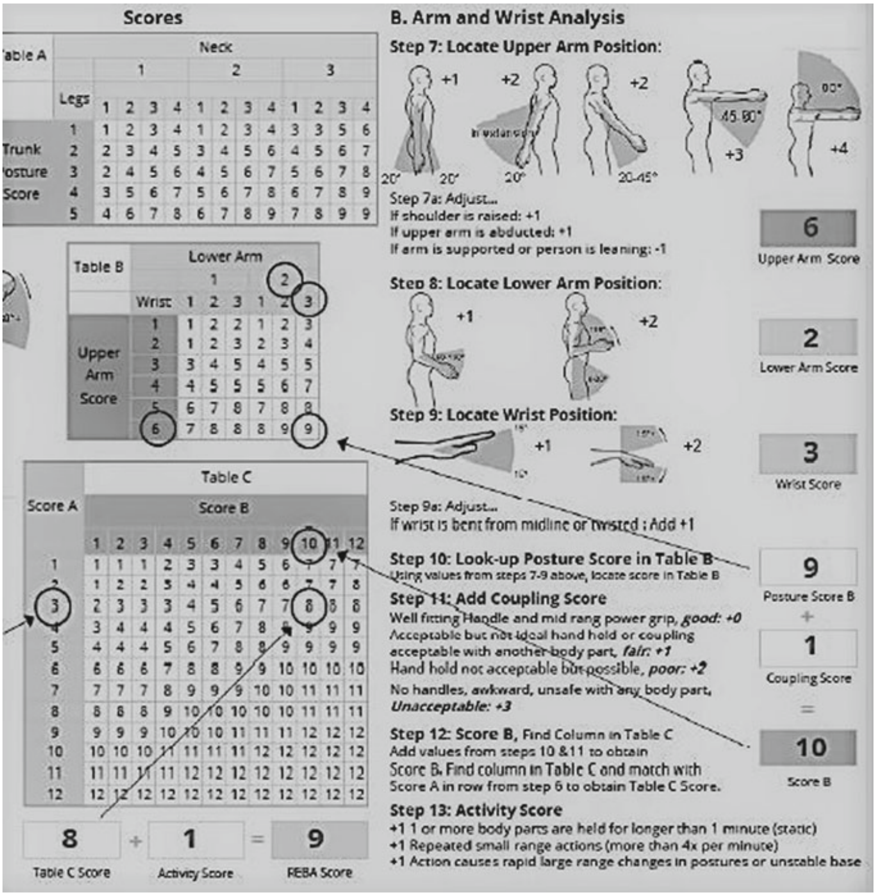


Fig. 5 Arm and wrist analysis of welder

4 Results and Discussions

The analysis predicted Final REBA Score as 10.

For this situation, the REBA score as 10 demonstrates high hazard and calls for further examination and designing as well as work technique changes to lessen or dispense with MSD chance. The corrected poster for the welding person has been demonstrated in Fig. 6. Scoring of various workers is shown in Tables 3, 4, 5, and 6.

After further examination, it was controlled by the laborer and the office bunch pioneer that an alternate strategy could be utilized to play out this errand.

A subsequent assessment utilizing the worksheet was carried out. Utilizing the new work technique, the last REBA score was diminished from 10 to 2.

These are the six welding workers in which only one worker works in a good posture. But then also the danger zone is there. But it's fine for the sixth worker.

Fig. 6 Corrected posture of welding worker

Table 3 Scoring of welding workers

Workers serial no.	Neck	Trunk	Legs	Upper arm	Lower arm	Wrist	REBA score
1	+3	+3	+2	+5	+2	+1	10
2	+3	+3	+1	+5	+2	+1	9
3	+2	+3	+1	+2	+2	+1	5
4	+3	+2	+1	+3	+2	+2	6
5	+3	+4	+2	+3	+2	+1	9
6	+2	+1	+1	+2	+1	+1	2

He will not be having any problem in the body due to his postures. The crisis arises here that the other 5 workers' posture is not correct and the changes have to be done in the postures so that they can feel good and the productivity of the company gets increases overall.

So, there are 13 press machines workers in the above table in which only 6 workers are out of danger. But the other seven workers are at the danger level. They really need to correct their postures so that they don't get any problem in the body like don't get any stress in their bodies.

So, there are 11 pipe bending workers whom the data has been taken. Only 3 workers are close to the good posture and the other 8 workers are at the danger level. Their working posture is not proper so there is a need to change in the posture of the workers.

In Fig. 7, we have categorized the industrial workers into three groups, we can see that there are a total of 30 industrial workers for which the data has taken in which 6 welding workers, 13 press workers, and 11 pipe bending workers are there. The blue

Table 4 Scoring of pressing machine workers

Workers serial no.	Neck	Trunk	Legs	Upper arm	Lower arm	Wrist	REBA score
1	+2	+3	+1	+4	+2	+3	9
2	+1	+1	+1	+4	+2	+2	4
3	+1	+1	+1	+2	+1	+1	2
4	+2	+4	+4	+3	+2	+2	11
5	+2	+1	+1	+2	+2	+1	2
6	+3	+2	+2	+2	+1	+1	5
7	+1	+1	+4	+5	+2	+1	8
8	+2	+1	+1	+1	+1	+1	2
9	+2	+2	+2	+4	+1	+1	5
10	+2	+1	+1	+2	+1	+1	2
11	+2	+1	+1	+2	+2	+1	2
12	+1	+3	+2	+1	+1	+1	2
13	+2	+3	+3	+2	+1	+1	7

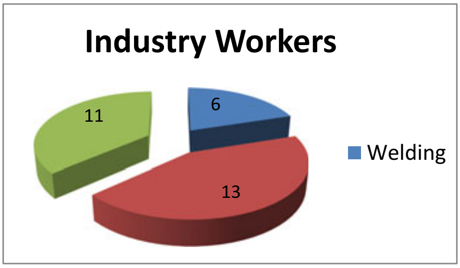
Table 5 Scoring of pipe bending workers

Workers serial no.	Neck	Trunk	Legs	Upper arm	Lower arm	Wrist	REBA score
1	+3	+2	+1	+2	+1	+1	5
2	+2	+4	+1	+3	+1	+2	6
3	+1	+3	+2	+3	+1	+1	5
4	+2	+2	+3	+2	+1	+1	5
5	+2	+2	+3	+4	+2	+2	7
6	+1	+1	+1	+2	+1	+2	2
7	+1	+1	+2	+1	+1	+1	2
8	+3	+3	+1	+2	+1	+2	5
9	+1	+1	+1	+2	+1	+3	2
10	+3	+2	+1	+1	+1	+2	5
11	+3	+4	+2	+4	+2	+2	10

Table 6 Enhancement of workers REBA score

S. no.	Worker	Normal posture	Enhanced posture
1	Welding 1	10	2
2	Welding 2	9	2
3	Press 1	9	2
4	Press 2	7	2
5	Pipe Bend 1	10	4
6	Pipe Bending 2	5	2

Fig. 7 Categories of case study industrial workers



color is indicating the 6 welding workers. The red color is for 13 press workers and green color representing the 11 pipe bending workers.

This indicates that there is an enhancement in the workers' posture. If the workers' posture is enhanced then their health also affects by becoming better. And if their health is better, then automatically the productivity and the profitability of the industry increases to very much extent. The workers' presence is now there is a very happy mood rather than a bad mood. The workers also didn't take many holidays now. Otherwise, in a single week, they used to take 3 days off and it would have been a major problem. But now they come and work every day without taking any holiday. The various workers considered for this study has been shown in Fig. 7.

In this above figure (Fig. 8), when standing in the normal postures, the industrial workers were getting very high REBA scores like ten, nine, nine, seven, ten, and five. But after enhancing their postures, they got good REBA scores like two, two, two, two, four, and two, respectively. And it is greatly improving their performance.

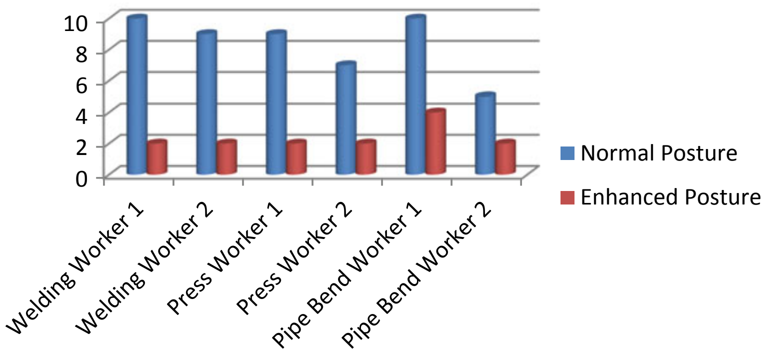


Fig. 8 Improved REBA scores

5 Conclusions

This study predicted problems faced by workers related to health. They were complaining about their health deterioration day by day. In this study, the authors presented an ergonomic technique known as REBA which is very useful for the health of the workers. By this, the fatigue level of the workers can be reduced to a very much extent. The present examination has attempted to connect the holes as left by earlier studies done by different scientists in a previous couple of decades. Different papers on REBA methodologies or systems or devices have been outlined alongside the techniques utilized and their principle point. The ongoing improvements and the future extent of the REBA system have been considered and mapped in this paper. It has been seen that the REBA tool or method have been intentionally considered for the advancement of the human stances. The utilization of different programming projects causes the scientists to examine the human stances all the more effectively. The pen and paper may take some time but we can also use different software available online. We can implement this technique in any type of industry. The workers working in any industry can be taken into consideration for this technique. Where there is the involvement of the workers or persons, we can apply this technique to reduce their stresses on the body parts. Using the computerized software can be much more effective in very less time. Only we have to put the required data into software and then it will give us the full brief information about the workers. Finally, we can achieve the desired status of the industrial workers.

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Manufacturing Intelligence in the Context of Indian SME's

Pravin M. Kinge and U. C. Jha

1 Introduction

1.1 Need for Manufacturing Intelligence

In today's technologically advanced world normal life is dominated by the smart technology-driven gadgets and applications which enforce the manufacturing companies to deploy high degree of automation along with data-driven technologies in order to excel the quality standards of products or processes. The essential part of Manufacturing Intelligence (MI) is to upgrade the manufacturing units with the latest automated tools coupled with automation for handling materials at different stages of manufacturing. With existing machine tools, if the changeover is not possible, it is required to go for the automation with automated data acquisition at various stages in order to support the intelligent decision-making process. Manufacturing Intelligence makes it possible the availability of analysis required for decision-making on finger touch handled devices like a smartphone, tablet, etc.

1.2 Electronic Hardware with Machine and Software Interface

Internets of Things (IoT) devices are quite popular and can be integrated with various Enterprise Resource Planning (ERP) packages in order to collect the data during different stages of manufacturing. Cloud computing enables the sharing of various

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resources over a wide variety of platforms. Various technologies like Radio Frequency Identification (RFID), Bluetooth, Wifi, Global System for Mobile Communication (GSM), and Infrared-enabled devices are available for real-time data capturing from different manufacturing stages which in turn can be directly interfaced with various ERP packages. With the revolution in the Industrial Internet of Things (IIoT) many big players are immerging as IIoT device suppliers; one such name which is gaining momentum recently is Mazak Smartbox. This smart box can be connected to the manufacturing equipment for data collection and can be interfaced with the ERP systems using the MTConnect protocol. With these advancements in technology, deployment of MI can be done to meet the requirements of the Industrial Revolution 4.0. Most of the modern machine tools have built-in interface ports for the connectivity of the various devices. For the machine tools which do not have the interface, sensor-enabled devices can be attached to them which in turn can be interfaced with the computer systems.

1.3 Management Information System

The integration of these technology-enabled devices with the management systems for collecting real-time data will enable the units to make smart decisions in the better interests of the organization. Analyzing the causes of failure will become easier. The main goal of every enterprise is to improve its performance. The various parameters which are an integral part of performance can be employee performance, market share, equipment performance, customer satisfaction, profit levels, etc. Visualization of analysis for effective decision-making is possible only when the system is updated with real-time data. Deployment of Manufacturing Intelligence (MI) facilitates the development of the system with the input of real-time data from all sections of the Small Medium Enterprise (SME) working environment. Various open-source Enterprise Resource Planning (ERPs) available are helpful to those SMEs which cannot afford the professionally developed software. These open-source ERPs have full functionality to satisfy the needs of the small to medium sector organizations.

1.4 Novelty and Aim

The work carried out highlights the importance of MI for improving Business Performance (BP) with the study of various core manufacturing units especially SMEs. Sincere effort is being made to find the answer to the basic questions.

Why MI?

How to go for the implementation of MI?

The work is supported by a case study to show how smart devices can be used for collecting data which in turn supports the decision-making the process. The primary aim of this work is to create awareness in SMEs of India. It provides guidelines for those emerging or established SMEs who wish to turn their units into smart manufacturing units.

2 Literature Review

Zhang et al. [26] extended IoT to the Internet of Manufacturing Things (IoMT) by integrating sensors with machines, pallets, materials, etc., for capturing real-time data. This would make the information readily available and reduction in personnel for collecting and storing data manually. He provided the architecture for IoMT for capturing real-time information. Coronado [27] developed shop floor digital twin by implementing a smartphone app with data entry from operator to supervisor on the shop floor and various personnel of the manufacturing unit. He attached the smart devices to modern machine tools for collecting real-time data. Data from both the smartphone app and machine tools are stored in the cloud database servers from where it is accessible to management, client, and providers. His work as part of the Cyber-Physical System (CPS) is stepping forward for implementing Industry 4.0. Dirican [1] has written a conceptual and hypothetical paper elaborating the scope of artificial intelligence, robots, and mechatronics in the coming future. Bogle [21] explored smart manufacturing for process system engineering. As per his opinion, Smart manufacturing ideas have been implemented in many process industries. Tao et al. [2] discussed the role played by big data in smart manufacturing and proposed a conceptual framework for the same. He developed an application covering various aspects of the smart manufacturing unit which are driven by the stored data. His study is supported by the case study on the silicon wafers production line. His research contributes to smart manufacturing with three perspectives, namely, historical, development, and envisaging the future data in manufacturing. Wang et al. [3] have done a survey on deep learning algorithms and their application for smart manufacturing. He proposed an analytical framework based on deep learning, especially for smart manufacturing. He discussed several deep learning architectures to explore manufacturing intelligence as a part of smart manufacturing. Finally, he elaborated the future development trends for data matter, model selection, model visualization, generic model, and incremental learning. Peschi et al. [17] developed manufactronic network architecture. The architecture can be applied from a single machine to the entire production process. The main subject which was part of his research was the Production Configuration System (PCS). He demonstrated the validity of his concept with three case studies from different industrial sectors. Munguía et al. [18] developed a model for showing different alternatives by rapid manufacturing. The suggested method fills the gap between the knowledge of conventional manufacturing and rapid manufacturing. Wang et al. [11] proposed a framework for correlating wireless networks and clouds with machine tools, products, and conveyors. The proposed framework by him makes it possible the communication between available resources which is in turn integrated with the information system. He expressed the need for smart software and hardware in order to meet the challenges of Industry 4.0. Zhong et al. [4] have provided a review of intelligent manufacturing, IoT, cloud manufacturing, and few technologies like cloud computing, cyber-physical systems, and big data analytics. May [5] has covered a review on system-on-package (SOP), which is dependent on manufacturers of various electronic devices. As per his opinion, the research article has the potential for the deployment of techniques like Artificial Intelligence (AI) and Genetic Algorithms (GA) in the manufacturing facilities of SOP. Sethi et al. [6] have proposed taxonomy for IoT technologies that can make considerable contributions to the betterment of human life. Shen et al. [7] have presented the iShopFloor concept for manufacturing the products intelligently. He proposed a reference architecture for implementing intelligent manufacturing on different kinds of the shop floor. The prototype developed was tested offline on the network of PCs. Li et al. [8] have developed an architecture based on Artificial Intelligence plus Internet. The architecture was divided into five layers. He elaborated the development of intelligent manufacturing in the context of global development. Bao et al. [9] used modeling in the form of virtual physical convergence for the manufacturing factory. He used Automation Markup Language for building the model. Three kinds of digital twin for product, process, and operation were developed in order to optimize the production process.

3 Levels of Data for Intelligent SME

This section provides details of various objects involved in the entire operations of SME followed by the framework which depicts the communication between these objects. The following subsections explain various parameters associated with SMEs in general and the goal of an intelligent system to optimize them. While carrying out the discussion with many SMEs in the context of the framework proposed and developed by the other researchers, it was observed that the key personnel from these units were not familiar with the terms used in the framework. It is a big challenge to provide a framework that will best suit the needs of most of the SMEs. They expected a neat and simple framework which they can understand easily and implement. Our effort is to provide a framework that will work as a guide for aspiring the existing SMEs who wish to implement intelligence manufacturing in their organizations.

3.1 Resources for SME

Various resources which are an integral part of any organization are employees, machines, materials, tools, etc. There is data associated with each and every resource which as part of the intelligent system is stored and retrieved for decision-making. There are various means for collecting data and it varies from one resource to another. For example, employee data consists of recruitment data, entered manually in the

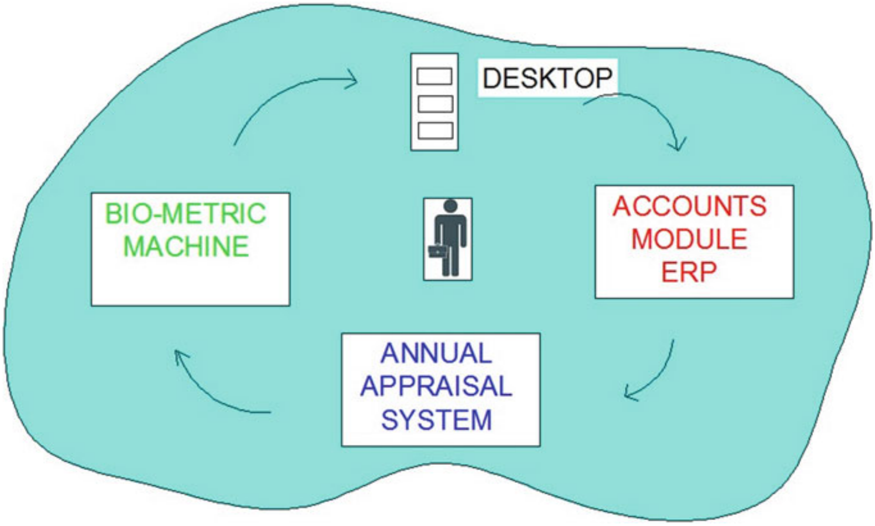

Fig. 1 Employee-centric database

software system; daily attendance captured with the help of a biometric scanner; leave-related data that is facilitated by web or app on the smartphone; auto calculation of salary on the basis of daily attendance and leave data forms the basis for smart calculations. Figure 1 shows how an employee-centric intelligent database can be generated.

The second important resource for any manufacturing unit is machine tools. Each individual machine tool is characterized by its specifications which are provided by the manufacturer. Most of the advanced machine tools have an interface for collecting data; IoT devices can be attached to the machine tools which do not have the inbuilt interface. Figure 2 shows machine-specific database.

The third important resource for any manufacturing unit is materials and tools. As most of the ERPs have integrated modules, so whatever data issued in the form of the purchase order will become part of the inventory module after due validation on the receipt of the material. Direct entry can also be done for existing materials and tools. Figure 3 shows materials- and tools-specific database. It is clearly evident from the figure that the inventory and purchase module of ERP software holds the database for various tools and materials including semi-finished and finished items produced in any particular SMEs. IoT devices can be used for data collection related to process items.

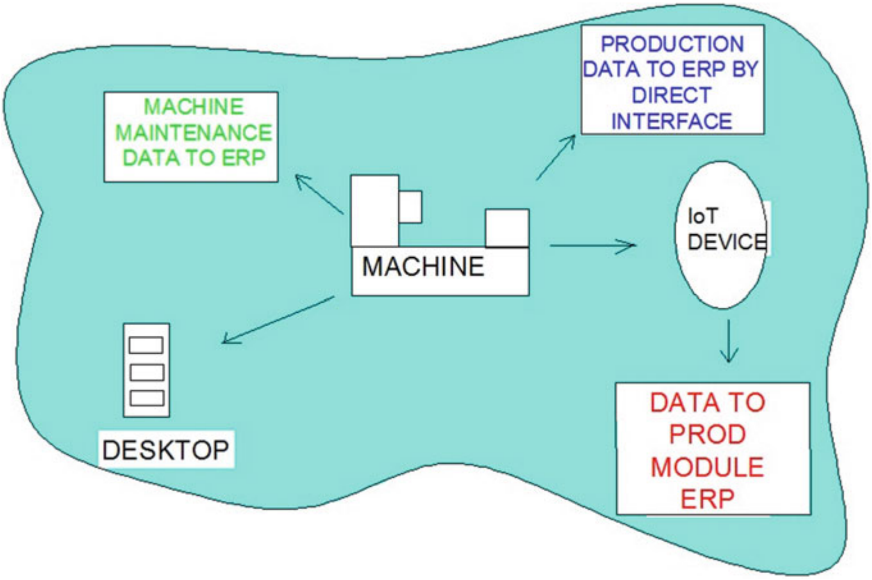

Fig. 2 Machine-specific database

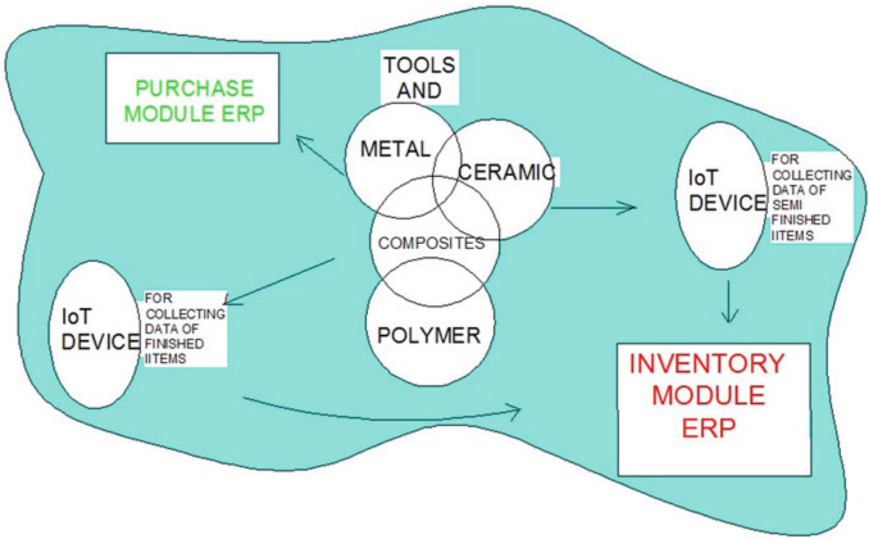

Fig. 3 Materials- and tools-specific database

3.2 Inputs for SMEs

The inputs for any SMEs are categorized as direct orders and revenue generated by outsourcing available resources that are free. There is data associated with both and this data can be stored in the intelligent database with the help of freeware ERP software. As a part of manufacturing intelligence, this data can be utilized for decision-making pertaining to the planning of available resources for executing the orders and simultaneously outsourcing free resources.

3.3 Outputs for SMEs

Processed products, semi-finished products, and revenue generated by outsourcing become an integral part of outputs produced by any industry. On the basis of data collected for these various outputs, intelligent decisions can be taken for production scheduling on various machines and processes with due consideration to the requirements of the clients (Fig. 4).

3.4 Data Collection

It is very essential to understand the tools and techniques used for collecting data during various stages of manufacturing. The two factors which play a crucial role in data collection are a selection of IoT devices and selection of ERP software and database.

3.4.1 Selection of IoT Devices

The following factors should be carefully considered while selecting the IoT devices

- It should have a ready interface with the machines available
- There should be ease in installation of such a device
- The interface driver should be easily upgradable so as to provide the interface for maximum resources
- It should allow interface for newly installed equipment

3.4.2 Selection of ERP Software

Following list provides open-source ERP software available for small businesses

- Dolibarr ERP

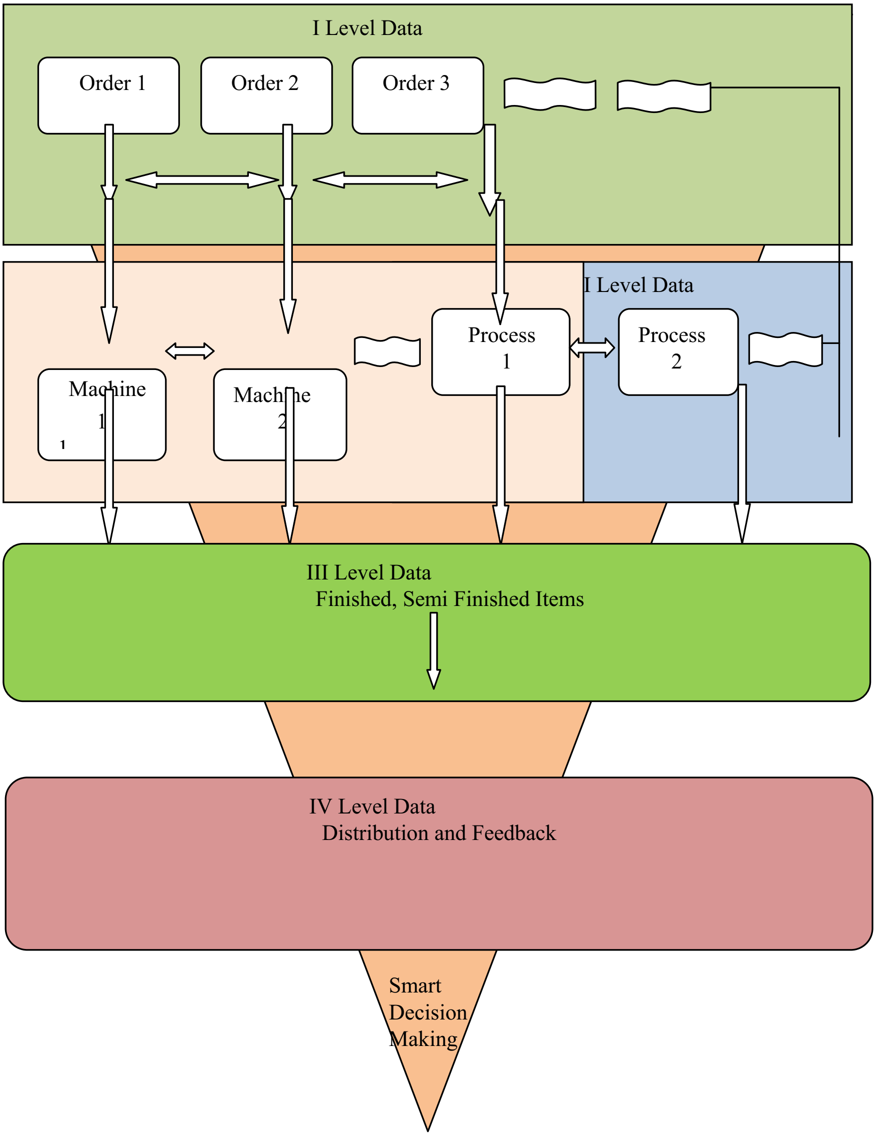

Fig. 4 Levels of data

- ERPNext
- Idempiere
- MixERP
- Odoo

There are much more available and can be easily downloaded from the Internet. Most of them provide professional services for customization.

3.5 Applications for Analysis and Decision-Making

3.5.1 Resource Availability

This application provides insight about the resources which are free and the duration for which they can be outsourced for revenue generation.

3.5.2 Production Schedule

This application can be utilized in those industries especially where batch production takes place. It is really a hectic job to plan the orders in order to meet the diversified requirements of different clients. This tool enhances the ability of the management to take better decisions.

3.5.3 Execution

This tool provides real-time monitoring of the actual work being processed at various stages of manufacturing so that uncertainties can be avoided for the timely execution of the orders.

3.5.4 Billing

To make the balance sheet ready at the end of the financial year, it is essential to have a database of all the transactions. With the help of such tools, it can be generated in real time and with one click financial statements can be generated at any point in time.

3.5.5 Distribution and Transportation

This tool takes care of generating and maintaining data related to managing the distribution network and transactions carried out with the external transportation agency.

4 Proposed Architectural Framework for Intelligent SME

The proposed architectural framework is mainly divided into 4 components as

- Preparing Blueprint
- System Deployment

- Measuring Business Performance
- Smart Decision-Making

With these major actions, data is collected from various sections of the manufacturing unit. The center of all is the manufacturing intelligence that supports smart decision-making (Fig. 5).

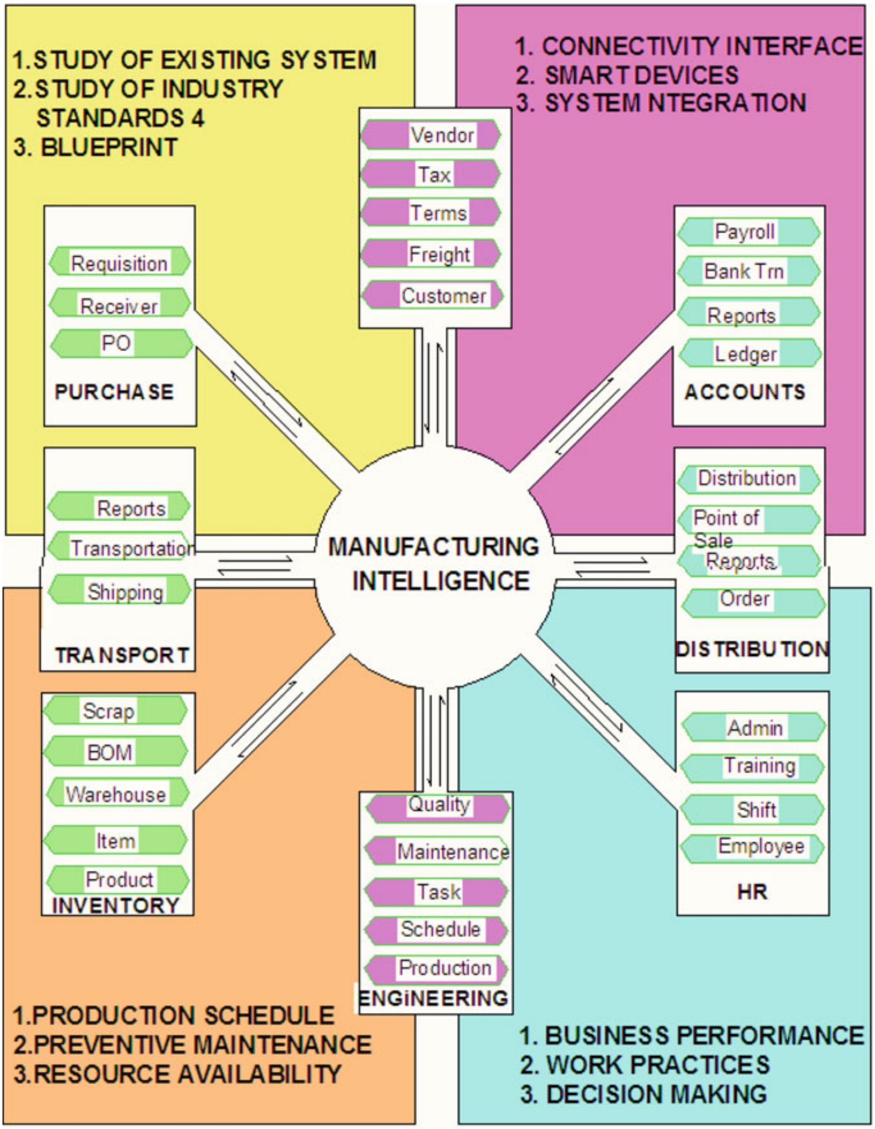

Fig. 5 Architectural framework for intelligent SME

5 Case Study

The practical aspects of the above-proposed framework are illustrated on the basis of the case study conducted at one of the plastic molding company located in Chakan MIDC, Pune. The plastic molding company produces around 45 various 2 wheeler and 4 wheeler components for the automobile industry. Managing batch production of 45 components on the 15 different capacity plastic molding machines is a difficult task and with the existing manual data collection, the time frame required for decision-making for the switchover is cumbersome and requires a high level of expertise. With the proposed architectural framework the majority of the data can be collected with the help of an overhanging smart box which is available in the market that is in its initial stage. Remaining data can be collected with the help of a ready interface available on the machines for desktop connectivity. With the proposed framework it is possible to graph the plot for the energy consumption of various machines which couples with the maintenance expenditure. The same can be compared with the newly available high-efficiency plastic molding machines in order to support the smart decision-making for replacing the existing machine with the new one.

The data for the existing machine M1 is collected by attaching the energy meter with it. The data for the new machine is provided by the manufacturer with testing of part A for one day. The comparison clearly shows that there are annual savings of Rs. 197901 if the management decides to replace the existing machine M1 with the new machine M2. The same concept can be applied across all horizontals and verticals in any manufacturing unit. The proposed architecture will serve as a guiding template to those SMEs who are ready for the deployment of Manufacturing Intelligence (Table 1).

Table 1 EC comparison

	200 ton existing machine (M1) for part A				200 ton new machine (M2) for part A			
Month	EC for M1	EB for M1	ME for M1	Total for M1	EC for M2	EB for M2	ME for M2	Total for M2
Jan	4800	72646	4000	76646	3200	47481	3000	50481
Feb	3700	55345	6000	61345	3200	47481	3000	50481
March	4200	63209	3500	66709	3200	47481	3000	50481
April	3900	58491	4700	63191	3200	47481	3000	50481
			Total M1	267891			Total M2	201924

EC-Energy Consumption
EB-Energy Bill
ME-Maintenance Expenditure

6 Conclusions and Future Scope

Smart decisions are based on the data collected from various functional departments of the manufacturing unit and these decisions, in turn, improve the business performance of the unit. This paper provides insight into the means for collecting data in future-ready intelligent manufacturing units. Elaborated details of various freeware tools are available for collecting and analyzing data in the SMEs. An architectural framework is proposed for efficient deployment of intelligent systems in the manufacturing units, especially in SMEs. The case study is conducted in a plastic molding company for making smart decisions regarding the replacement of energy-inefficient machines. The future economy of any nation is based on the network of such intelligent manufacturing units. There is a huge scope for developing simulated factories in order to provide a ready solution for the deployment of manufacturing intelligence.

Acknowledgements This work is supported by the inputs given by various SMEs located in Chakan MIDC, Pune. Special thanks to Shivam Enterprises for allowing to conduct a case study in their unit.

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Multi-objective Optimization of Process Parameter During Dry Turning of Grade 5 Titanium Alloy with Carbide Inserts: Hybrid Fuzzy-TOPSIS Approach

Swastik Pradhan, Manisha Priyadarshini, and Sambit Kumar Mohapatra

1 Introduction

Titanium alloy is one of the most widely used metals in the industrial sectors. The high strength to weight ratio properties allows it to sustain in the manufacturing field. Nowadays, most of the durable and wear resistance components are made by using titanium alloy. Titanium alloy is amplifying its uses in every field of engineering and technology such as rotors, compressor blades, engines, frames and hydraulic system components. Above 50% of the aircraft components are made from the titanium grade 5 alloy. Due to the diversity properties in terms of non-toxicity and adaptability, it has increased its application towards making of the aircraft, armor plating, naval ship, landing gear and some of the medical–surgical equipment and implants. Nowadays, its unique quality of biocompatibility is also helping towards the computed tomography (CT) and magnetic resonance imaging (MRI) [1]. But mostly difficult and challenging task that arises during manufacturing of components using titanium alloy is its machining. As it is chemically reactive and less thermally conductive, it very difficult and a challenging task to machined. The adhesion and welding tendency of the titanium alloy with the chips flowing out during machining deteriorate the surface finish of the product and also the power, cutting force, tool wear and temperature required during machining increased [2–5]. Most of the researcher reveals

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that manufacturing cost of the components goes on increasing as the number of cutting inserts increase due to high tool wear rate [6]. At high temperature and lower DOC, the chips get chemically active and react with the cutting tool material and the machined surface [7–9]. Some of new techniques are involve to reduces the surface roughness and improve tool life of the cutting insert such as applying high-pressure coolant at the workpiece and cutting tool interface [10, 11]. Using of duplex liquid nitrogen jet of cooling [12], where one jet aims at tool–chip interface and second one at tool–work interface [13]. Fitzsimmons et al. [14] suggested that, for general practice, straight cemented carbides were the best cutting tool material for machining of titanium alloy. Researchers also revealed that, to achieve good machinability a good combination of process parameter through various multi-optimization techniques is also required. Some of the researchers also performed various types of optimization techniques to achieve a better combination of process parameter such as responses surface methodology, principal component analysis, grey relational analysis and desirability function analysis [15–17]. In this investigation, a multi-objective optimization technique is used to optimize the tool wear (TW), chip reduction coefficient (CRC) and surface roughness (SR) by finding out the optimal setting of the process variables with Cs, F and DOC during machining titanium alloy with K313 carbide insert. Further, the most significant process variable affecting the response has found by performing analysis of variance (ANOVA).

2 Experimentation Details

Left-hand dry turning operation of the titanium alloy was performed with cemented carbide inserts of Wida-made and model number K313. Taguchi L9 orthogonal array is designed to reduce the experimental cost and number of experimental runs. This experiment is done with a high precision lathe machine (Model No NH26 HMT). Ti–6Al–4V round bar of 600 mm length and 50 mm diameter. The process parameter considered for machining were F (0.04, 0.08 and 0.16 mm/rev), Cs (40, 65 and 112 m/min) and DOC (0.4, 0.8 and 1.6 mm). The FW, SR and CRC are measured with surface roughness tester (Make: Taylor/Hobson Surtronic 3+) and tool-maker's microscope.

3 Fuzzy-TOPSIS Multi-objective Optimization Method

TOPSIS method is one of the suitable optimization techniques that deals with the multi-response problem related to the manufacturing sector. The longest distance and the shortest distance from the ideal solutions gives the most suitable option from rest of the runs [18, 19]. The linguistic variables are given important weights within 0–1 interval by triangular fuzzy number as given in Table 1. The weights assigned by the four decision makers are given in Table 2. The aggregated fuzzy weights are

Table 1 DM responses for machining responses

Machining responses	Decision makers (DM)			
	DM-1	DM-2	DM-3	DM-4
Flank wear	L1	L3	L2	L1
RA	L1	L2	L2	L3
CRC	L1	L3	L2	L1

Table 2 Linguistic variables

Importance fuzzy weights	
Lowest (L1)	(0, 0, 0.1)
Lower (L2)	(0, 0.1, 0.3)
Low (L3)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)
High (H3)	(0.5, 0.7, 0.9)
Higher (H2)	(0.7, 0.9, 1)
Highest (H1)	(0.9, 1, 1)

Table 3 Aggregated fuzzy weights assigned to the responses

Machining responses	Fuzzy weights		
Flank wear	0.025	0.1	0.25
Ra	0.025	0.125	0.3
CRC	0.025	0.1	0.25

specified in Table 3. Equation 1 helps to develop normalized performance matrix [20].

$$X_{mn} = \frac{a_{mn}}{\sqrt{\sum_{m=1}^{9} a_{mn}^{2}}} \tag{1}$$

where the a_{mn}, m and n are the experimental runs and responses, respectively, and X_{mn} symbolizes the normalized values as in Table 4. The weights of the responses were multiplied with the corresponding normalized performance matrix. The ideal value set (H^{+}) and (H^{-}) were calculated using Eqs. 2 and 3, respectively.

$$\begin{aligned} H^{+} &= [[\max(h_{mn}), n \in M] or [\min(h_{mn}), n \in M], m = 1, 2, 3, \ldots 9] \\ &= h_1^{+}, h_2^{+}, h_3^{+}, \ldots h_9^{+} \end{aligned} \tag{2}$$

$$\begin{aligned} H^{-} &= [[\min(h_{mn}), n \in M] or [\max(h_{mn}), n \in M], m = 1, 2, 3, \ldots 9] \\ &= h_1^{-}, h_2^{-}, h_3^{-} \ldots h_9^{-} \end{aligned} \tag{3}$$

Table 4 Normalized performance matrix

Run no.	Process parameters			Normalized values			Ideal solution		Closeness coefficient	S/N ratio
	A	B	C	Flank wear	Ra	CRC	dm^{+}	dm^{-}	C+	SNRA1
1	1	1	1	0.00023	0.018	0.324	0.096	0.352	0.784	−2.109
2	1	2	2	0.00056	0.346	0.098	0.159	0.289	0.644	−3.819
3	1	3	3	0.00063	0.166	0.136	0.093	0.356	0.792	−2.021
4	2	1	2	0.00114	0.036	0.324	0.105	0.344	0.765	−2.317
5	2	2	3	0.00119	0.492	0.116	0.232	0.216	0.482	−6.334
6	2	3	1	0.00071	0.073	0.098	0.037	0.412	0.917	−0.751
7	3	1	3	0.00025	0.071	0.681	0.254	0.194	0.433	−7.268
8	3	2	1	0.00159	0.051	0.145	0.045	0.404	0.899	−0.920
9	3	3	2	0.01382	0.173	0.065	0.074	0.374	0.833	−1.583

The distance between the ideal solutions was estimated. Finally, proximity of all experimental value of the ideal solution for the response was derived from the closeness coefficient. The closeness coefficient is calculated using Eq. 4. The ideal solutions and the closeness coefficients are tabulated in Table 4.

$$C_c = \frac{d_m^-}{d_m^- + d_m^+} \tag{4}$$

4 Results and Discussion

Since the experimental run is done as per the L9 orthogonal array the optimal parametric setting has been predicted by using statistical software Minitab trail version 18 software. Figure 1 portrays the main effects plot of the responses. The optimum parametric setting found from the Fig. 1 of main effects plot is F at 0.16 mm/rev, Cs at 40 m/min and DOC at 0.4 mm. Predicted S/N ratio along with mean value for the optimal solution is found to be 0.6652 and 0.9988, respectively. ANOVA is performed to find out each process parameter percentage contribution on the responses and to know the most influencing process parameter. From Table 5 ANOVA, it is observed that DOC has the percentage contribution of 55.6%, accompanied by feed of 25.3% and cutting speed of 1.41%. DOC is the most important process parameter trailed around with feed and cutting speed. Fig. 2 portrays that decreasing the DOC

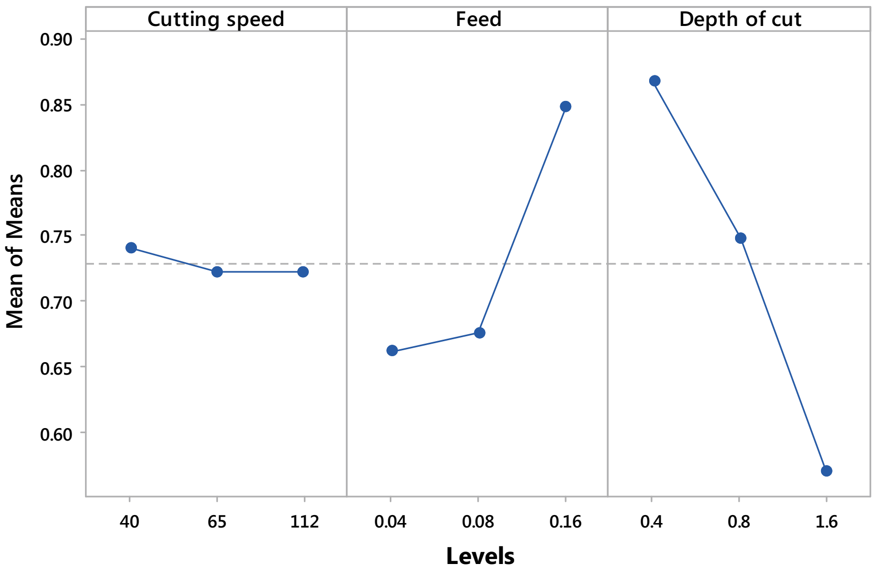

Fig. 1 Main effect plot for closeness coefficient

Table 5 ANOVA for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	% contribution
Cs (m/min)	2	0.6188	0.6188	0.3094	0.08	1.42
F (mm/rev)	2	11.0429	11.0429	5.5214	1.43	25.32
DOC (mm)	2	24.2491	24.2491	12.1245	3.15	55.60
Residual error	2	7.7012	7.7012	3.8506		
Total	8	43.612				

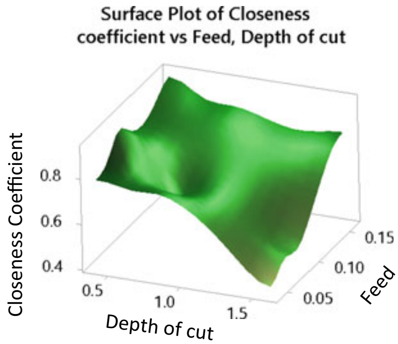

Fig. 2 3D surface plot of closeness of coefficient with feed and depth of cut

and increasing the feed the closeness coefficient increased. Actually, the tool wear occurred at a high-speed cutting, since at this instance the adhesion of chip to the workpiece takes place. Thus, increases in feed rate affect the tool wear. Temperature formation in chip–tool interface is also high. At this time, more the DOC the more will be adhesion, which leads to an increase in the tool wear. Increase in wear of tool reduces the surface finish of the newly machined surface and thus increases the surface roughness. The chip cross section increases with feed and the increase in cutting speed increase the temperature between the tip of the cutting inserts and workpiece. An excessive heat is generated in the interface of chip and tool due to increase in the friction.

5 Conclusion

An attempt was made to search the optimum parameter setting with the process variables i.e., F, DOC and Cs using a hybrid fuzzy-TOPSIS method while machining titanium alloy with uncoated carbide inserts. Based on the analysis of fuzzy-TOPSIS method and the predicted closeness coefficient, the optimum parametric setting was established as Cs at 40 m/min, DOC at 0.4 mm and feed at 0.16 mm/rev. The DOC was found to be the most influencing process variable.

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Analysis of Factors for Green Supply Chain in Indian Timber Market: An ISM Approach

Vinayak Goel and Sonal Khurana

1 Introduction

The implementation of Logistics, Operations, Planning, and Sourcing knew as LOPS strategy cumulatively accounts for the basis of the SC. The supply chain is involved in both manufacturing as well as the service sector. We specifically center our research on the SC in the manufacturing side.

With growing modernization, supply chain management strategy alone is not enough for disruptive growth. Specific concerns need to be paid attention to regarding the environment. The manufacturing industries are among the top reasons responsible for polluting nature due to increasing emissions of CO_2 [1]. As the production increases, negligible heed is given to the increasing effect of greenhouse gases leading to the depletion of the Ozone layer. Green Supply Chain deals with the practices that are used to devise a particular product, product design, material source, and selection of the raw material, final product delivery along with waste management techniques for the industry. Green supply chain often deals with triple bottom line (TBL), i.e., economic, environment and social dimensions [2]. Sustainability could be better achieved for the long term if we implement green practices in the manufacturing plant [3]. Practices often become dirty or brown as supply chain prevails due to several parameters such as economic growth, financial constraints, lack of entrepreneurial education and experience. Entrepreneurs must be open to learning and developing new innovation which is based on green drivers as compared to non-green drivers, thereby leading the employees on the same platform and promoting green practices. Companies should not only comply with environmentally friendly practices to meet the government regulations but also they should make it their whole sole purpose of production [4].

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Timber is one of the major building materials being used in construction as well as furniture and interiors. Lumbers are cut from the forests all over the world and are transported in rough square logs to the sawmills for further processing. Timber is of different species and its demand varies according to the usage and environmental or geographical conditions. Procuring wood, i.e., deforestation in itself is a practice which is continuously deteriorating the environment, and its processing often leads to the production of sawdust which causes air pollution by increasing the level of particles in the air.

We will be majorly focusing on the timber market in Delhi NCR which is a major concern due to the industry being set up within the city as compared to other places where industries are often set up in the outskirts of the city in open areas. Delhi NCR has a different kind of wood processing plant from a sawmill to particle board manufacturer.

The study is performed with an aim to bridge the gap between timber industries with respect to green supply chain in order to adapt sustainable development. The research was based on keywords based study.

Supply chain optimization is the key to solve any problem, but the GSC is adequately sustainable. Using the available resources and capabilities in the best possible way to implement engineering and meet the needs of society is all that it requires.

2 Literature Review

Marchi et al. [1] explain how the production rate booms the green supply chain. Vendor—buyer supply chain can be greener with investment made in the preaching of production techniques and thereby abate the CO_2 emissions of the production process. Critical points aligning the plant manufacturers toward environmental friendly production system are government legislation. Oh et al. [5] discuss the challenges of the demand uncertainty, short product life cycle, and to customize the products in the market. Challenges include an increase in flexibility, complexity in supply. Barack Obama who served as the president of America for two terms came up with supplier pay initiative which emphasizes on company's faster payments to small suppliers or provides some financing solution to enable them to access working capital at a lower cost. This initiative will promote small businesses to enjoy affordable working capitals by reducing the short term borrowing costs thereby facilitating them to invest, hire, and grow. This initiative will not only benefit smaller firms but also facilitate the big companies by stabilizing their supplier and experience overall growth in the economy [6]. Liu et al. [7] explain the supply chain flexibility with the adoption of green operations. With the implementation of mass customizations, managing cost, quality, and responsiveness has become a significant burden which can be resolved by developing flexible supply chain where firms apply agile, adaptive, and responsive changes to cope with uncertainty and ensure smooth flow of products which includes examples like Toyota's eco-design and Volkswagen's green design initiative. El Berishy et al. [8] figured out the necessity of green logistics for a sustainable

Table 1 Green supply chain: literature

S. No.	References	Definition
1.	Dube et al. [9]	The process of developing a sustainable SC by transforming environment-friendly inputs into reclaimable outputs which may be used at the closing of the life cycle
2.	Abu Seman [10]	GSCM integrates environmental concerns into supply chain management through environmental innovations
3.	Infosysblogs.com [11]	Product deliverables, supplier services, material flow through manufacturers to end customers, the flow of information and cash all aligned to the idea of the environment by incorporating environmental innovations
4.	Chin et al. [12]	SC activities can be influenced moderately through the integration of environmental thinking and influence the total environmental impact is GSCM

enterprise where green initiative links the economic, environment, and social impact (Table 1).

Huo et al. [13] differentiate between lean and green processes, lean helps in improvement of social, environmental as well as social aspects, whereas green processes majorly work only for environmental performance. Supplier and customer green processes are related to the environmental performances, social performance, and economic performances adding to the supplier and customer lean processes linked which are also linked with similar aspects. In the next 20 years, Asia will be the hub for most of the world's manufacturing activities due to which green supply chain is gaining relevance in India [14].

2.1 Research Objectives

- To draw out the priority of the parameters which will help in the incorporation of green supply chain in the Indian Timber Market.
- To perform the qualitative analysis through ISM approach and figure out the driving and the driven parameters in the implementation of GSC in Indian Timber Market.

The various parameters having an influence to establish GSC in timber market, after the systematic review of literature are shown in Table 2. A systematic review of literature was conducted.

3 Research Methodology: Interpretive Structural Modeling

Interpretive structural modeling(ISM) is a technique used to establish a relation between parameters which usually define a problem. In this paper, we have used the

Table 2 Critical factors of GSC

S. No.	Critical factors	Authors
1.	Collaboration with suppliers	[2, 15]
2.	Leadership style	[2, 16–19]
3.	Financial resources	[2, 3, 20–22]
4.	Social responsible activities	[22]
5.	Linkage capabilities	[15, 18, 23–25]
6.	Technology infrastructure	[2, 24–26]
7.	Government support	[1, 2, 15, 25, 27]

Table 3 Structural self-interaction matrix (SSIM)

S. No.	Factors	7	6	5	4	3	2
1	Collaboration with suppliers	A	A	A	A	A	A
2	Leadership style	A	V	V	V	V	
3	Financial resources	A	V	V	X		
4	Social responsible activities	A	V	V			
5	Linkage capabilities	A	X				
6	Technology infrastructure	A					
7	Government support						

ISM technique to prepare a model for GSC implementation for timber market in India. The steps followed are given below:

(1) Initially, the criterions were identified using the literature and categorized according to the relevance of the issue.
(2) The parameters were then arranged in a structural self-interaction matrix (SSIM) for comparing the variables. The same is shown in Table 3.
(3) Then the SSIM is converted into an initial reachability matrix (IRM). After the reachability matrix is formed, then the formed matrix is checked for transitivity and 0 is replaced with 1^* wherever the rule of transitivity is violated. This leads to the formation of final reachability matrix as shown in Table 4.
(4) Once the final reachability matrix is achieved, the level partitioning is performed by drawing the reachability set and antecedent set and finding intersection between these sets. Final level partitioning table is depicted by Table 5.
(5) This is later developed into an ISM model where nodes of factors are replaced with statements [17, 28, 29].

Table 4 Final reachability matrix

Factor	1	2	3	4	5	6	7	Driving power
1	1	0	0	0	0	0	0	1
2	1	1	1	1	1	1	0	6
3	1	0	1	1	1	1	0	5
4	1	0	1	1	1	1	0	5
5	1	0	0	0	1	1	0	3
6	1	0	0	0	1	1	0	3
7	1	1	1	1	1	1	1	7
Dependence power	7	2	4	4	6	6	1	30

V: parameter i help to achieve parameter j
A: parameter i is achieved by parameter j
X: parameter i and j help achieve each other and
O: parameter i and j are unrelated

Table 5 Final level partitioning table

Factor	Reachability set	Antecedent set	Intersection	Level
1	1	1, 2, 3, 4, 5, 6, 7	1	I
2	2	2, 7	2	IV
3	3, 4	2, 3, 4, 7	3, 4	III
4	3, 4	2, 3, 4, 7	3, 4	III
5	5, 6	2, 3, 4, 5, 6, 7	5, 6	II
6	5, 6	2, 3, 4, 5, 6, 7	5, 6	II
7	7	7	7	V

4 Results and Discussion

The objective of the research was to establish the parameters necessary to incorporate GSC practices in the MSME of the Indian timber market using the ISM approach. The drive and dependence power was derived depending upon the influential properties of the respective critical factors.

Highest Driving Power was that of government support which could enhance the green supply practices by subsidizing greener initiatives like energy resources, providing special economic zones set up manufacturing plants, supplier linkage facilities, innovation, and sustenance. De Oliveira et al. [30] have also emphasized that Governmental incentives motivate the firms to incorporate environmentally friendly technologies. One of the factors that influence the leadership style of the firm is the support provided by the Government in the direction of green supply chain. Capitals needed to buy the technologies which are sustainable require top management support. Network of the firms with the outside world depend on the financial resources available and also on the socially responsible activities in which the firm is engaged.

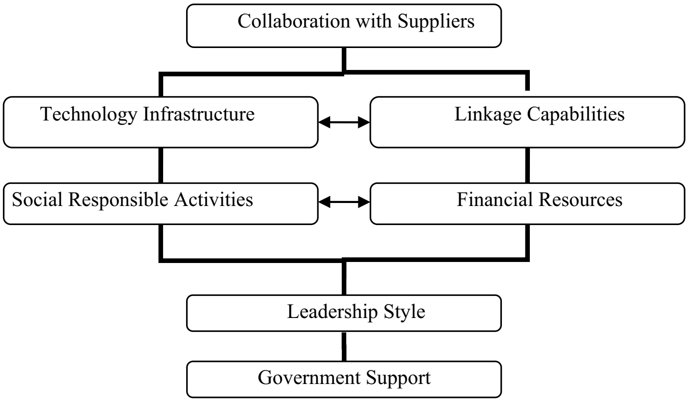

Fig. 1 ISM structure of critical factors affecting green supply chain

Collaboration with suppliers had highest dependence power and it depends on the technological infrastructure available with the firm and linkage capabilities of the firm. Khurana et al. [2] have mentioned that cooperation with suppliers is an essential aspect for incorporating green practices. The ISM model is represented in Fig. 1.

5 Conclusions

The Green Supply Chain is not a choice or fancy to be adapted in the present day scenario in Delhi. The increasing emissions of CO_2 from timber industries and spreading of sawdust have caused the air quality index to degrade by a considerable amount. The present research aims to identify the factors which influence the incorporation of green supply chain in Indian timber market. Government support is found to have highest driving power in Indian context. It drives the leadership style of the firm. Collaboration with suppliers has received the highest dependence power. The above results obtained are qualitative in nature as the ISM model is obtained with the help of the opinion of the experts. The limitations of the study are that the study was conducted with the expert's opinion but was not checked pragmatically to reinforce the findings. Moreover, it is difficult to preach the manufacturers with conventional production techniques to adapt new practices and lead a stronger association to integrate with the necessary enhancements. Future work can take the present research as base and this can be validated using statistical techniques.

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The Value Engineering Way: A Case of Industrial Fans

Vijay Kumar Singh, Rajeev Rathi, and Arshia Kaul

1 Introduction

Each manufacturing company wants to consider production at the best cost possible in the most effective manner [1]. The firm would want to get maximum return on the investment that it puts. The investment for the company maybe in various forms: (i) cost of machines, (ii) cost of raw materials, (iii) cost of maintenance and repair of the machines, (iv) cost for hiring personnel, and (v) cost of providing a conducive environment to work in the company and any other investments in the interim [2–4]. This can be achieved by implementation of value engineering concept in any organization [5, 6]. The concept of Value Analysis or Value Engineering was given by Miles (2015), as a purchase executive in GEC, USA. The major difference between this cost reduction techniques from the others, is that it focuses on the function [7, 8]. Also additionally, one would try and find the same function or performance at a lower cost [9]. The step by step procedure which applies the recognized techniques and helps is to identify the function of the product or services [10]. Through this one is also able to determine the worth for the particular function. There are also alternative ways in which the necessary function can be accomplished at the lowest overall cost by using creative techniques [11]. Value analysis is a method which helps to solve the cost and technical problem. The value analysis or engineering can help to boost the productivity of the organization. This particular tool is used for reducing the cost and improving the productivity [12]. There are a number of industries which have used this technique, for example, the manufacturing, automobile, construction, telecommunication, defense, etc. [13–16].

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An industrial fan is a cooler for individuals working in an organization for providing conducive working environments. Some of the details of the types of the industrial fans are given below:

- *Utility Industrial Fans*: This is a direct drive tubeaxial fan with an airfoil propeller and a front and rear PMS type guards for maximum protection and safety. This has a design such that the fan can operate on the floor as a free-standing unit or it can be mounted on the wall. The air delivery can be adjusted through 360°. This is normally used in welding booths and control panel ventilation, insect chasing, process cooling, and smoke dissipation [17].
- *Axial industrial fans*: These are the fans which move out large volume of air under very low pressure. The air enters the fan along the axis of fan hub. These have many applications for ventilating buildings to tunnels etc. [18, 19].
- *Centrifugal Industrial fans*: These are fans which in which the air or gas inside the spinning fan is thrown off the outside of the wheel at the largest diameter. These types of fans draws more gas and also through them off the central hole. There are two main types of centrifugal fans: (i) Forward curved centrifugal fans and (ii) Backward curved centrifugal fans [20].
- *Pedestal Mount Industrial fans*: These fans are the ones which are in standing position. They are used in smaller rooms in a company [21].

The industrial fans are installed for the comfort of the workers [22, 23]. It is important to understand the cost–benefit trade-off for any company in manufacturing [24, 25]. The question that arises is that what will be the return on the investment. On one hand, providing comfort to the workers would increase the efficiency of the workers, but will this increase of efficiency of the workers comes at a cost. The company would want to have a good trade-off between the benefit it provides and the investment for the industrial fans installed. In the present case, it is to understand the best utilization of industrial fans. The industrial fans must be used such that they provide a conducive environment to employees of the company keeping in mind the cost effectiveness. The question that arises is the trade-off that could be achieved while providing a conducive environment and the cost associated with it. It is essential to understand in detail what the various types of the industrial fans are so that we are able to use these in both an effective and efficient manner.

2 Methodology Adopted

For evaluating the best cost to providing conducive environments to workers in plants of the company, the value engineering analysis is used. The methodology adopted for value engineering is highlighted in Fig. 1.

Step 1 *Orientation Phase*: In this phase, the input which is required for the value engineering technique is understood.

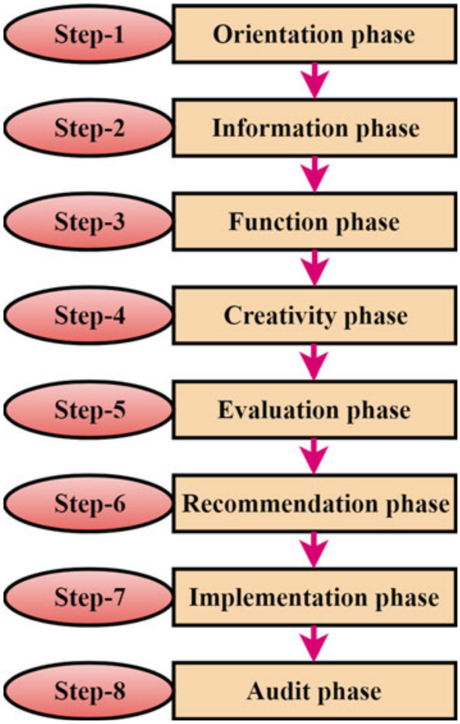

Fig. 1 Flow chart of methodology

Step 2 *Information Phase*: In this phase, the collection of relevant information is gathered.

Step 3 *Function Phase*: In this phase, the functions are defined of an item, process, or service under study. The functions are defined in only Verb and Noun forms. Then the functions are also defined as primary or secondary. The functions also need to be categorized as higher order or lower order functions and in terms of the necessity. Also in this phase, a link is made between the FAST (Function Analysis System Technique) to define the interrelationship between the functions and the help in understanding of the problem clearly. Quantitatively, the FUNCTION–COST–WORTH is evaluated and also the value gap and value indexes are calculated.

Step 4 *Creativity Phase*: The alternatives are searched to achieve the functions defined in the function phase at a lower cost. Some of the techniques to use are: Brainstorming technique, Crawford slips writing technique, Gordon Technique.

Step 5 *Evaluation Phase*: In this phase, the ideas in the creativity phase are filtered and the implementable ideas are put aside from the non-implementable ones. Further, these are further evaluated using a pair-wise comparison method. The decision matrix, criteria matrix, and making criteria are used.

Step 6 *Recommendation Phase*: The ideas which are to be implemented are written with a complete plan.
Step 7 *Implementation Phase*: In this phase, the plan proposed is implemented.
Step 8 *Audit Phase*: The savings are audited to check.

3 Case Explanation

The case presented here is for a value evaluation for axial industrial fans in different sub-plants of a large steel plant in India. This was taken up to reduce the cost of energy in running the industrial fans, which were being utilized in plants to provide comfort to the operators.

Step 1&2 *Orientation and Information Phase*

The following information was collected about industrial fans and the details of the total hours of operation are given in Table 1.

i. Air Delivery equipment: 51,000 m^3/h
ii. Total number of industrial fans: 551
iii. Number of industrial fans in service: 496 in various sub-plants
iv. Average number of industrial fans that undergo repair annually—68
v. Number of new industrial fans procured annually—12
vi. Power Consumption by one industrial fan—3 kW (Record on testing)
vii. Power Consumption by 496 industrial fan—1.5 MW
viii. Energy Consumption—98,88,240 units
ix. Annual Energy Bill @ Rs. 6/unit–Rs. 59,329,440.

Besides the heavy stand (350), heavy impeller (20 kg), and higher size of motor (3.7 kW) caused concern. In general an industrial fan consists of the following five basic components Motor, Starter, Stand, Guard, and Impeller. All the components are store stock items, catering to the needs of repair/replacement and also for assembly of new industrial fans at our electrical repair shop. Table 2 gives specific consumption number of units annually for each part of the industrial fans (Table 3).

Cost details as percentage of (Rs. 3500 approx.).

Table 1 Hours of operation

Number	Hours/Day	Day/Year	Total hours of operation
250	24	365	21,90,000
200	16	310	9,92,000
46	8	310	1,14,080
		Total	32,96,080

Table 2 Yearly consumption of different parts of the industrial fans

Annual consumption in units	
Motor-3.7 kW	12
Starter	50
Guard	18
Stand	28
Impeller	23

Table 3 Percentage consumption for each part

Part	Consumption	Total (%)
Motor	1	33.0
Starter	1	4.0
Stand	1	27.6
Guard	1	6.5
Impeller	1	22.7
Assembly cost	–	6.2

Step 3 Function Phase

In Table 4 gives the functional analysis of each part defining basic or secondary functions. A FAST diagram was prepared to identify the scope of functions, which could be fruitfully analyzed by Value Engineering technique. Though all the basic functions are to be performed, the worth of the functions is not the same. Hence, in order to identify the value gap, that is, potential saving area, a Function–Cost–Worth analysis was carried out as shown in Table 5. The maximum value gap for the function "Provides Torque" was found to be potential saving area. Hence, this function demanded immediate attention.

Step 4 Creative Phase

During the brainstorming session, a suitable atmosphere was created to enable the members to be at their creative best by remembering the four simple rules:

- Quantity breeds Quality
- Suspend judgment for the time being
- Free wheel the ideas
- Cross-fertilize ideas with others.

Through brainstorming session as many as 60 ideas were generated.

Step 5 Evaluation Phase

All the ideas generated during the creative phase were analyzed with the reference to the desired criteria. The score and corresponding ranks of the criteria were computed and were given in Table 6.

Table 4 Functional analysis

S. No.	Component	Function		Basic or secondary
		Verb	Noun	
1	Motor	Provides	Torque	B
		Supports	Weight	S
		Converts	Energy	B
		Rotates	Parts	B
2	Starter	Starts	Motor	B
		Stops	Motor	B
		Conducts	Current	B
		Protects	Motor	S
3	Impeller	Circulates	Air	B
		Creates	Draft	B
4	Guard	Protects	Machine	S
		Protects	Person	B
		Allows	Air	B
5	Stand	Supports	Weight	B
		Provides	Stability	S
		Provides	Reach	B

Using criteria matrix and decision matrix, we could arrive at the following alternatives which are called Proposals.

- **Proposal 1**: Replace existing 3.7-kW motor with 2.2-kW motor
- **Proposal 2**: Change all industrial fan to simpler design available in the market
- **Proposal 3**: Replace existing 3.7-kW motor with 1.5 k- motor and lighter impeller.

For the case of alternative (ii), the team also studied the provisions given in IS 6272 and industrial fans of different makes available in the market. A comparative statement of the study is given in Table 7. During this study, the team suggested a few changes in the design available in the market to meet our requirements, which were carried out as under:

(i) Type of guard was changed by increasing the mesh size to 50 mm, thereby achieving economy without compromising on safety.
(ii) Mounting of the guard was changed to ensure stability of guard.
(iii) Diameter of the base was increased for improved stability of the industrial fans. Impeller locking arrangement was incorporated to ensure safety.
(iv) Oscillating system was removed as found redundant.
(v) Use of standard motor was recommended to enable easy procurement.

The feasibility of the above modifications was discussed with the manufacturers and their occurrence was obtained. Life cycle cost is the total cost of the system/product

Table 5 Function–cost–worth analysis[a]

S. No.	Function	Allocated cost "C"	Function worth "W"	Basic of worth	Value gap (C-W)	Value index (C/W)
1	Provide torque	33	13.8	0.55 kW motor	19.2	2.3
	Convert energy	–	–	–	–	–
2	Operate motor	4	3.6	0.55 kW starter	0.4	1.09
	Protect motor					
3	Circulate air	22.7	11	Reduced weight local supply	11.7	2.05
4	Protects person	8.25	0.22	Rejected S.P. screen	3.03	14.7
	Allows air	3.24	0.005		3.235	648
5	Provides support	10.77	2.40	Reduced height, reduced size	8.37	4.48
	Provides stability	15.22	8.2		7.02	1.85
	Provides reach	1.68	1.68		–	1.00

[a]Cost values are percentages of cost of industrial engineering
The basis of worth was identified as follows [27]
Actual power required for 900-mm-sweep industrial fan is shown in Eq. 1
Horse Power = $(V \times P)/(6356 \times E)$ (1)
Here HP: Actual Horse Power required in HP
V: Volume of air 5,000 m^3/h = 30,000 cfm
P: Static Pressure in inches (0.1 for free air delivery)
E: Static efficiency (65% of industrial fan)
HP = $(30{,}000 \times 0.1)/(6356 \times 0.65) = 0.73$
KW = $0.73 \times 0.746 = 0.545$
Actual power required = 0.545 kW

incurred during its span life. It includes cost of repair, preventive maintenance, operations, and depreciation in addition to capital cost. Accordingly initial and operation costs were calculated given in the Table 8. Based on these figures cost savings, return on investment (ROI), and pay back periods were calculated for three alternatives.

The criteria matrix given in Table 8 has been filled up using the criteria matrix scale as given below:

Major Difference = 3; Medium Difference = 2.

Minor Difference = 1; No Difference = 0.

The decision matrix is give in Table 9 and is filled up using the scale as given below:

Table 6 Criteria of decision analysis[a]

Identity	Criteria	Score	Rank
A	Air delivery	10 + 1=11	3
B	Air velocity	7	7
C	Availability	7 + 1=8	6
D	Cost	3	9
E	Manufacturability	5	8
F	Safety	12	2
G	Satisfaction	21	1
H	Maintainability	9 + 1=10	4
I	Availability	9	5
J	Maneuverability	0 + 1=1	10

[a]Definition of Criteria are given in the appendix

Table 7 Comparison of 900-mm-sweep industrial fans of different makes

Makes	RPM	KW	Volts	Total free air delivery, Nm3/h
IS:6272	1000	1.8 (max)	415	51,000
Calcutta fan	1000	1.5	415	56,000
G.T.R.	1000	1.58	415	56,000
Khaitan	1000	2.2	415	51,000
G.E.C	1000	1.5	415	56,000
TISCO	1000	3.00	415	51,000 (1000 mm sweep)

Excellent = 5; Very Good = 4; Good = 3; Fair = 2; Poor = 1.

Step 6 Recommendation Phase

The recommendation that has been achieved on the value chain analysis is that all industrial fans must be changed to simpler design available in the market. This coincides with the Proposal 2.

Step 7 Implementation Phase

Finally, the management decided to replace the existing machines in phases.

Step 8 Audit

The total savings on the basis of value chain analysis has been given in a savings in energy cost of Rs. 2.5 crores was achieved implementing above recommendations. Table 10 given in details of the life cycle cost in lakh.

In Table 11, the details of savings and return on investment from each proposal have been described. In Table 12, the summary of overall benefits has been given on the assessment of all three proposals.

Table 8 Criteria matrix

A	A3	A0	A3	A0	A1	G3	A0	I2	A3	10
	B	B0	B3	B0	B1	G3	B0	I2	B3	7
		C	C2	C2	F1	G3	H2	C0	C3	7
			D	E2	F2	G2	H3	I2	D3	3
				E	F2	G2	H3	I2	D3	5
					F	F0	F2	F2	F3	12
						G	G2	G2	G3	21
							H	H0	H1	9
								I	I2	9
									J	0

Table 9 Decision Matrix

Alternatives	Air delivery	Air velocity	Availability	Cost	Manufacturability	Safety	Satisfaction	Maintainability	Space	Maneuverability	Total
	A 11	B 7	C 8	D 3	E 5	F 12	G 21	H 10	I 9	J 1	
Proposal 1	5	5	5	5	5	5	5	5	4	5	426
	55	35	40	15	15	60	105	50	36	5	
Proposal 2	5	5	5	5	5	5	5	5	4	4	434
	55	35	40	15	25	60	105	50	45	4	
Proposal 3	5	5	5	5	5	5	5	5	4	5	435
	55	35	40	15	25	60	105	50	45	5	

Table 10 Life cycle cost (Lakh)

S. No.	Items	Existing	Proposal 1	Proposal 2	Proposal 3
1	Initial cost				
1a.	Purchase and Installation		19.29	52.35	50.14
1b.	Less credit for scrap of motor		3.28	3.28	3.28
1c.	Less credit for component		0	5.51	0
1d.	Less credit for scrap of impeller		0	4.95	4.96
	Initial cost sub total		16.01	38.61	41.9
2	Annual operation cost of power	88.99	77.12	46.87	46.87
3	Annual maintenance cost material overhead	4.59	4.29	3.6	3.98
4	Total operation & maintenance	93.58	81,041	50.47	50.85

Table 11 Savings and return on investment (Lakh)

S. No.	Items	Proposal 1	Proposal 2	Proposal 3
1	Savings against the method	12.17	43.11	42.73
2	Return on investment (R.O.I)	76	110	101
3	Pay back period (year)	1.3	0.89	0.98
4	Power savings (MW)	0.24	0.79	0.79
5	Energy savings (kWh)	13.18	52.07	52.07

Table 12 Summary of benefits

S. No.	Components	Existing	Proposal 1	Proposal 2	Proposal 3
1	Weight of M/c (Kg)	520	495		
2	Motor (kW)	3.7	2.2		
3	Design	Heavy Strl	Heavy Strl	Tubular	Heavy Strl
4	Performance (Nm3)	51,000	51,000	51,000	51,000
5	Power consumption (MW)	1.5	1.26	0.60	0.70
6	Energy consumption (kWh)	9,888,240	8,569,808	4,680,100	4,680,433
7	Energy bill (Rs. In Lakh)	88.99	77.12	42.00	42.12
8	Savings (Rs. In Lakh)		77.12	42.12	42.73

4 Conclusion

The present case highlighted the cost–benefit analysis of a company for the case of industrial fans. This analysis has been carried out using the step-wise methodology through the value chain analysis. The implementation of the case has been shown for the case company with set of industrial fans for multiple small plants in a larger plant setup. The case study concludes that among the three proposals, proposal 2 has been chosen on the evaluation. It provides best way to installation of industrial fans which enhance performance of workers at site and saved Rs. 42.12 lakh per annum. The insights into present case can be further explored as reference for value engineering analysis for different applications.

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To Find the Effectiveness of Barriers in Reverse Logistics by Using ISM

Deeksha Tiwari, K. K. Shukla, and Ubaid Ahmad Khan

1 Introduction

In an organization, the major challenge is managing return product to the customer, can be done with the help of Reverse Logistics (RL). RL is the path used for mange all process connected to the return and use again the return items. This is a latest approach to increase the productivity and effectiveness using the sustainability concept and activity which involved reducing the cost, managing the goods, arranging of hazardous waste from packaging and production; From a commercial perspective, Reverse Logistics is a process where products move from final destination to manufacturer, to capture value otherwise unavailable, and for proper dumping of the goods [1]. Technology and human resources are gifts for India. Despite this, just because of the successful implementation of RL companies face lots of problems, which is the barriers of RL, due to it the idea of RL is not generally accepted. Some of these RLBs are lack of strategic planning, lack of personnel training, financial constraints, company policies, the problem with product quality, etc. For the top management, it is hazardous to handle the involvement of economic and other operational feature that recognize the long term company activities [2]. Mentioned RLBs are affecting the implementation of RL and also they are influences to each other, so it is necessary to know the reciprocal relationships between them. Recognize that barrier which provokes some other barriers and that independence barrier which are influenced by driving barrier and support in the implementation of the RL program by top management. Taking correct action for dealing with barriers in RL can guide to come out form that implementation problem. For structuring the barriers of RL, the ISM approach has been used here.

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2 Literature Review

2.1 Reverse Logistics

In the beginning, RL was introduced for both business and society and the Logistics management commission start publishing those studies [3]. After that other studies are stretching the opportunities on reuse and recycling the goods. RL encourage another use of resources, which can be cost-effective by extending the product life cycle. RL motivates the producer to make blueprint that can be dismantle and renewal, in the structure of sustainable development [4].

2.2 Studies Related to RL

From the last few years, companies have been planed the RL programs and reuse the damage products and try to increase the product life-cycle have been concentrated and complete structure to set up. A wide range of RL company put into practice have presented by Chandra Prakash and Pandya [5]. Multiple attribute decision-making (MADM) approach is most widely used in industry to take better decision [6].

In his study (G. Thiyagarajan and Saifil Ali), they identify the most affecting RLBs that prevent implementation in different–different online retail industries and for this, they used methods to recognize the most influencing obstructions for Reverse logistics execution [7].

Analysis of RL strategies for An Indian perspective has been discussed by S. K. Sharma et al. in his paper focus points are: hierarchy of action and obstruct the execution of RL, Relationships, inventory management, planning and control [8]. Most of the articles are dedicated to the analysis of practice that has been appeared in RL.

Marta Starostka- Patyak, Marcin Zawada, and Aleksander Pabian explain how to implement RL in enterprises [9].

However, a computer-assisted learning process called Interpretive Structural Modeling (ISM) methodology, which is used to recognize the interrelationship between the variables (or elements) and build a structure on the basis of RLBs level. Analyses of interactions among the reverse logistic barriers have studied by V. Ravi and Ravi Shankar using ISM methodology [10].

Here in this paper use, fifteen barriers are mentioned, some of them are from different-different research papers and others from the self-study. A Literature Review for this paper is shown in a chart, which is given in Table 1.

Table 1 Literature review

S.No.	Barriers	Researcher
1	Lack of strategic planning	Chehab Ali (2017), Chandra Prakash (2015), Marta Starostka-Patyk (2013), V. Ravi (2004)
2	Lack of advanced information system	Chehab Ali (2017), Dr. Saifil Ali (2016)
3	Shortage of devoted employees/staffs for handle returned product	Chehab Ali (2017)
4	Financial constraints	Chehab Ali (2017), Chandra Prakash (2015), S.K. Sharma (2011), V. Ravi (2004)
5	Lack of personnel training	
6	Lack of economic support from the government	Muhammad Waqas (2018)
7	Lack of inspection	
8	Lack of higher authority commitment	Muhammad Waqas (2018), Dr. Saifil Ali (2016), Marina Bouzon (2015), Marta Starostka-Patyk (2013), Sharma (2011), Ravi (2004)
9	Quality issue	Muhammad Waqas (2018), S.K.Sharma (2011), V. Ravi (2004)
10	Company policies	Muhammad Waqas (2018), Marina Bouzon (2015), Marta Starostka-Patyk (2013), Chandra Prakash (2015), V.Ravi (2004)
11	Opportunist behavior	Chehab Ali (2017)
12	Lack of knowledge about reverse logistics	Muhammad Waqas (2018), Marina Bouzon (2015), Marta Starostka-Patyk (2013), S.K. Sharma (2011).
13	Restrictive return policy	Muhammad Waqas (2018), Marina Bouzon (2015), Chehab Ali (2017)
14	long processing cycle time of returned product	Chehab Ali (2017)
15	Unknown total cost of return process	Muhammad Waqas (2018), Chehab Ali (2017)

3 ISM-Based Framework Development

To analyzing the complex systems researcher Warfield in [11] first proposed a methodology called Interpretive Structural Modeling (ISM), it is an interactive learning process. Here in this study to determine the relationship between RLBs uses ISM methodology.

In 2013 an overview is presented by Rajesh Attri. According to them, ISM is an established methodology where develops a hierarchy of system variables who represent the structure of that system. In this method structure those elements in a comprehensive systematic model that are different–different and directly affect the system. Using this model, try to find driving barriers and independent barriers which are based on the driving and dependence power [12].

ISM can be used as an individual or group process. The ISM methodology involved various steps, they are given below:

1. To identify those variables which are related to the problem;
2. To create a contextual connection between elements,contextual relation between any two variable can be drawn;
3. Develop a structural self-interaction matrix (SSIM) of variables which depicts pair-wise relation between variables;
4. Develop a Reachability matrix (RM) from the SSIM, and scrutinize it for transitivity;
5. Partitioning of the Reachability matrix into several levels;
6. Depends on relationship given in the Reachability matrix, drawn a directed graph;
7. Convert the resultant diagraph into an ISM-based model by placing the statements instead of variables nodes; and
8. Re-examining the model to test for conceptual in consistency and performing the modification if required.

3.1 Development of Self-interaction Matrix

ISM methodology recommends taking the specialist suggestion depend on different-different management techniques, to build up the appropriate relationship among the variables. For the contextual relationship ^{i}leads to^{j} type method is chosen. An appropriate relation is selected for analyzing the RL barriers. Maintaining the appropriate relationship for every RL barriers in intelligence, the existence of a relationship among any two barriers (i and j) and associated direction of the relationship is questioned. Development of SSIM led to describe the appropriate relationship between different pair of variables [12]. For representing the direction of a relationship between RLBs (i and j), following four symbols have been used (Table 2):

1. V is used for the relation from RLB_i to RLB_j (i.e. if i support to j).
2. A is used for the relation from RLB_j to RLB_i (i.e. if j support to i).
3. X is used for the relation in both directions (i.e. if i and j support to each other).
4. O is used for no relation between two RLBs (i.e. if i and j are unrelated).

Table 2 Structural Self-Interaction Matrix (SSIM)

RLB's	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	V	V	V	X	V	V	V	A	V	V	V	V	V	V	X
2	A	A	V	A	V	V	V	A	X	O	A	A	V	X	
3	O	A	O	A	A	O	A	A	A	A	A	A	X		
4	V	A	V	A	V	V	V	A	V	V	A	X			
5	O	V	V	A	V	V	V	A	V	V	X				
6	O	O	O	O	X	A	A	A	A	X					
7	A	A	A	A	V	V	V	A	X						
8	V	V	V	V	V	V	V	X							
9	A	A	O	O	V	V	X								
10	A	A	X	A	V	X									
11	A	A	A	A	X										
12	V	V	V	X											
13	A	A	X												
14	O	X													
15	X														

Table 3 SSIM Entry Rules

Entry in SSIM at the (i,j) cell	Entry in initial RM	
	(i,j)	(j,i)
V	1	0
A	0	1
X	1	1
O	0	0

3.2 Establishment of Initial Reachability Matrix

In this step, SSIM is converted into the initial Reachability matrix by transforming the information of each cell of SSIM into binary digits (i.e. ones or zeros). Table 3 shows the transformation has been done by the following rules:

3.3 Final Reachability Matrix

The final RM is generated by eliminating the transitivity in initial RM. Concept of transitivity is, if element X is related to Y and Y is related to Z, and then X is related to Z.

So, following incorporating the transitivity relationships by 1* final Reachability matrix is established:

3.4 Developing Level Partition

With the help of the final Reachability matrix, reachability and antecedent set for all barriers are found out. The Reachability set included the variable itself and the other variable help to achieve it [13]. Then, the intersection of these sets is derived for all the RLB's and the element having reachability & intersection sets are equal in leveling at the apex level (level I) in structure. After reaching the apex-level variable, it is divided from other variables. To find the criterion in the next level the similar manner iteration procedure is repeated and continued till the every level is found (level II, III, IV, V and so on…).

Table 4 shows the final partition level of RLB's for reverse logistics after all iterations.

Table 4 Final Reachabiliuty Matrix

RLB's	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	D.P.
1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	14
2	0	1	1	0	0	1*	1	0	1	1	1	0	1	0	0	8
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	1	1	1	0	1	1	0	1	1	1	0	1	0	1	10
5	0	1	1	0	1	1	1	0	1	1	1	0	1	1	0	10
6	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	3
7	0	1	1	0	0	1	1	0	1	1	1	0	1*	0	0	8
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
9	0	1	1	0	0	1	1*	0	1	1	1	0	1*	0	0	8
10	0	0	1*	0	0	1	0	0	0	1	1	0	1	0	0	5
11	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	3
12	1	1	1	1	1	1	1	0	1*	1	1	1	1	1	1	14
13	0	0	1*	0	0	1*	0	0	0	1	1	0	1	0	0	5
14	0	1	1	0	0	1*	1	0	1	1	1	0	1	1	0	9
15	0	1	1*	0	0	1*	1	0	1	1	1	0	1	0	1	9
Dp.P.	3	10	15	4	4	14	10	1	10	12	14	3	12	5	5	

3.5 Development of the ISM Model

Eighth levels have been found for fifteen RLBs. From these results, the ISM model has been generated by changing variables node by relationship status exposed in the final reachability matrix after eliminating the indirect relations (Fig. 1).

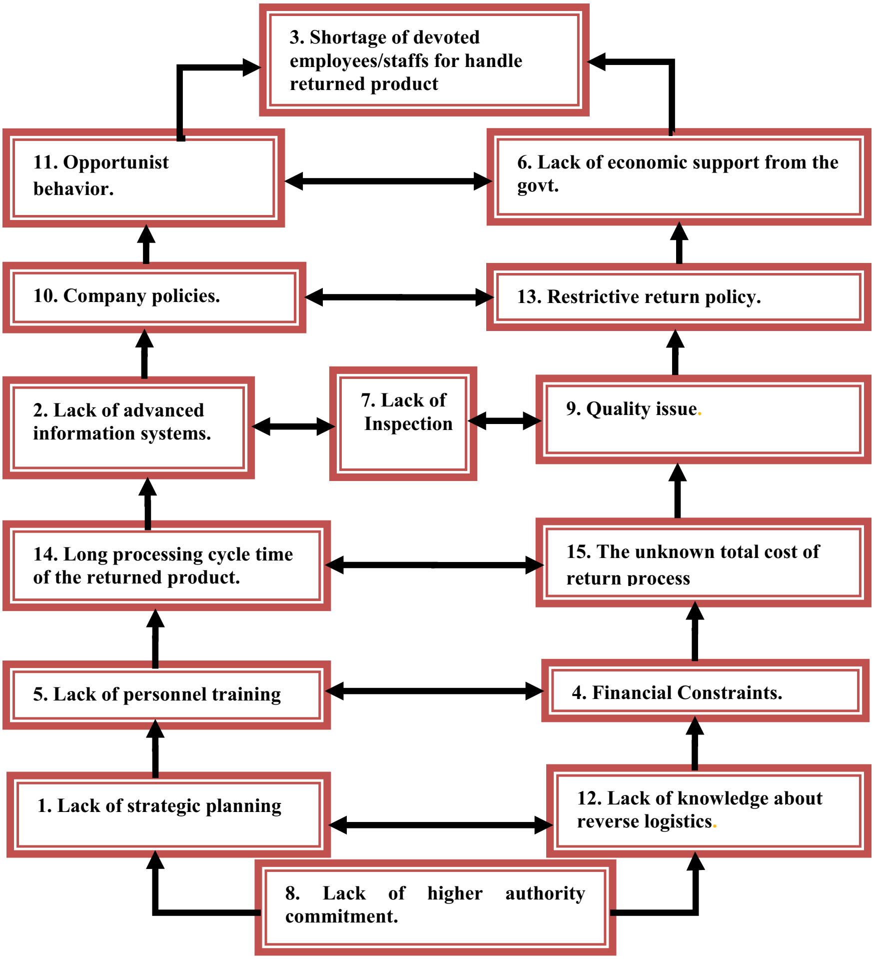

Fig. 1 ISM Based Model for Barriers of Reverse Logistics

4 MICMAC Analysis of Obtained Results

The MICMAC analysis is simply a 2D graph (Fig. 2), and the main purpose of this is to examine the driver power and dependence of variables.

The RLB's are organized into four various groups:

4.1 **Cluster-I Autonomous RLB**—Autonomous Barriers is those which driving and dependence powers are low. They do not have much influence on the system. In the present study, no autonomous barrier is found.

4.2 **Cluster-II Dependent RLB**—Dependent Barriers those which have low driving power and high dependence power. They are at the top in the model, therefore, considering the important BARRIER. Barrier numbers 2, 3, 6, 7, 9, 10, 11, 13 are dependent barriers in this study.

4.3 **Cluster-III Linkages RLB**—Linkages RLB are those which have high driving as well as high dependence power. These Barriers are not stable in nature and effect on successful Reverse logistics implementation. There are no Linkage barriers.

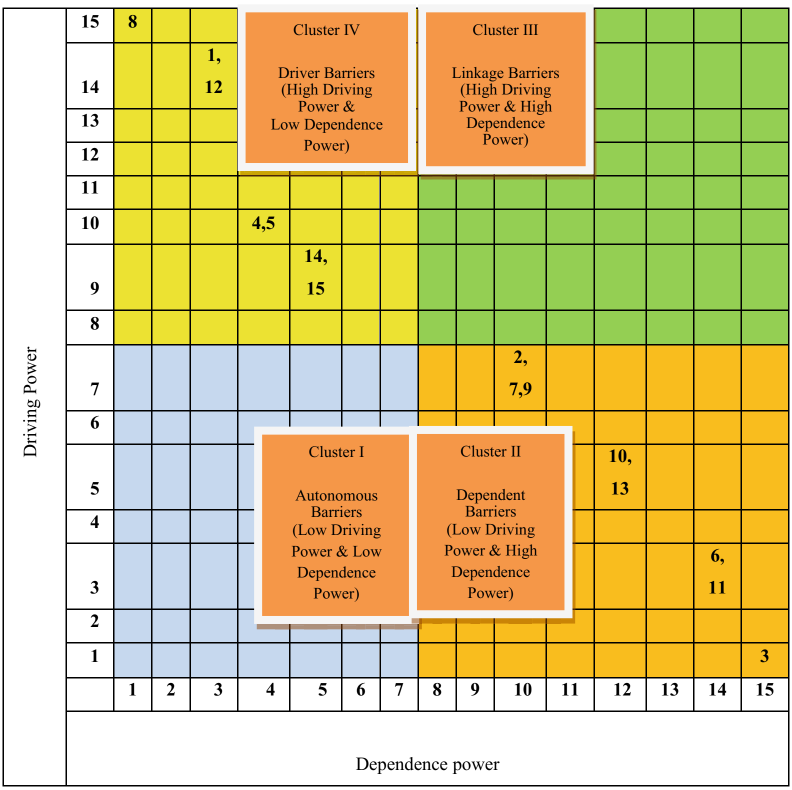

Fig. 2 Cluster formation by MICMAC analysis

4.4 **Cluster-IV Independent or Driver RLB**—Independent RLB is those which have high driving power and low dependence power. Therefore, the manager should try to remove it for effective implementation of RL. Barrier number 1, 4, 5, 8, 12, 14, 15 are independent barrier.

5 Conclusion

Lots of works have been done on factors which affect RL behavior. However, every time human behavior is complex and not easy to guess, more research work should be done. For this purpose, the present research tries to find the effectiveness of RL barriers. The company theatre a very important role in the development of any nation. This thesis summarized the mostly repetitively used RLBs which influence RL along new dimensions from industries viewpoint. It is very helpful for the researchers and managers involved in RL. Learning from old faults, times have come to modify and take RL toward the concept in the correct way and reap its advantages to the fullest.

In research, a try to identify and recognized the RLBs for smooth RL in the company. RL helps firms for their continued existence, profit, and growth. The RL increases the efficiency and production rate. Most of the companies face RL problems due to RLBs. Overcoming the identified RLBs provides a sustainable competitive benefit to the firms through smooth RL. Hence, the managers of the industries must consider these RLBs in order to utilize the benefits of RL. Result of study is that Lack of higher authority commitment, Lack of strategic planning, and Lack of knowledge about reverse logistics are significant RLBs. Therefore, for good management it is necessary to give attention to these Barriers during RL practices. This result assists the managers in judgment making and strategies to enable the identified RLBs according to their driving power.

ISM model results in an imaginary ranking that require a appropriate quantitative technique to calculate their effectiveness. From ISM and model, this thesis concludes that lack of higher authority commitment is the most effective barrier and lack of strategic planning and lack of knowledge about RL are the second most effective barriers in RL so managers should focus on these barriers while implementation of RL activity in the organizations.

Since the ISM model is depend on the experts view. So, it doesn't need further validation. But for the accuracy and sustainability of the result, structural equation modelling (SEM) used to test the model fitness for any organization.

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Optimization of MQL Machining Parameters Using Combined Taguchi and TOPSIS Method

Anjali Gupta, Rajesh Kumar, Harmesh Kumar, and Harry Garg

1 Introduction

The exceptional properties of Titanium and its alloys like high specific strength, high resistance to corrosion, nonmagnetic properties and bioadaptability, have found their extensive applications in aerospace, marine, medical and oil and gas industries. But along with these advantages, there are also many challenges associated with the machining of these alloys. They are usually considered as difficult-to-cut materials on account of their low thermal conductivity, high chemical reactivity [1]. Due to their poor machinability, extra care is to be taken to avoid failure of the tools due to overheating and to obtain desired surface finish. Minimum quantity lubrication (MQL)-based machining of such alloys has resulted in the improved performance of these alloys. Several studies over the years have obtained many encouraging results during the successful application of MQL for the machining of these alloys [2–7]. MQL involves supplying a miniscule amount of cutting fluid (of the order of ml/h) in the form of droplets near the tool–work interface. These droplets are formed as a result of atomization of cutting fluid by using the high-pressure air. In MQL, high air pressure results in effective penetration of oil droplets in the cutting zone and hence providing the necessary lubrication, which is lacking in conventional flood machining where a large amount of cutting oil(of the order of l/min)is supplied at low pressure. Improved lubricity, as a result of the improved droplet penetration in the cutting zone, results in lesser friction and consequently lesser cutting forces and lesser cutting energy. Moreover, drastically reduced utilization of the cutting fluid in MQL as compared to conventional flood machining address the problems caused to the environment due to the disposal of this hazardous pollutant. MQL

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was also found to be superior over dry conditions during the investigations carried out by Liu et al. [2] on distinctly coated tool inserts during the high speed turning of Ti–6Al–7V. Wang et al. [4] studied the effect of MQL on cutting forces, surface roughness and tool wear while turning Ti–6Al–4V and compared the results with dry and flood machining. MQL outperformed as compared to the other modes of cutting conditions in terms of all the response parameters. Khatri et al. [5] also observed the suitability of MQL during the end milling of Ti–6Al–4V as the least occurrence of tool wear was obtained for MQL as compared to both dry and flood conditions. It has been also reported that the use of biodegradable environment-friendly vegetable oils in MQL results in favorable machining performance. Prakash and Ramana [6] studied the effect of using palm oil in MQL turning of Ti–6Al–4V. It was observed that the better turning performance in terms of both surface finish and tool life was obtained in MQL as compared to dry and flood lubrication. In comparison to dry and flood lubrication, least tool wear was obtained during the vegetable oil-based MQL machining of Ti–6Al–4V by Garcia, U. and Ribeiro, M.V [7].

Literature review indicates that favorable machining performance is expected with MQL machining of titanium-based alloys. Ti–6Al–4V has been widely used as an implant material in applications such as hip and knee prosthesis, dental implants and artificial joints, etc. However, the release of cytotoxic Vanadium ions from these implants may cause health disorders such as Alzheimer's disease, neuropathy and osteomalacia. Replacing cytotoxic vanadium by nontoxic niobium, Ti–6Al–7Nb can be used as an alternative of Ti–6Al–4V. Further, as Ti–6Al–7Nb has the Young's modulus comparatively nearer to bone than Ti–6Al–4Nb, the former can be considered as a favorable choice for implants [8, 9].

The purpose of this study is to examine the effects of independent variables on multi responses tool flank wear (TW) and surface roughness (Ra) during the MQL-based turning Ti–6Al–7Nb. Furthermore, an effort has been made to know the optimal set of these independent process variables through the combination of "Taguchi" and "multi-attribute decision multi-making technique (TOPSIS)" to simultaneously minimize both TW and Ra.

2 Experimental Conditions

2.1 Details of Equipment Used

The workpiece used in this study was Ti–6Al–7Nb and with dimensions Φ13 mm × 70 mm. Titanium nitride-coated carbide inserts TNMG120408 were chosen as the tool materials and were mounted on the tool holder MTJNL 2525 M16 for the turning operation. The experiments were performed in the MQL environment on CNC center lathe machine, while Noga Minicool MQL system was used to atomize the cutting oil. The details of experimental setup of the turning tests are as shown in Fig. 1

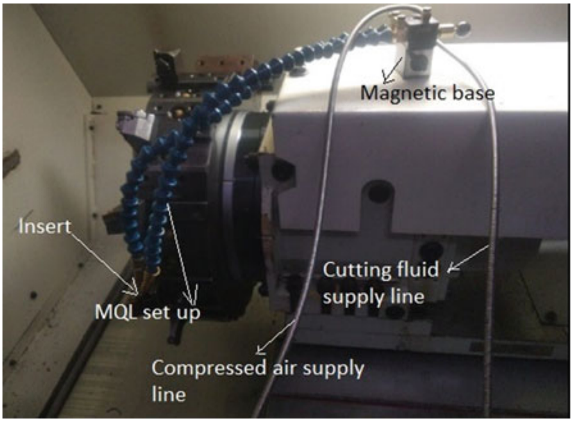

Fig. 1 Details of experimental setup

2.2 *Design of Experiments*

The experiments are usually designed based on the number of factors and their levels. Kind of the cutting oil (vegetable oil, synthetic oil and mineral oil), rate of the flow of cutting oil (60 ml/h, 100 ml/h and 120 ml/h) and cutting speed (50 m/min, 80 m/min and 100 m/min) were the independent process variables considered for this study. Table 1 shows the process variables and their levels. As there were three factors and each at three levels (3^3), thus total of 9 experiments were performed based on Taguchi L9 orthogonal array design. In each experiment, workpiece was turned up to a length of 55 mm and the fixed values of depth of cut at 1.5 mm and feed at 1 mm were used.

After the machining, the surface roughness parameter (Ra), which is the average of the height of the irregular profile with respect to the mean line of a surface. was recorded with the help of Mitutoyo surface roughness tester (Fig. 2). For the measurement, the values of sampling length and cut-off length were set at 2.5 mm and 8 μm, respectively. For each cut, three values of Ra were measured at three different positions and their mean is considered for further analysis. An optical microscope (Fig. 3) was used to measure the second response function, i.e., flank wear of the inserts (TW).

Table 1 Independent parameters and their levels

Parameter	Type of oil (A)	Flow rate of oil (ml/h) (B)	Cutting speed (m/min) (C)
Level 1	Vegetable oil	60	50
Level 2	Mineral oil	100	80
Level 3	Synthetic oil	120	100

Fig. 2 Surface roughness tester

Fig. 3 Optical microscope

3 Multi-objective Optimization

3.1 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is one of the technique of multi-criteria decision-making (MCDM) that has been satisfactorily used for decision making in earlier studies in the field of machining [10, 11]. TOPSIS methodology with its simple calculations puts forward two reference solutions, namely the positive ideal solution (Si^+) and negative ideal (Si^-) solution. Further, closeness coefficient (Ci) (representing the best solution) is closest to Si^+ and at the same time remotest from Si^- is found out. The complete procedure of TOPSIS is summarized as follows:

Step-I: Deducing decision matrix

The decision matrix comprising "n" attributes and "m" alternatives is first formed. For this study, "n" attributes represent two response functions Ra and TW and 'm' alternatives represent nine experimental runs.

Step II: Normalization matrix

The following expression is used to obtain the normalized matrix:

$$Rpq = \frac{a_{pq}}{\sum_{p=1}^{p=\mathrm{m}} a_{pq}{}^{2}} \tag{1}$$

here, $p = 1, 2, 3 \ldots$ m; $q = 1, 2, 3 \ldots$ n

Step III: Acquiring weighted decision normalized matrix

The normalization matrix as obtained in step II is multiplied by the weight of each attribute, w_q, $q = 1, 2, 3....n$ to obtain weighted normalized matrix as shown in the expression below:

$$\mathrm{U}pq = \mathrm{w}_q * R_{pq} \tag{2}$$

where, $\sum_{q=1}^{n} \mathrm{w}_q = 1$

Step IV: Determining the positive ideal (U^+) and negative ideal (U^-) solutions

The positive ideal solution (U^+) which represents the best possible value and the negative ideal solution (U^-) which is the worst value of every attribute can be obtained from the weighted decision matrix as follows:

$$\mathrm{U}^+ = \left[\left\{\max\left(\mathrm{u}_{pq}\right)/q \in Q\right\}, \left\{\left(\mathrm{U}_{pq}\right)/q \in Q'\right\}\right] \tag{3}$$

$$\mathrm{U}^- = \left[\left\{\min\left(\mathrm{u}_{pq}\right)/q \in Q'\right\}, \left\{\max\left(\mathrm{U}_{pq}\right)/q \in Q\right\}\right] \tag{4}$$

where Q is associated with beneficial attribute and Q' is associated is associated with non-beneficial attribute. Here, Ra and TW are non-beneficial.

Step V: Calculating the separation measure from positive ideal (Si^+) and negative ideal (Si^-)

Next, the separation measure of each alternative from the positive ideal (Si^+) and from the negative ideal one (Si^-) is calculated as below:

$$\mathrm{Si}^+ = \sqrt{\sum_{q=1}^{n} \left(u_{pq} - u_q^+\right)^2} \tag{5}$$

$$\mathrm{Si}^- = \sqrt{\sum_{q=1}^{n} \left(u_{pq} - u_q^-\right)^2} \quad (6)$$

Step VI: Calculating the closeness coefficient (Ci)
The respective closeness to the ideal solution is calculated in terms of closeness coefficient (Ci) with the help of equation below:

$$\mathrm{Ci} = \frac{\mathrm{Si}^-}{\mathrm{Si}^+ + \mathrm{Si}^-} \quad (7)$$

The largest value of closeness coefficient *Ci*, corresponds to most preferred solution.

4 Results and Discussion

4.1 Estimation of Closeness Coefficient (Ci)

The combined Taguchi and TOPSIS methodology is used to covert the muti-responses Ra and TW in terms of single objective function as closeness coefficient (Ci).

Decision matrix corresponds to three input parameters at their separate levels as shown in Table 1. The experimental results obtained for response parameters (Ra and TW) corresponding to nine experiments performed are as shown in Table 2. The two responses (Ra and TW) are first normalized using Eq. (1). Both Ra and TW are given equal weights of 0.5 and the weighted normalized matrix is obtained as shown in Table 3. Further, the positive ideal (U^+) and the negative ideal (U^-) solutions are calculated to obtain the values of separation measures (Si^+ and Si^-). The respective

Table 2 Experimental results for Ra and TW

Exp no.	Process parameters			(Ra) (µm)	(TW) (mm)
	(A)	(B) (ml/h)	(C) (m/min)		
1	Vegetable oil	60	50	2.456	0.029
2	Vegetable oil	100	80	1.823	0.018
3	Vegetable oil	120	100	1.203	0.021
4	Synthetic oil	60	80	2.583	0.075
5	Synthetic oil	100	100	1.823	0.065
6	Synthetic oil	120	50	2.28	0.055
7	Mineral oil	60	100	2.19	0.045
8	Mineral oil	100	50	3.523	0.035
9	Mineral oil	120	80	2.276	0.025

Table 3 Estimation of closeness coefficient

Normalized matrix		Weighted normalized matrix		Separation measures		Closenesscoefficient
Ra	TW	Ra	TW	Si^{+}	Si^{-}	Ci
0.3531	0.2140	0.3531	0.2140	0.0987	0.1862	0.6534
0.2621	0.1329	0.2621	0.1329	0.0445	0.2432	0.8452
0.1729	0.1550	0.1729	0.1550	0.0110	0.2598	0.9591
0.3713	0.5536	0.3713	0.5536	0.2325	0.0675	0.2251
0.2621	0.4798	0.2621	0.4798	0.1790	0.1276	0.4162
0.3278	0.4060	0.3278	0.4060	0.1569	0.1158	0.4247
0.3148	0.3321	0.3148	0.3321	0.1223	0.1464	0.5448
0.5065	0.2583	0.5065	0.2583	0.1781	0.1476	0.4531
0.3272	0.1845	0.3272	0.1845	0.0813	0.2051	0.7161

Table 4 Mean effect of each factor

Level	Kind of oil	Flow rate of oil (ml/h)	Cutting speed (m/min)
1	0.819	0.474	0.510
2	0.355	0.571	0.595
3	0.571	0.700	0.640
Delta	0.46	0.225	0.129
Rank	1	2	3

closeness coefficient (Ci) as shown in Table 3, has been finally obtained for each combination of factors.

Mean response table for average value of Ci is shown in Table 4, shows the mean effect of each process parameter on Ci at different levels. The ranks indicates that cutting oil is most influencing parameter followed by flow rate and then cutting speed. S/N ratio plot for Ci as shown in Fig. 4, indicates that optimal setting for turning correspond to level settings A1B3C3 (A1 = Vegetable Oil, B3 = 120 ml/h, C3 = 100 m/min) for simultaneous optimization of both Ra and TW. Also, the highest value of Ci as seen in Table 3 corresponds to experiment run 3 for which the level settings correspond to A1B3C3.

4.2 ANOVA for Closeness Coefficient (Ci)

ANOVA table at a 95% confidence interval is used to identify whether there is significant effect of process variables (kind of oil, rate of flow of oil and cutting speed) on the responses (Ra and TW). ANOVA result for means of closeness coefficient (Ci) is shown in Table 5. As the P value for kind of oil less than 0.05, it can be considered as

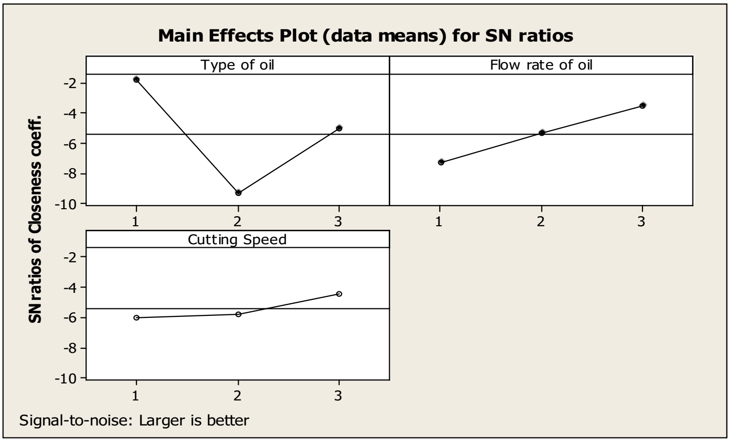

Fig. 4 S/N ratio for Ci

Table 5 ANOVA table for Ci

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% age contribution
Kind of oil	2	0.3233	0.3233	0.1616	53.55	0.018	74.81
Flow rate of oil	2	0.0767	0.0767	0.0383	12.72	0.073	17.7
Cutting speed	2	0.0260	0.0260	0.0130	4.31	0.188	6.02
Error	2	0.0060	0.0060	0.0030			
Total	8	0.4321					

S = 0.0549415 R-Sq = 98.60% R-Sq (adj) = 94.41%

the significant parameter. The value's percentage contribution shows that the cutting oil is the most dominant parameter affecting Ci.

5 Conclusions

The present investigation aims at improving the machining performance of titanium alloy Ti–6Al–7Nb by simultaneously minimizing both the surface roughness and tool wear. Taguchi methodology is used to design the experiments by varying the type of cutting oil, flow rate of oil and cutting speed. Optimal settings of process variables are found out by multi-attribute methodology TOPSIS. The optimal settings found are A1B3C3 (kind of oil = vegetable oil, rate of flow of oil = 120 ml/h and cutting speed = 100 m/min). The better performance of vegetable oils may be attributed to their high viscosity index (as there is low susceptibility of viscosity of the vegetable oils to temperature changes) and thus resulting in more stability at high temperatures.

ANOVA results deduce that the oil type has the maximum influence on closeness coefficient and accounts for 74.81% followed by flow rate of oil 17.76%. Thus, vegetable oils proved to be a good substitute to overcome environmental and health hazards posed by mineral oils.

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Life Cycle Assessment Framework for Sustainable Development in Manufacturing Environment

Mahender Singh Kaswan, Rajeev Rathi, Dinesh Khanduja, and Mahipal Singh

1 Introduction

Increased levels of greenhouses gases and other environmental issues have become a challenging task for industrial organizations [1, 2]. Moreover, to meet the targets of Paris pact 2022, there is the immense need for a robust and comprehensive tool that aids decision makers to identify solutions that support sustainable development [3, 4]. To encounter these challenges, ecological contemplations have to be incorporated in decision-making by businesses, individuals, public administrations, and policymakers [5–7]. Life cycle assessment (LCA) is a tool that supports decision makers to develop the solution to the problem meanwhile taking into considerations all the dimensions of sustainability [8]. It is a tool that assesses environmental load of process, product, or any activity from its initial stage to the disposal [9]. Life cycle assessment is a tool that considers life cycle perspective while assessing the ecological impacts of a product or process [10]. In the case of use of biofuel to run vehicles, LCA not only considers the usage stage of the product but also takes into account industrial and agriculture processes to produce the biofuel. Figure 1 represents the biofuel life cycle from its inception to the ultimate customer.

Besides the development in LCA, the organizations are not much aware of the long-term gains of LCA in terms of future prospective customers and increased social value of the organization [11]. The small and medium-sized enterprises are lagging behind large companies to implement LCA [12]. The main bottlenecks behind this perception are the change in the workplace routine, high cost of LCA methodology, complexity to execute LCA, and lack of qualified personnel to implement LCA. The

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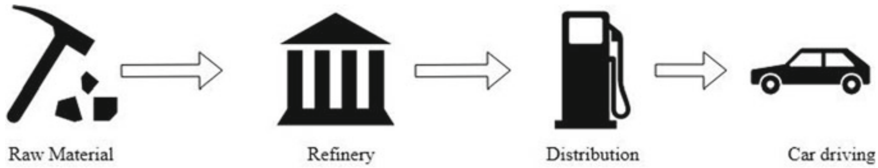

Fig. 1 Life cycle of biofuels from inception to end customer

comprehensive literature survey reported that major barriers to implement LCA by SMEs were

(i) Deficiency of knowledge base of sustainability problems;
(ii) Deficiency of apparent profits;
(iii) Expertise training on problem-solving by LCA;
(iv) Lack of monetary resource;
(v) Deficient external drivers and motivations;
(vi) Complications of tool sets.

The changed customer perception toward environmentally friendly products, government regulations, and environmental pacts enforced the organizations to think from an ecological point of view [13]. To meet these challenges industrial organizations are incorporating various tool sets like strategic environment assessment (SEA), environmental impact assessment (EIA), environmental risk assessment (ERA), cost-benefit analysis (CBA), material flow analysis (MFA), and LCA [14]. LCA is a tool to assess the green impact of a product and process, but to conduct LCA in an industry a lot of uncertainties are evolved like the type of data set to be taken in consideration, the ambit of LCA study, uncertainty of monetary gain, and lack of framework to conduct LCA [15, 16]. There is no evidence in the literature to establish an LCA framework pertaining to the manufacturing organization. Therefore, issues related to industries and environmental concern provide motivation and direction to conduct the present study. The present work provides a systematic LCA assessment procedure that if implemented with due care and full knowledge leads to the fulfillment of the sustainable development goal of SMEs.

The present work has been systematized into four sections including introduction. Section 2 depicts the background of LCA and its development. The third section of the manuscript presents the methodology adopted in the present research: LCA framework. The fourth section of the article embodies conclusions, limitations, and future research direction of the present study.

2 Background of LCA

The LCA came to the picture in the 1960s due to increased concern about the ecological degradation and depletion of natural sources of energy. LCA had the first application in packaging studies and in the early stages of its development,it mainly focused on energy and emissions [17]. There have been numerous efforts to develop LCA methodology since the 1970s, but it has been receiving much consideration from researchers of environmental science since the 1990s. The term LCA was coined in the 1990s; earlier it was known by the names of life cycle oriented methods and Resource and Environmental Profile Analysis (REPA), eco-balancing resource and cradle-to-grave assessment [18, 19]. The earlier development of LCA primarily took place in northern America and Europe. In earlier methods of LCA, material and energy accounting were predominately considered. The earlier developed method primarily focused on energy efficiency, source use, emissions of gases, and generation of solid matter as waste, from each industrial process [20]. There was no uniformity of the applied methods in the early years of LCA development because ecological concerns addressed by the methods tended to change with public anxieties. Earlier impact assessment method represented the amount of water and pollutants needed to dilute up to the safe levels [21].

Main characteristics of LCA
Take a life cycle perspective
The LCA considers the product system or life cycle perspective which means all the practices needed to make the product are taken into account. The main reason to consider life cycle perspective is that it permits to recognize and avert the problem alteration between various stages of life cycle or processes.

Cover a wide scale of ecological issues
In LCA, not only the exposure to processes over the whole product life but also complete coverage of ecological issues is done. It not only covers climate change but also ponders a wide kind of eco-friendly issues. These issues comprise climate change, water use, occupation and land transformation, hypertrophication, etc.

Is Quantitative
LCA is quantitative in the sense that it is used to investigate the ecological effects of numerous processes and systems under consideration. The quantitative assessment by LCA results in the identification of a process or system that is better from the environmental point of view [22].

Is based on science
LCA is associated with science as the assessment of potentials effects is intrinsic in a natural science like measurement of water consummation by a flow meter, etc. In LCA, a value judgment is done to allocate weights to numerous kinds of environmental issues for estimation of the inclusive impact of the system under consideration.

To model complex product systems, propagation of LCI data and impact valuation methodologies made a need for devoted LCA software and the first version of both SimaPro and GaBi software were unconfined in 1990 [23]. In the early 1990s, a very impactful assessment method was developed: CML 92, EPS method and Eco indicator-99 [24]. The early 1990s also show the birth of many inventory databases managed by different institutions to cover a wide spectrum of processes. The data sets

Table 1 Major events of LCA history

Prominent LCA Study	Year	References
LCA study for the energy requirement of LCA product	1963	[26]
Coca Cola did a study on LCA to compare beverage containers	1969	not revealed
Environmental profile analysis of beverage industry	1974	[27]
Development of impact measurement method for critical volume	1984	[28]
Gabi software of LCA was released	1989	[29]
SimaPro software launched	1990	[30]
Term life cycle assessment was coined	1990	[31]
LCA ISO 14040 standard released	1997	[32]
The LCI database eco-invent version 1.01 was released	2003	[32]
Life cycle sustainability framework analysis was proposed	2008	[32]
Publication of International Life Cycle Data System handbook	2010	[33]
Product environmental footprint and Organization environment footprint guidelines released	2012	[33]
Life cycle assessment of energy and environment impact	2015	[34]
Sustainable conversion of carbon dioxide	2017	[35]
Environmental impact of municipal solid waste using LCA	2018	[36]
LCA of microalgae-based biofuel	2019	[37]

managed were different for even the same type of process results in the discrepancy of the final results. To overcome this difficulty consistent data standard v.1.01 was released [25]. In the twentieth century, impact assessment methodologies have been developed and refined. Globalization led to increased attention on bio-based products in LCA and a slew of activities regarding impact assessment of land and water used have been reported in the literature. The inclusion of social dimensions in sustainability leads to the development of life cycle sustainability assessment to take into consideration each dimension of sustainability. Table 1 indicates the major events of LCA history.

2.1 Main Issues Related to LCA

LCA is a tool to evaluate ecological impacts, support strategic improvement and making decisions. It is a new discipline with 50 years of history and 30 years of intense development in the areas of food processing and agriculture construction [38]. The main aim of the life cycle initiative (International life cycle partnership) an initiative of the United Nations Environment Programme (UNEP) is to maintain ecological balance with the support of better indicators, data sets, and practical frameworks [39]. The researchers in the past have focused only on the carbon study of global warming whereas other potential parameters (eutrophication, acidification, ecotoxicity, and human toxicity) of sustainable development were not considered [40]. The inclusion of all these parameters needs a lot of data sets and the evaluation of these parameters. So, there is great potential to develop a systematic way and procedure to explore these other parameters to evaluate sustainability through LCA. Moreover, the execution of LCA is a difficult task as it demands for huge data collection and thorough knowledge base of Green Lean indicators [41]. Therefore the industrial managers and practitioners are focusing on a decision support system to identify the environmental hot spots in the entire supply chain. The identifications of the environmental hot spots in the entire supply chain is a cumbersome and challenging task as it needs a real-time database of all the inventory of supply chain and measurements of various inputs and outputs(energy, water, material) at the intermediate stage of the supply chain [42].

The industrial organizations are now incorporating the LCA as a tool to meet the strategic initiative of sustainable development that not only provides an impetus to meet government regulations but also depicts an environment-conscious image of the organization [36]. There is a need to explore the relative impacts of inducing green technology in the organization on the marketing strategies and perceptions of the customers. Moreover for a particular application of LCA within an industry is very cumbersome work as there is a need for a lot of data and specific knowledge base to conduct together the number of indicators to be considered, interpretation and comparisons with the previous study to evaluate the results.

3 Methodology

The methodology for the framework development of LCA consists of five phases: goal definition, scope definition, analysis of inventory, assessment of impact, and interpretation (refer Fig. 2).

3.1 Goal Definition

The first phase of the LCA framework is to define the goal of the study. The main purpose of the study is well-defined and designated comprehensively in this phase. This phase affects much of the later stages of LCA because the decisions made at the later stages of LCA must be in accordance with the goal of the study [43, 44]. There are generally six aspects that must be considered while defining the goal of the study. These aspects are as follow:

1. Envisioned applications from the results obtained of the study,
2. Methodological choices limitations,
3. Motives and decision context for conduction of the study,

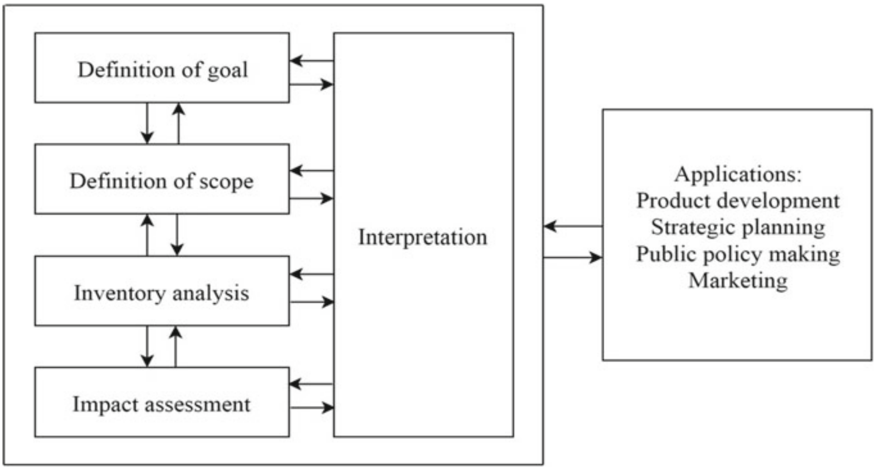

Fig. 2 LCA framework

4. Target people,
5. Revelation of proportional studies to the people,
6. Representative of the work and other prominent players.

To determine the envisioned applications of the LCA, results are very indispensable at the start, as it affects LCA's later stages, like drawing of boundaries of the system, tracking of inventory data set, and elucidation of results [37, 45]. The methodological choice exhibits that LCA results are dependent on the chosen method for the study. Besides, the prime motive to carry out LCA should reflect in the goal together with the intended population to whom the results of the study will affect. Moreover, the goal of the study should consider whether the results of a comparative of the present work with the existent study will be made public. The goal definition should obviously state who ordered the study, who supported it, the organization which will affect the study, and clearly state the LCA experts for the study.

3.2 Scope Definition

The scope definition phase of LCA determines the system to be considered and estimation of the system. The main purpose of the scope of the study is to confirm and document the reliability of the methods; postulation and data set together will fortify the reproduction of the study [46, 47]. The various elements of the scope definition are

1. Deliverables,
2. Object assessment,
3. Modeling framework and multifunctional processes handling,

4. System boundaries and completeness requirements,
5. Interpretation of LCI,
6. Readiness of the basis for the impact assessment,
7. Necessities for appraisals of systems,
8. Critical review need,
9. Preparation for reporting of results.

The deliverables should directly replicate the intended applications results. The ISO 14044 standard specified that LCA must comprise an impact valuation like LCI and the LCIA results. LCA considers single or multiple product systems poised of many unit processes of the product systems. The functions, functional unit, and reference of the said systems must be understood for the study of the system. The scope description deals with the choice of an appropriate modeling framework of LCI and procedures to care multi-facets practices. The selections must be made in coherence with the definition of the goal, predominantly in the context of the decision. The system boundary means the periphery between the system being considered and (1) economy considered and (2) ecosphere. The unit procedures applied to designate the product system must be illustrative of the processes considered in the system. The planning of the impact assessment should be done to conformity with the definition of goal. The scope definition should also include the requirements for comparisons of systems when the same function has been performed by two systems. The critical review is also done to report the credibility and quality of the study and the reflected results. Finally, to lessen the danger of improper LCA use, it is vital that the report must be very perfect and translucent with an impeccable signal of what has and has not been encompassed in the study.

3.3 Life Cycle Inventory Analysis

This phase is directed by goal scope goal definition and consumes a considerable time period. The output of this process is the fulfilled inventory of fundamental flows that work as a foundation for impact assessment of the life cycle. Life cycle inventory (LCI) analysis requires a lot of efforts and it is hardly pragmatically possible to collect the utmost quality data set for LCI. In LCI at first, the processes are identified thereafter planning and collection of data is done. The collection of data should be done over an extended duration, ideally covering several production runs. The data collection is followed by construction of the unit process and quality of the unit process should be ensured for any error in the reported measurements. Subsequently, the LCI model is constructed and each unit process works as a building block for the LCI model. In fact, the inventory modeling is done by qualified software that is also capable to make product system model connect the relevant unit processes. Finally, the LCI results are published and the sensitivity analysis is used to check the consistency and finally the results are reported.

3.4 Life Cycle Impact Assessment

In this phase of LCA, the information on inventory is interpreted into the environmental impacts. This phase of LCA is dedicated to software but the fundamental ethics, models, and aspects should be well perceived for interpretation of results. There are some mandatory steps which must be performed on LCIA.

- Proper selection of categories that impact indicators of category and characterization model. This step gives the answer to the question of which impact to be assessed.
- The next step is called as classification in which LCA results are assigned to each category.
- The characterization is how much LCI results contribute.

3.5 Interpretation

The final phase of LCA is the interpretation. The results of the previous phases are considered simultaneously and investigated to take care of the uncertainties of the realistic data and the suppositions that have been made and recognized throughout the study. The following are the steps of interpretation:

1. The noteworthy issues (main procedures and suppositions, salient elementary flows) of the previous LCA phases are recognized.
2. These concerns are measured with reference to their effect on the whole results of LCA.
3. Formulation of the inferences and recommendations from the study.

4 Conclusion

LCA is a comprehensive tool set for measuring, assessing, equating, and cultivating products and services in terms of their probable ecological impacts. It is very useful to evaluate environmental impacts and make the organization capable to make sustainable decisions. The LCA framework of Saad et al. [48] of sustainability development does not address the problem of sustainable decision-making, nor depicts the range of data collection for material, waste, carbon emission and lacks the interpretation of the data. The sustainable business framework developed by Nilsson 2018 [49] had not included LCA to include the environmental dimension of eutrophication and acidification that generates a negative effect on the ecological balance of the system. The present study overcomes these issues in the development of the LCA framework for the sustainable development of the organization and includes every dimension of sustainable development and provides a rigorous approach for the assessment and interpretation of LCA indicators. The present work enables the organization to define the goal of the study and covers a wide range of aspects that should be included with goal definition. Besides, the study also facilitates organizations' managers to outline scope by considering deliverable boundaries and object assessment. Moreover, the current research provides guidelines for the analysis of inventory and impact calculation categories. The society will gain for this work in terms of indirect benefits like the reduced levels of emissions and resource use by sustainable decisions through the life cycle assessment. The main limitation of the present work is that the framework proposed has not been tested pragmatically in the organizations. The future research directions lie in the application of LCA in product development and its potential effects on project selection for sustainable development.

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Artificial Neural Network Models for the Prediction of Metal Removal Rate in Rotary Ultrasonic Machining

Dipesh Popli, Parveen Sharma, and Shubham Verma

1 Introduction

Rotary ultrasonic machining (RUM) plays a key role in the machining of the complex material (newer materials) in the current industry. RUM is an undeniably nonthermal process where no heat-affected zone is generated during the cutting operation. Due to that, thermal stress can never deteriorate the material.

Many researchers have done the investigation on alumina ceramic to find the significant parameters on stationary-type Ultrasonic Machining (USM). The response surface methodology (RSM) and Taguchi techniques have been employed as a design of experimentation to predict the metal removal problems. Jadoun et al. [22] engaged Taguchi technique to investigate the consequence of selected input bound on the accuracy and tool wear in ultrasonic drilling on ceramics (alumina-based). Some other researchers investigated the power of various operating constraint on quality of surface, MRR, and different attributes on USM of complex materials. Modeling and optimization of laser machining attributes are done using ANN and particle swarm optimization [4]. Attempts have been made to optimize the input parameters of USM [14, 22]. Churi et al. [2] studied, in the machining of SiC using rotary ultrasonic, an experimental design has been given. The authors in this work used full factorial design with four variables and two levels to description major property and the interaction effects of ultrasonic power, grit size, tool rotational speed, feed rate, cutting

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force, chipping size, and surface roughness was the main focus point in the output. [20] The authors investigated machining characteristics and hole quality [21] of Inconel 718 alloys experiments conducted on ultrasonic machine. Churi et al. [3] analyzed the effects on USM tool force, MRR, roughness of titanium and its alloy, and [18] cutting temperatures. Feng et al. [10] worked on quality of hole, TWR, roughness; thrust force, at different levels of RUM attributes as feed rate, RPM, and ultrasonic power. Hu et al. [12] investigated the machinability of shaphire ceramic by RUM using different attributes: static force, vibration amplitude, grit size. However, no literatures have been found regarding the model by artificial neural system for the forecast of MRR in RUM. In the present study, the predicted models of MRR values is obtained by ANN and compared by RSM. The parameters like feed rate of tool, rotation of tool, power rating, diamond mesh size, and various kinds (basically two) of tool profiles are taken as independent controlling parameters.

In the course of the last six decays, a view has created that processing-based models inspired function of the biological neural networks like artificial neural systems may hold the key accomplishment for unraveling smart assignments. In the last decade, ANN have appeared as an extremely flexible modeling tool appropriate in several areas of current discipline [1, 6, 9].

A counterfeit neural system is characterized as an information-preparing framework comprising countless basic, profoundly interconnected handling neurons in a design enlivened by the arrangement of brain's cerebral cortex [11, 16]. As far as ANN in RUM is concerned no data are published yet. But only handful literature reported where ANNs are applied, that is only for the forecast of the MRR [13, 17] while estimating the surface roughness is reported only by [23]. In the present study, the implementation of this model for the estimation of MRR of RUM is discussed.

ANN overview

Two fundamental and significant highlights of neural systems are their design and the calculation utilized for its training. After the right preparing, the pick system can impart the estimation of yield to known input. These two sorts of system alongside a few methods utilized for the enhancement of their presentation are quickly introduced underneath. Neural system's engineering and non-natural neural systems are scientific portrayals of the human cerebrum work. The "center" component of an ANN system is the neuron. These are associated with one another with a lot of connections, called neurotransmitters. An illustration of neuron is revealed in Fig. 1. The primary layer is input layer.

ANN training

When the quantity of layers and units for each layer are chosen, the system's weight has to be put so that limits the error of forecast for the system. The distinctions are joined together by an error capacity coming about the system's error. Generally, the mean square error of the system's response to a vector p is determined as indicated by the condition:

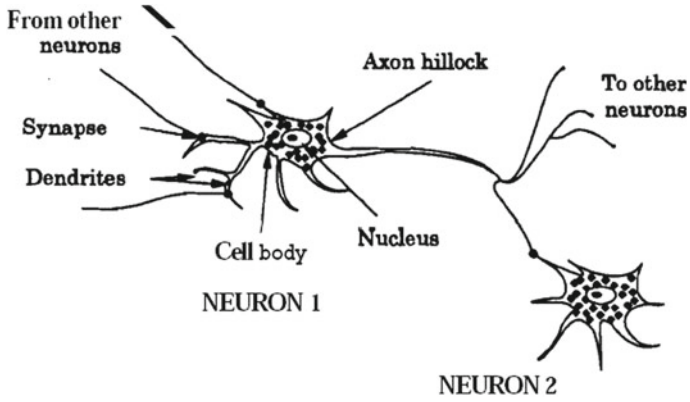


Fig. 1 Typical neuron or nerve cell [24]

$$E_p = \frac{1}{2}\sum_{i=1}^{l}\left(d_{p,i} - o_{p,i}\right)^2$$

where

$o_{p,i}$: output vector's values$p$ and $d_{p,i}$: the input vector corresponding to p.

The complete cycle has to be repeated until MSE reaches to minimum or near to 0 [7, 23].

The input vectors and the comparing output vectors are utilized for the preparation of the system until a capacity is moved toward which relates the information vectors with the specific yield vectors. At the point when mean square error's worth is determined, it is spread to the back so as to decrease the blunder with the fitting alteration of the loads. Their capacity to sum up is another significant parameter of the neural system models,. Accurately prepared back-spread systems can perform speculation; this capacity offers the chance of preparing the system utilizing an agent set of information attractive yield esteems sets. A flow diagram of ANN model is shown in Fig. 2.

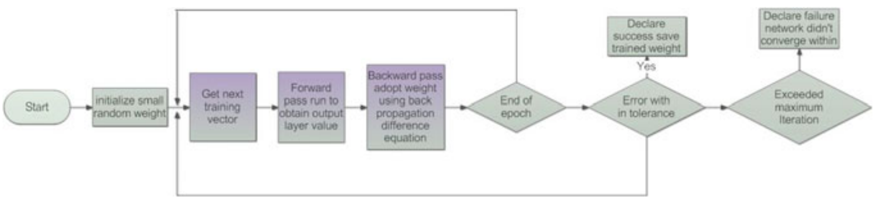


Fig. 2 A flow diagram of ANN model

2 Material and Method

In the present study, nickel alloy (Inconel 718) is taken as a work piece for the machining with RUM. The various properties of Inconel 718 are revealed in the Table 1.

The present work has been conducted on RUM, made by Sonic Mill Series 10 [19], the experimental setup has been installed at NIT, Kurukshetra, India. The Table 2 shows the detail of the machining condition which are used in the current study. The complete experimental setup has been demonstrated in the Fig. 3.

The hardest known substance is diamond. In the proposed work, diamond tool with metal bonded has been utilized for the machining. The selected tool is consisting broad uses while working on brittle and hard materials. In the selected tool, a bond between metal and abrasives has been made by mixing diamond abrasives with metal powder. Only metal removal has been done by diamond segments. The metallic powders wear down as the tool has been used and expose fresh crystals on tool. In this work, outer diameter of tool is selected as 8 mm and inner diameter of the tool is taken as 6.5 mm. The details of the tool used in the current work have been demonstrated in Fig. 4.

3 Machining Parameters and Design of Experiment

In the earlier days, researchers normally prefer trials before the main experimental work. In the proposed work levels and factors have been elected on the basis of screening test. For the pilot experiments steepest accent/decent approach used, this approach was provided by Montgomery [15]. In the present experiment work, five parameters listed in Table 2 were selected. Some others least significant attributes are kept constant such as coolant flow rate 36.4×10^3, frequency of vibration 21 kHz, tool diameter 8 mm. Center composite design and collection of five input parameters have been demonstrated in Table 2.

MRR is taken as response in RUM of nickel alloys. MRR values are measured by an electronic weighing scale which has a precision of 0.00004 g.

The measurements were repeated two times. Equation (1) shows the response parameter of

$$Machining\ Rate = \frac{\text{material removed}}{\text{time taken for } machining} \quad (1)$$

Table 1 Various properties of Inconel 718

Chemical composition											
Element	Ni	Fe	Cr	Nb	Mn	C	Co	Al	Si	Ti	Mo	Other
Weight (%)	51.05	19.43	18.7	5.7	0.07	0.04	0.2	0.56	0.08	1.01	3.1	0.06
Ultimate tensile strength	1100 MPa											
Hardness	97 HRB											
Density	8.19 g/cm^3											

Table 2 Selected factors along with their levels

Sr. no	Symbol	Input factors	Level					Units
				Low	Center	High		
1	A	Spindle speed	4200	4600	5000	5400	5800	RPM
2	B	Feed rate	0.01	0.0125	0.0150	0.0175	0.02	mm/s
3	B	Power rating	55	60	65	70	75	%
4	D	Diamond abrasive size	80	100	120	140	160	Mesh
5	E	Tool profiles	–	Plain	–	Lateral slotted	–	

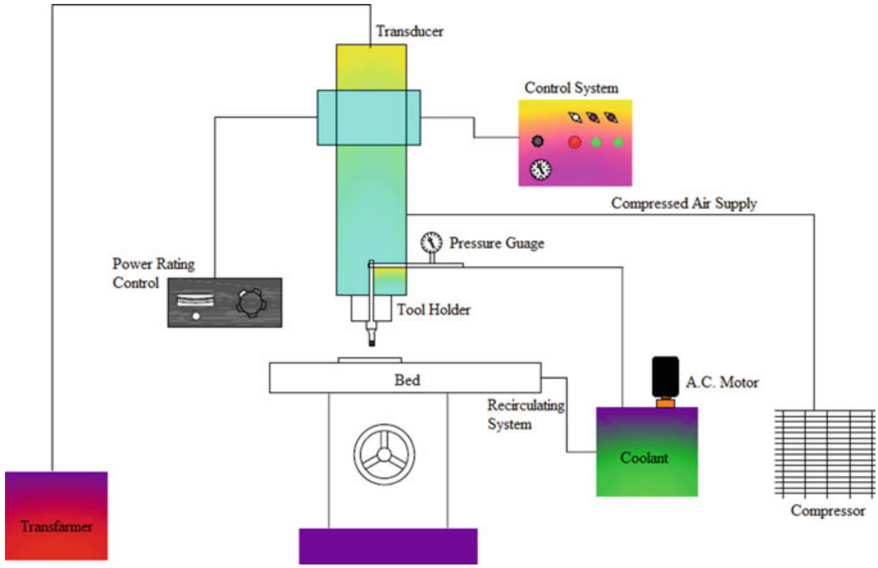
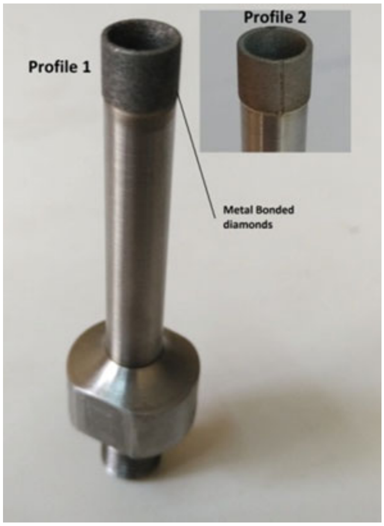


Fig. 3 Rotary ultrasonic machining set up

4 Results and Discussion

The system design or highlights, for example, a count of neurons and layers are significant components that decide the usefulness and speculation ability of the system. For this model, standard multilayer feed-forward back-propagation was utilized with MATLAB 9 Neural Network Toolbox [13]. In general, an ANN is portrayed by its key highlights, for example, the design, the enactment work, and the learning calculations [13]. A few models were structured and examined so as to decide the best design, the most reasonable enactment capacities, and the most amazing preparing calculation appropriate for the expectation of MRR. Each model was checked more than once so as to assess whether it really joins to a low esteem or not. For all systems straight move capacity and digression sigmoid exchange work "tansig" was utilized

Fig. 4 Tools used in RUM



in the yield and concealed layer, individually. The systems were prepared with Levenberg–Marquardt calculation. This preparation calculation was picked because of its high exactness in comparable capacity estimation [5, 8, 9]. The structural design of the network is presented in Fig. 5.

For preparing the structured models, the exploratory information classified in Tables 3 and 4 were utilized. These information speculations of a neural system the early stopping method were utilized. By this philosophy, existing information are isolated in three subsets. The main subset comprises of the preparation vectors, which are utilized to compute the slope and to shape the weight factors and the bias. The subsequent subset is the approval gathering. The error in that gathering is seen during preparing and in like manner preparing bunch typically diminishes during the underlying period of preparing. In any case, when the system starts to alter the information more than required the mistake in that gathering raises and when that expansion proceeds for a specific number of reiterations, preparing stops. At last, the third subset is the test gathering and its blunder isn't utilized during preparing. It is utilized to think about the various models and calculations. So as to utilize this system, 1/2 of the information was utilized for preparing, 1/4 was utilized for approval, and 1/4 was utilized for testing. The exhibition capacity of each system was inspected dependent on the connection coefficient between the system forecasts and the trial esteems utilizing the preparation, test, and whole dataset. The best outcomes got after various preliminaries utilizing diverse arbitrary beginning loads and predispositions (Fig. 6).

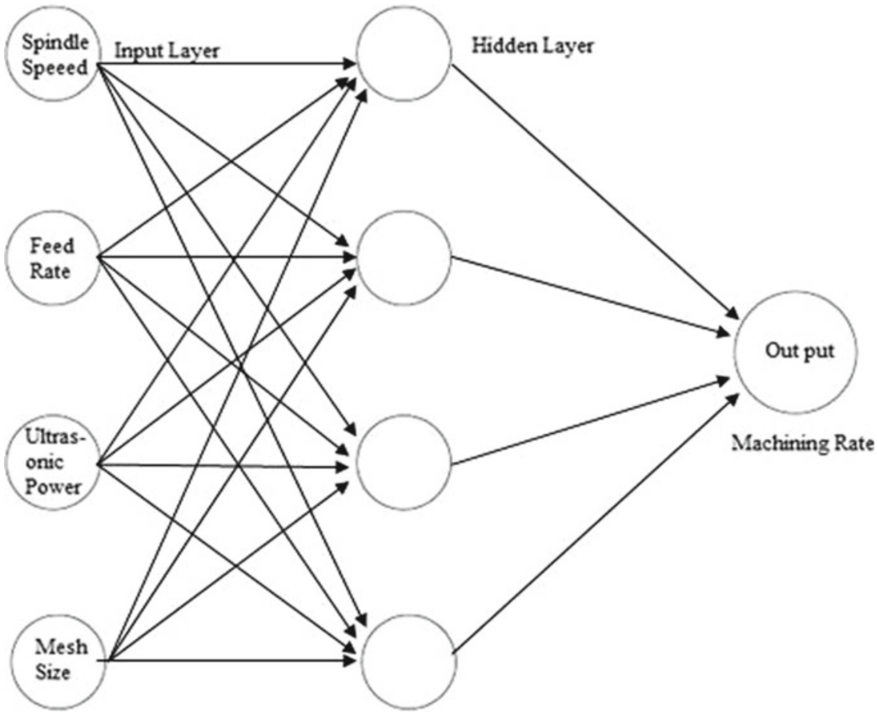


Fig. 5 Neural network architecture

Increment in quantity of neurons in the hidden layer has no critical enhancement for the exhibition of the systems. As results, organize having two layers and 10 neurons in each hidden layer [4–10], prepared with Levenberg–Marquardt calculation was picked as the ideal system and utilized for improvement of this model. The exhibition of the model for expected MR utilizing the training and whole dataset is appeared in Fig. 7a, b. The connection coefficient of 0.971 and 0.963 were acquired between the whole dataset and the model forecasts for tool profile 1 and profile 2 separately. The error conveyance of the model for the forecast of MR utilizing the whole dataset is appeared in Table 5. The outcome shows that 80% of the whole dataset have the rate error going between 10%. Satisfactory results were likewise acquired for the various procedure parameters. This showed the models have high precision for anticipating the procedure parameters. The MSE of training of the selected ANN were about 0.0044 and 0.0000569 for tool profile 1 and tool profile 2, respectively.

Table 3 DOE and their results—tool profile 1

RUN	Input 1	Input 2	Input 3	Input 4	Response 1
	A: Tool rotation	B: Feed rate	C: Ultrasonic power	D: Mesh size	Machining rate
	RPM	mm/s	%	GRIT	mm^3/s
1	4600	0.0175	70	140	1.0079068
2	4600	0.0125	60	100	0.6978734
3	5000	0.015	65	120	0.7718218
4	5000	0.015	65	120	0.7819723
5	5000	0.015	75	120	0.7795012
6	5000	0.015	65	160	0.8652756
7	5000	0.015	65	120	0.7705292
8	5000	0.015	55	120	0.7719358
9	5000	0.02	65	120	1.0853609
10	4600	0.0125	70	100	0.6993345
11	4600	0.0175	60	140	0.998381
12	5400	0.0125	60	140	0.7181413
13	5000	0.015	65	120	0.7760036
14	5800	0.015	65	120	0.7934155
15	5400	0.0125	70	140	0.712947
16	5000	0.01	65	120	0.5130018
17	5400	0.0175	70	100	0.9838271
18	5000	0.015	65	80	0.8435394
19	5000	0.015	65	120	0.7710234
20	5400	0.0175	60	100	0.9767723
21	4200	0.015	65	120	0.7813641

As expected, the MSEs are found to be high comparative to training group, as expected. The results of the neural system preparing qualities show that the proposed neural system has great speculation capacity, hence having the option to display RUM procedure. Comparison values of ANN predicted and experimental values are shown in Figs. 8 and 9, respectively.

Table 4 DOE and their results—tool profile 2

RUN	Input 1	Input 2	Input 3	Input 4	Response 1
	A: Tool rotation	B: Feed rate	C: Ultrasonic power	D: Mesh size	Machining rate
	RPM	mm/s	%	GRIT	mm^3/s
1	4200	0.015	65	120	0.8141701
2	5400	0.0175	70	100	0.9840404
3	5000	0.015	65	120	0.8233505
4	5000	0.015	65	120	0.8134141
5	5000	0.015	65	120	0.8077259
6	4600	0.0125	60	100	0.7097516
7	4600	0.0175	70	140	0.9236097
8	5400	0.0125	60	140	0.6464128
9	4600	0.0125	70	100	0.7137265
10	5000	0.02	65	120	1.0937205
11	5000	0.015	65	120	0.8044498
12	5000	0.015	65	120	0.8144221
13	5400	0.0125	70	140	0.6485735
14	5000	0.015	75	120	0.7920293
15	5000	0.01	65	120	0.541196
16	5800	0.015	65	120	0.8076539
17	5400	0.0175	60	100	1.0051191
18	5000	0.015	65	160	0.8598649
19	5000	0.015	55	120	0.8140621
20	5000	0.015	65	80	0.8341709
21	4600	0.0175	60	140	0.9108963

5 Results and Simulation

5.1 Effect of Process Parameters on Cutting Conditions

In view of the streamlined system parameters, a model using ANN has been created to foresee every procedure parameter dependent on conditions, with a high level of exactness inside the extent of cutting conditions explored in the investigation.

5.1.1 Effect of Feed Rate on the MRR

Feed rate is one of the most vital input parameters in RUM. It influences the MRR during machining process. MRR of Inconel-718 was studied using the ANN model

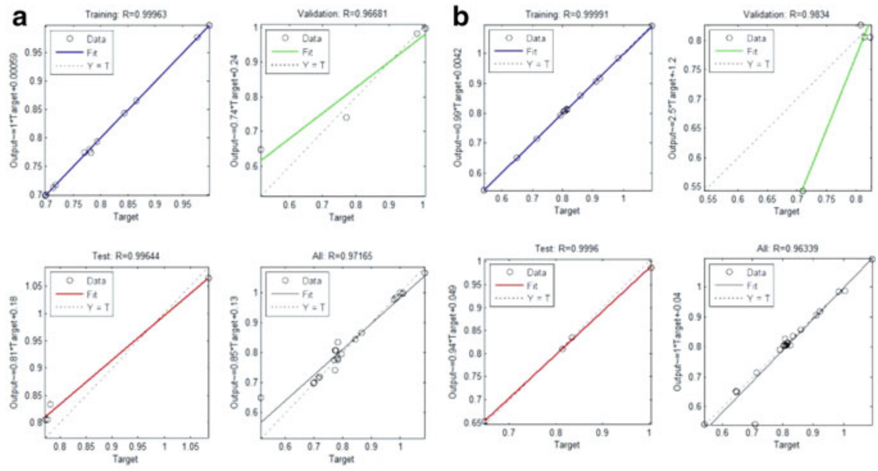


Fig. 6 **a)** Correlation values for tool T1 **b)** correlation values for tool T2

at constant ultrasonic power = 65%, diamond mesh size = 120, tool rotational = 5000 rpm. The comparison of ANN forecasts (Fig. 10). Figure 11 depicts that the expected MR increased significantly with increase of feed rate.

5.1.2 Effect of Interacted Parameters on Machining Rate

The interactions plot is shown in Fig. 12 revealed that the power rating (ultrasonic) and grit size of the abrasive did not represented countable effect on the metal removal rate of RUM process while cutting selected alloy (Inconel 718). Even though, a combine upshot of feed rate and rotation speed shows an important part in cutting operation. A mixed effect of feed rate and tool rotation on machining rate shows that MR goes to a maximum value at a higher value of tool rotation as well as value of feed rate while it reaches at a minimum level where tool and feed rate both are at a lower level. This thing investigated and finds out that the fact was that higher tool rotation and feed rate both factors are accountable for recurrent metal removal in this kind of machining (Fig. 12).

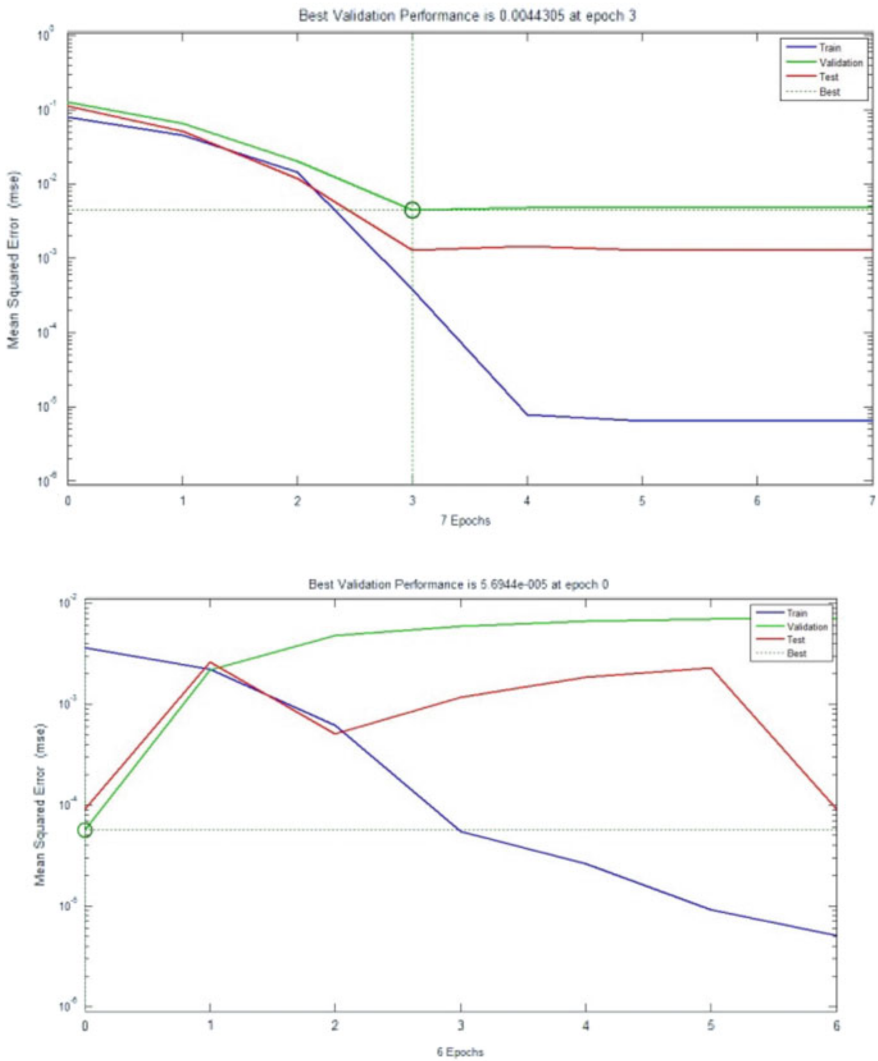


Fig. 7 MSE values for **a)** profile 1 **b)** profile 2

6 Conclusions

1. A number of experiments are carried out on Inconel 18 using two different tool profiles.
2. The multilayer network with two hidden layers having "tangent sigmoid" function trained with Levenberg–Marquardt algorithm was found to be the optimum network for the model developed in this study.

Table 5 ANN predicted value versus experimental value for both tools

Run	A: Tool rotation	B: Feed rate	C: Ultrasonic power	D: Mesh size	E: Tool catagory	Machining rate	ANN predicted value	Residual
2	5000	0.015	65	120	T1	0.771821776	0.772	−0.0002
3	4600	0.0175	70	140	T1	1.007906783	1.0035	0.0044
4	5000	0.015	65	120	T1	0.771023418	0.772	−0.001
6	5800	0.015	65	120	T1	0.79341545	0.7952	−0.0017
8	5400	0.0125	60	140	T1	0.718141253	0.7215	−0.0033
9	4600	0.0125	60	100	T1	0.697873432	0.6996	−0.0017
15	4200	0.015	65	120	T1	0.781364051	0.8481	−0.0667
16	5000	0.015	65	120	T1	0.770529197	0.772	−0.0015
21	5000	0.015	65	120	T1	0.781972324	0.772	0.0099
27	5400	0.0175	60	100	T1	0.976772339	0.9781	−0.0013
28	4600	0.0175	60	140	T1	0.998380978	0.9896	0.0088
29	5400	0.0175	70	100	T1	0.983827107	0.8496	0.1342
30	5000	0.015	65	80	T1	0.843539379	0.857	−0.0135
31	5000	0.02	65	120	T1	1.085360908	0.8638	0.2215
32	5000	0.015	55	120	T1	0.771935827	0.7833	−0.0114
33	5000	0.015	65	120	T1	0.77600365	0.772	0.004
34	5000	0.015	75	120	T1	0.779501217	0.7781	0.0014
35	5400	0.0125	70	140	T1	0.712947016	0.5844	0.1285
37	4600	0.0125	70	100	T1	0.699334478	0.6983	0.001
38	5000	0.015	65	160	T1	0.865275554	0.8677	−0.0024
40	5000	0.01	65	120	T1	0.513001825	0.5554	−0.0424
1	5400	0.0175	70	100	T–2	0.984040375	1.0315	−0.0475
5	5000	0.015	65	120	T–2	0.807725886	0.8078	0
7	5000	0.015	75	120	T–2	0.792029305	0.7717	0.0203
10	5000	0.01	65	120	T–2	0.541196024	0.6582	−0.117
11	5400	0.0175	60	100	T–2	1.005119125	1.0184	−0.0133
12	5400	0.0125	70	140	T–2	0.648573495	0.6666	−0.0181
13	5400	0.0125	60	140	T–2	0.646412836	0.7674	−0.1209
14	4600	0.0175	70	140	T–2	0.923609741	0.9334	−0.0098
17	5000	0.015	65	80	T–2	0.834170854	0.9436	−0.1094
18	5000	0.02	65	120	T–2	1.093720468	1.0411	0.0526
19	4600	0.0125	70	100	T–2	0.713726482	0.6622	0.0515
20	5000	0.015	55	120	T–2	0.81406212	0.8248	−0.0107
22	5000	0.015	65	120	T–2	0.804449765	0.8078	−0.0033
23	5000	0.015	65	160	T–2	0.859864882	0.8583	0.0015
24	5000	0.015	65	120	T–2	0.813414096	0.8078	0.0056

(continued)

Table 5 (continued)

Run	A: Tool rotation	B: Feed rate	C: Ultrasonic power	D: Mesh size	E: Tool catagory	Machining rate	ANN predicted value	Residual
25	4600	0.0125	60	100	T–2	0.709751632	0.7472	−0.0375
26	4600	0.0175	60	140	T–2	0.910896298	0.9188	−0.0079
36	4200	0.015	65	120	T–2	0.814170124	0.8984	−0.0842
39	5000	0.015	65	120	T–2	0.823350464	0.8078	0.0156
41	5000	0.015	65	120	T–2	0.814422134	0.8078	0.0067
42	5800	0.015	65	120	T–2	0.807653883	0.7692	0.0385

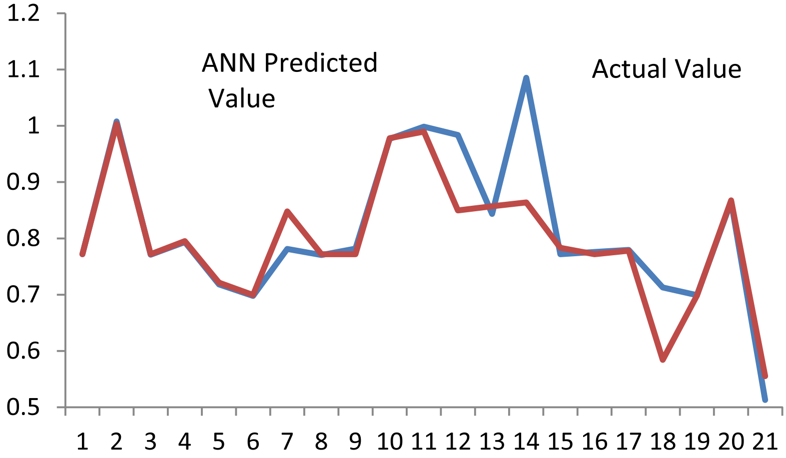


Fig. 8 Experimental data comparison for tool profile 1 (Experimental values, ANN values)

3. The predicted machining rate of RUM is much close to the experimental values, thus showing the efficiency of back propagation neural network for predicting machining rate.

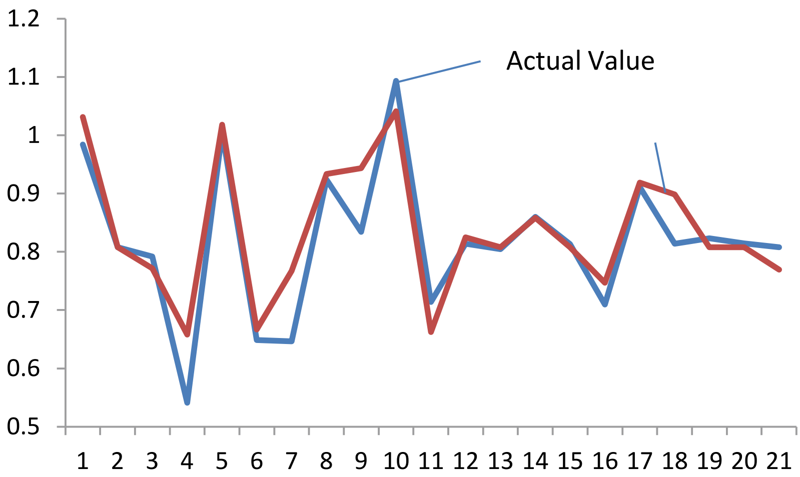


Fig. 9 Graph 2 Experimental data comparison for tool profile 2 (Experimental values, ANN values)

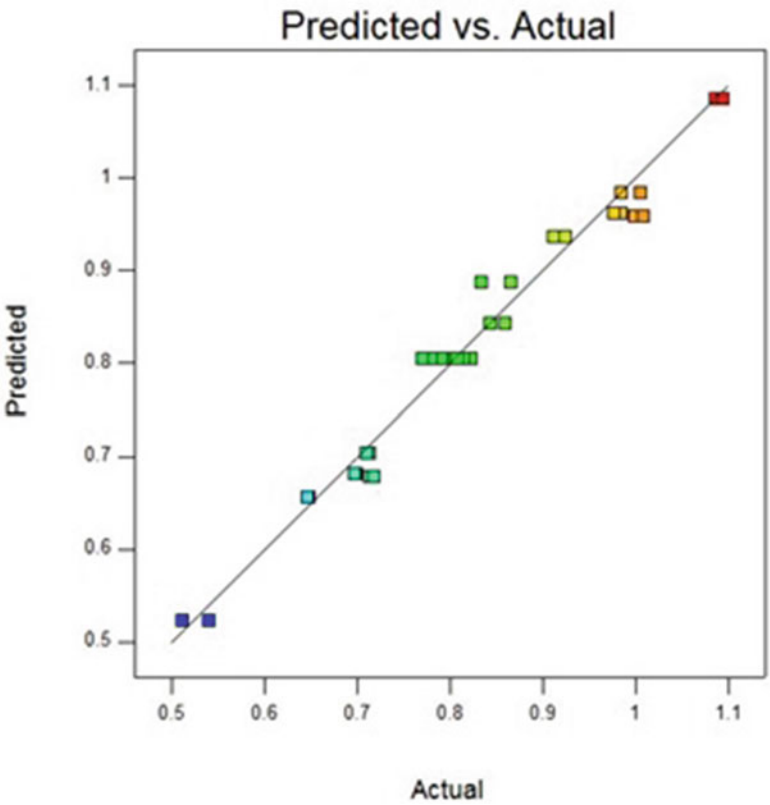


Fig. 10 ANN prediction and the experiment's values

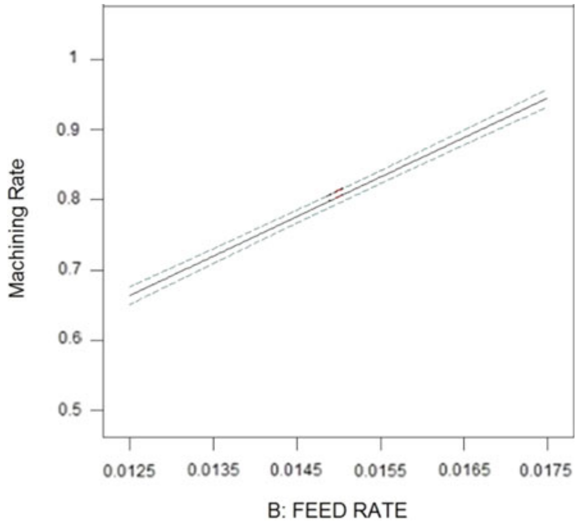


Fig. 11 Influence of feed rate on machining rate

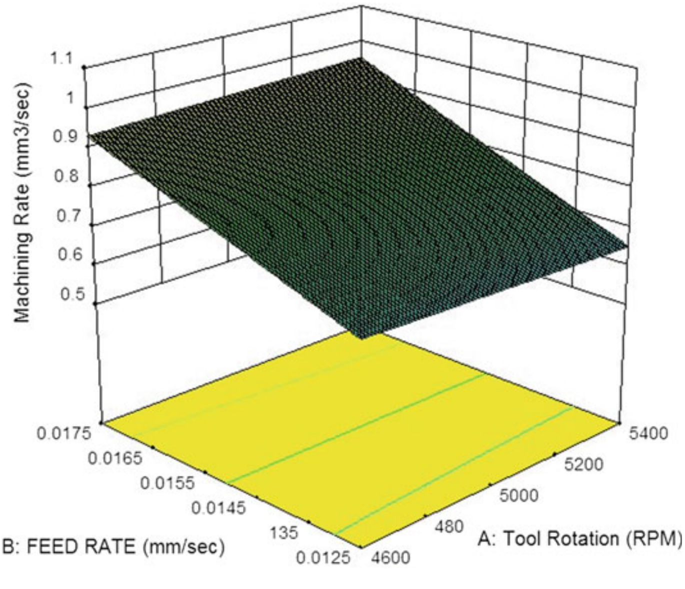


Fig. 12 Interaction plot for MR

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Finding the Percentage Effectiveness of Agile Manufacturing Barriers: An AHP Approach

Abbas Haider and Ubaid Ahmad Khan

1 Introduction

Agile manufacturing comes from the term "agility" which means to respond quickly and effectively as per the condition arrived [1]. Hence we can say that agile manufacturing helps the organization to thrive in this era of continuous and dynamic changes which arise from the customer side. The term agile manufacturing is evolved in the year 1991 at Lacocca Institute at Lehigh University (USA), a group of researchers planned to germinate the seed of agility [2]. Agile manufacturing can be defined as the capacity of an organization to participate in an environment of unforeseeable change by acting quickly and effectively driven by customer demand [3].

As the emergence of the multi-national company begins, there is a sharp increase in the competition among the organization. So only those organizations which able to satisfy customer needs can sustain in this competitive environment. These lead to an increase in competition among the organization and every organization try to adopt innovative strategies and technologies to produce high-quality product as per customer requirement, to reduce the cost of manufacturing, and reduce lead time. Within such an environment, the focus is given to the capability of the organization to respond quickly to customer demand and delivers a high-quality product to the customer in the shortest time [3]. The mass market is converted into the fragmented market as a variety of component manufactured and rapidly changing customer demand, to cope up with this change manufacturing has gone through various changes from a craft industry to mass production and now agile manufacturing [4]. Basically, there are four dimensions to agile manufacturing and they are managed to master change, focusing on the effect of people and information, increase competition by cooperation, and enrich the consumer [2].

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It is the agile manufacturing that enables an organization to achieve cost-effective response against any unpredictable change in the market. It is the agile manufacturing which utilizes the unforeseen and unpredictable future change in order to make leverage over their competitor. It also supports rapid launches of unplanned production tailored to meet unexpected customer demand [5].

2 Literature Review

There is some reason which makes delay in traditional manufacturing and these are wastages like financial secrecy, inaccurate record, inadequate strategy, and bottleneck and improper handling of inventory. In contrast to this, Agile manufacturing focuses on customer enrichment, cooperation to increase competitiveness and this can be only done by integrating people, information and technology at a single stage [6]. Agile manufacturing is committed to the formation of virtual enterprises by using modern information and communication technology, which aims to respond to change in the market [7]. Organizational and vendor cooperation helps an organization to achieve agility by leveraging resources through virtual enterprises [8]. Agility is an art and approach that lets an organization pursue its objectives in a self-organizing, courageous, and transparent manner. As a consequence of this, it is seen that there is a change in employees like they become more satisfied, more engaged, and more flow in the task implementation [9]. Based on the literature review 16 AMBs have been identified and listed in the Table 1.

3 AHP Methodology

AHP stands for "analytical hierarchy process" and it was originated by Satty in the year of 1977. AHP is applied to the result of ISM. ISM model has been created to develop the hierarchy of the identified AMBs. Since, ISM model results a hypothetical hierarchy which needs a quantitative analysis to find their percentage effectiveness. ISM is used to generate relationship among variable of a system and it is a logical methodology as it performs in an uninterrupted way [14]. Thus, Analytical Hierarchy Process (AHP) approach can be applied to test the soundness of the ISM model. AHP was originated in the 70 s by Thomas L. Saaty and tremendously used, being present implement in decision-making for intricate situation, where people work collectively to take decisions when human consciousness, opinions, and effect have a long-term result [15]. The application of AHP starts with an issue being broken into a hierarchy of criteria so as to effortlessly examine and differentiate in an autonomous way to develop logical hierarchy. The decision-makers can properly review the available option or alternatives or variables by performing pairwise comparisons for each of the selected benchmark or criteria. The comparison may utilize

Table 1 Identifying agile manufacturing barriers

S. no	AMB's	[10]	[11]	[7]	[12]	[13]	[1]
1	Lack of reconfigurable layout	✔		✔			
2	Fear of and resistance to organizational change	✔	✔			✔	✔
3	Lack of methodology		✔				✔
4	Lack of feedback system		✔	✔			✔
5	Insufficient training &rewards	✔	✔	✔		✔	✔
6	Improper forecast				✔		
7	Improper H.R. management				✔		
8	Improper production planning				✔		
9	Government policies and support	✔			✔		
10	Lack of virtual partnership			✔			
11	Vertical organizational structure			✔			
12	Unavailability of appropriate technology		✔				✔
13	Non-conductance of meeting			✔			
14	Lack of Retention of expertise staff			✔			
15	Lack of top management support	✔	✔		✔	✔	✔
16	Inappropriate technique for measuring the agility		✔				✔

existing data from the criteria or human judgments as a way to input subjacent information [16]. In order to quantifying the variable, first we have to obtain the rank of variable or barriers which are obtained from ISM methodology. After getting ISM model, we formed a group of barriers by different judges as per their choices. The aim (i.e., the ranking of the barriers) is labeled as "T" and judges are labeled as J1 and J2. Firstly normalized vector of the weights for the two judges with regard to T has been found out. The two judges quantify the ISM result using AHP [17]. It is serene to observe that using a full symmetry of the two judges we obtain a fully consistent 2 $\times$ 2 matrix (with all elements equal to 1) to which it relates the maximum eigenvalue = 2 and an eigenvector as L1 (1/2, 1/2) (Fig. 1).

As the successive step, we have to determine two 16 $\times$ 16 matrices of the pairwise comparisons of the sixteen alternatives, each matrix with for a single judge (Fig. 2).

AHP provides a systematic framework to manage multi-criteria condition involving qualitative, quantitative, rational, and intuitive aspects. AHP has been extensively used technique to take complicated decision at strategic level for planning [18]. AHP converts the comparisons, which are most of the times are real, into numeric number that is analyzed and compared. The weight of each factor makes sure the proper assessment of each element inside the defined hierarchy [19]. This possibility of changing empirical data into mathematical models is the primary unique properties of the AHP methodology when compare to other methodologies. After all comparisons have been done, the relative weights between each criterion is developed and the calculation of probability of each alternative is done. This probability evaluates

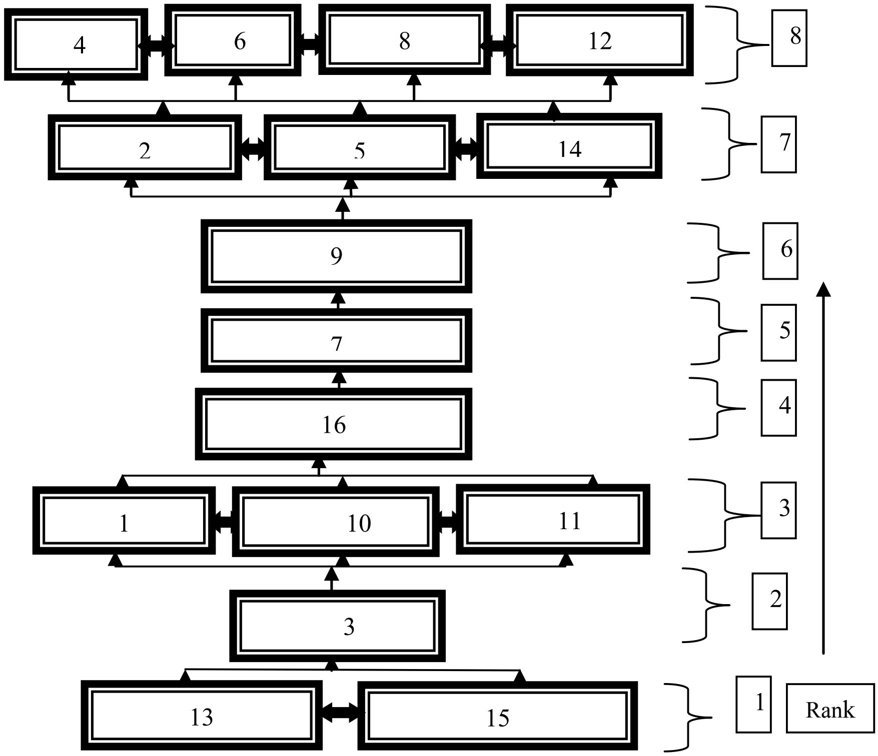

Fig. 1 ISM model

the possibility that the alternative has to execute the anticipate objectives. The better the probability, the higher likelihood the alternative has to achieve the ultimate aim (Fig. 3).

Pairwise comparison is done to evaluate the comparative significance of each alternative. In this method, the judge has to show his view regarding the significance of one single pairwise comparison. Pairwise comparison of the variable will permit the calculation of priority/significance weights for the variable. On comparing two elements, we follow the straightforward rule as suggested by Saaty though more intricate methods can be solved by fuzzy triangular numbers that are often utilized to input data to various variables [19].

As priorities are recognized only if obtained from consistent matrices, a consistency check must be done. Saaty [19] has found a consistency index (CI), which is obtained from the eigenvalue method:

$$\mathrm{C.I} = \frac{\lambda_{\mathrm{avg}} - \mathrm{n}}{(\mathrm{n} - 1)} \tag{1}$$

where $\lambda_{\mathrm{average}}$ is an average of eigenvalue.

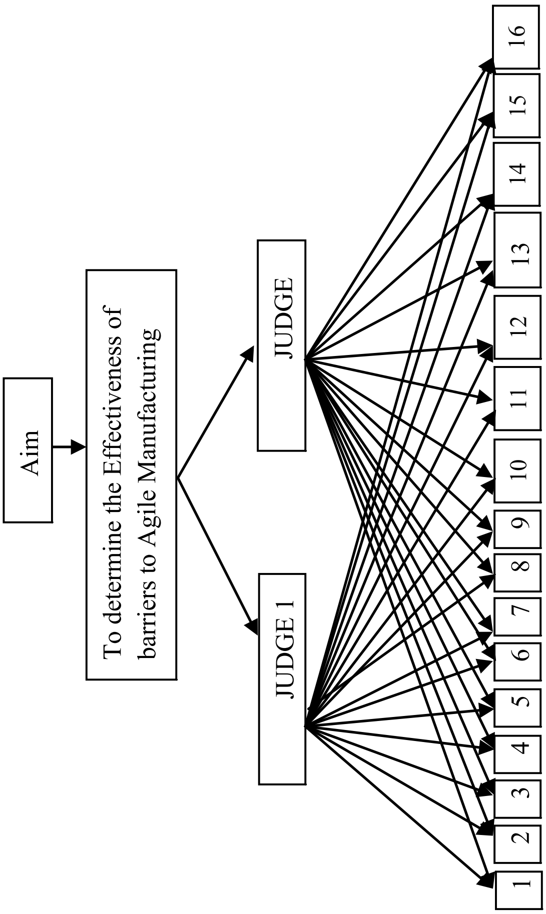

Fig. 2 AHP model

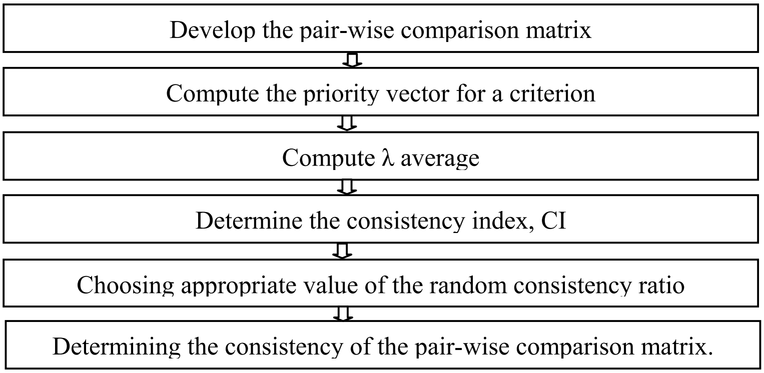

Fig. 3 AHP steps

In the year of 1980 Saaty define, a consistency ratio is a variance between consistencies index and random consistency index, or numerically we can explain C.R as

$$\text{Consistency Ratio (C.R)} = \frac{\text{Consistency index (C.I)}}{\text{Random index (R.I)}} \tag{2}$$

Saaty suggests that
If, C.R. $<$ 0.1 (Matrix is acceptable).
If, C.R. $=$ 0.1 (Matrix must be handle with care).
If, C.R. $>$ 0.1 (Matrix is rejectable).

3.1 Judge-1

In this pairwise comparison, we equally divide the eight levels of Agile Manufacturing barriers into eight groups from 1 to 9 on the Saaty scale ranking by the judge-1 (Tables 2, 3 and 4).

Table 2 Grouping of AMBs

Group	G1	G2	G3	G4	G5	G6	G7	G8
AMBs	13,15	3	1,10, 11	16	7	9	2,5,14	4,6, 8,12
Intensity of Importance	1	2.14	3.28	4.42	5.56	6.7	7.84	9
Reciprocal	1	0.467	0.304	0.226	0.179	0.149	0.127	0.111

Table 3 Pairwise comparison matrix

AMBs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.00	5.56	0.47	6.67	5.56	6.67	3.28	6.67	4.42	1.00	1.00	6.67	0.31	5.56	0.31	2.14
2	0.18	1.00	0.15	2.14	1.00	2.14	0.31	2.14	0.47	0.18	0.18	2.14	0.13	1.00	0.13	0.23
3	2.14	6.67	1.00	7.84	6.67	7.84	4.42	7.84	5.56	2.14	2.14	7.84	0.47	6.67	0.47	3.28
4	0.15	0.47	0.13	1.00	0.47	1.00	0.23	1.00	0.31	0.15	0.15	1.00	0.11	0.47	0.11	0.18
5	0.18	1.00	0.15	2.14	1.00	2.14	0.31	2.14	0.47	0.18	0.18	2.14	0.13	1.00	0.13	0.23
6	0.15	0.47	0.13	1.00	0.47	1.00	0.23	1.00	0.31	0.15	0.15	1.00	0.11	0.47	0.11	0.18
7	0.31	3.28	0.23	4.42	3.28	4.42	1.00	4.42	2.14	0.31	0.31	4.42	0.18	3.28	0.18	0.47
8	0.15	0.47	0.13	1.00	0.47	1.00	0.23	1.00	0.31	0.15	0.15	1.00	0.11	0.47	0.11	0.18
9	0.22	2.14	0.18	3.28	2.14	3.28	0.47	3.28	1.00	0.23	0.23	3.28	0.15	2.14	0.15	0.31
10	1.00	5.56	0.47	6.67	5.56	6.67	3.28	6.67	4.42	1.00	1.00	6.67	0.31	5.56	0.31	2.14
11	1.00	5.56	0.47	6.67	5.56	6.67	3.28	6.67	4.42	1.00	1.00	6.67	0.31	5.56	0.31	2.14
12	0.15	0.47	0.13	1.00	0.47	1.00	0.23	1.00	0.31	0.15	0.15	1.00	0.11	0.47	0.11	0.18
13	3.28	7.84	2.14	9.00	7.84	9.00	5.56	9.00	6.67	3.28	3.28	9.00	1.00	7.84	1.00	4.42
14	0.18	1.00	0.15	2.14	1.00	2.14	0.31	2.14	0.47	0.18	0.18	2.14	0.13	1.00	0.13	0.23
15	3.28	7.84	2.14	9.00	7.84	9.00	5.56	9.00	6.67	3.28	3.28	9.00	1.00	7.84	1.00	4.42
16	0.47	4.42	0.31	5.56	4.42	5.56	2.14	5.56	3.28	0.47	0.47	5.56	0.23	4.42	0.23	1.00

Table 4 Calculations for priority weight (W) and eigenvector λ_{avg}

AMBs	SQUR (P)	Ω	Aω	λ = Aω/ω
1	2.264	0.0894	1.48684306	16.6308
2	0.488	0.01928	0.31812613	16.5044
3	3.298	0.13022	2.19171201	16.8309
4	0.309	0.0122	0.20234319	16.5895
5	0.488	0.01928	0.31812613	16.5044
6	0.309	0.01222	0.20279167	16.5954
7	1.071	0.0423	0.71723387	16.9557
8	0.309	0.01222	0.20279167	16.5954
9	0.738	0.02915	0.49049984	16.8251
10	2.264	0.0894	1.48684306	16.6308
11	2.264	0.0894	1.48684306	16.6308
12	0.309	0.01222	0.20279167	16.5954
13	4.592	0.18134	3.1123134	17.1628
14	0.488	0.01928	0.31812613	16.5044
15	4.592	0.18134	3.1123134	17.1628
16	1.539	0.06076	1.02397348	16.8541
	25.32	1		16.7233

Table 5 Grouping of AMBs

Group	G1	G2	G3	G4	G5
AMBs	3,13,15	1,10,11	7,9,16	2,5,14	4,6,8,12
Intensity of importance	1	3	5	7	9
Reciprocal	1	1/3	1/5	1/7	1/9

3.2 Judge-2

In this pairwise comparison, we equally divide the eight levels of Agile Manufacturing barriers into five groups from 1 to 9 on the Saaty scale ranking by the judge-2 (Tables 5, 6 and 7).

3.3 Checking Consistency Ratio

If the consistency ratio, C.R. = 0.1 the matrix must be considered intently.

If the consistency ratio, C.R. > 0.1, the matrix is rejectable. Since every matrix, CR < 0.1, hence, the given matrix is consistent and hence acceptable (Table 8).

Since C.R. < 0.1 matrix is acceptable.

Table 6 Pairwise comparison matrix

AMBs	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1	5	1/3	7	5	7	3	7	3	1	1	7	1/3	5	1/3	3
2	1/5	1	1/7	3	1	3	1/3	3	1/3	1/5	1/5	3	1/7	1	1/7	1/3
3	3	7	1	9	7	9	5	9	5	3	3	9	1	7	1	5
4	1/7	1/3	1/9	1	1/3	1	1/5	1	1/5	1/7	1/7	1	1/9	1/3	1/9	1/5
5	1/5	1	1/7	3	1	3	1/3	3	1/3	1/5	1/5	3	1/7	1	1/7	1/3
6	1/7	1/3	1/9	1	1/3	1	1/5	1	1/5	1/7	1/7	1	1/9	1/3	1/9	1/5
7	1/3	3	1/5	5	3	5	1	5	1	1/3	1/3	5	1/5	3	1/5	1
8	1/7	1/3	1/9	1	1/3	1	1/5	1	1/5	1/7	1/7	1	1/9	1/3	1/9	1/5
9	1/3	3	1/5	5	3	5	1	5	1	1/3	1/3	5	1/5	3	1/5	1
10	1	5	1/3	7	5	7	3	7	3	1	1	7	1/3	5	1/3	3
11	1	5	1/3	7	5	7	3	7	3	1	1	7	1/3	5	1/3	3
12	1/7	1/3	1/9	1	1/3	1	1/5	1	1/5	1/7	1/7	1	1/9	1/3	1/9	1/5
13	3	7	1	9	7	9	5	9	5	3	3	9	1	7	1	5
14	1/5	1	1/7	3	1	3	1/3	3	1/3	1/5	1/5	3	1/7	1	1/7	1/3
15	3	7	1	9	7	9	5	9	5	3	3	9	1	7	1	5
16	1/3	3	1/5	5	3	5	1	5	1	1/3	1/3	5	1/5	3	1/5	1

Table 7 Calculations for priority weight (W) and eigenvector λ_{avg}

AMBs	P	Ω	Aω	λ = Aω/ω
1	2.2	0.0876	1.4614	16.682
2	0.55	0.0219	0.3653	16.680
3	4.145	0.1651	2.8010	16.967
4	0.277	0.011	0.1849	16.782
5	0.55	0.0219	0.3653	16.680
6	0.277	0.011	0.1849	16.782
7	1.106	0.04404	0.7363	16.719
8	0.277	0.01102	0.1849	16.782
9	1.106	0.04404	0.7363	16.719
10	2.2	0.0876	1.4614	16.682
11	2.2	0.0876	1.4614	16.682
12	0.277	0.01102	0.1849	16.782
13	4.145	0.1651	2.8010	16.967
14	0.55	0.0219	0.3653	16.680
15	4.145	0.16509	2.8010	16.967
16	1.106	0.04404	0.7363	16.719
	25.11	1		16.7675

Table 8 Consistency ratio

Judge	λ_{avg}	Consistency Index (C.I.) = $\frac{(\lambda_{avg} - n)}{(n - 1)}$	Consistency Ratio (C.R.) = $\frac{\text{Consistency Index (C.I.)}}{\text{Random Index (R.I.)}}$
Judge-1	16.7233	0.04822	0.030179
Judge-2	16.7675	0.05116667	0.0320232

3.4 Effectiveness of Agile Manufacturing Barriers

For calculating the effectiveness of individual barriers, we perform matrix multiplication of barriers by individual judges (Fig. 4, Table 9).

4 Result and Discussion

Nowadays every manufacturing organization should have to adopt AM to sustain in this competition and to satisfy customer demand. Contrary to the title finding the percentage effectiveness of AMBs using AHP, the main aim of study is to quantify the result obtained by the ISM. In our study on quantifying the effectiveness, there

$$\left\{\begin{matrix} J1 & J2 \\ 0.0894 & 0.0876 \\ 0.01928 & 0.0219 \\ 0.13022 & 0.16509 \\ 0.0122 & 0.01102 \\ 0.01928 & 0.0219 \\ 0.01222 & 0.01102 \\ 0.0423 & 0.04404 \\ 0.01222 & 0.01102 \\ 0.02915 & 0.04404 \\ 0.0894 & 0.0876 \\ 0.0894 & 0.0876 \\ 0.01222 & 0.01102 \\ 0.18134 & 0.16509 \\ 0.01928 & 0.0219 \\ 0.18134 & 0.16509 \\ 0.06076 & 0.04404 \end{matrix}\right\} \text{X} \left\{\begin{matrix} 1/2 \\ 1/2 \end{matrix}\right\} = \left\{\begin{matrix} 0.0885 \\ 0.02059 \\ 0.147655 \\ 0.01161 \\ 0.02059 \\ 0.01161 \\ 0.04317 \\ 0.01161 \\ 0.0366 \\ 0.0885 \\ 0.0885 \\ 0.01161 \\ 0.173215 \\ 0.02059 \\ 0.173215 \\ 0.0524 \end{matrix}\right\}$$

Fig. 4 Matrix multiplication

are three barriers which severely affect the successful implementation and operation of agile manufacturing with high-percentage effectiveness and they are lack of top management support, non-conductance of meeting, and lack of methodology.

5 Conclusion

After obtaining the percentage effectiveness of AMBs, the results obtained can contribute in eliminating AMBs for the successful implementation of AM. The results of AHP can be implied for theoretical and managerial aspects of AM as it assists manager to eliminate AMBs for proper operation of AM by taking some action according to the barriers percentage effectiveness. This study also helps in understanding the concepts of agile manufacturing and their barriers by implementing the various research methodologies like ISM and AHP. There is a huge scope of agile manufacturing in future research direction as manufacturing is moving toward innovation and customization, so research should be done on AMBs for successful implementation of AM. In future we can also integrate AM with other manufacturing techniques like lean agile six sigma integrated manufacturing, agile green integrated manufacturing as per the conditions arises. One of the limitations of AHP technique that it does not differentiate among the AMBs that occupy the same level so in this case, we have to apply analytic network process technique. There are various software used to determine the effectiveness like LISREL.

Table 9 Effectiveness of AMBs

S. no	AMB's	Rank obtained by ISM	Effectiveness obtained by AHP (%)
1	Lack of reconfigurable layout	3	8.85
2	Fear of and resistance to organizational change	7	2.059
3	Lack of methodology	2	14.7655
4	Lack of feedback system	8	1.161
5	Insufficient training & rewards	7	2.059
6	Improper forecast	8	1.161
7	Improper H.R. management	5	4.317
8	Improper production planning	8	1.161
9	Government policies and support	6	3.66
10	Lack of virtual partnership	3	8.85
11	Vertical organizational structure	3	8.85
12	Unavailability of appropriate technology	8	1.161
13	Non-conductance of meeting	1	17.3215
14	Lack of Retention of expertise staff	7	2.059
15	Lack of top management support	1	17.3215
16	Inappropriate technique for measuring the agility	4	5.24

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Modeling the Knowledge Sharing Barriers in Indian Small and Medium Industries Using ISM

Gaurav Shrivastava, K. K. Shukla, and Ubaid Ahmad Khan

1 Introduction

In this time of globalization, knowledge management plays a very crucial role to achieve organizational goals. Due to rapidly changing the demand of the customer, industries should prepare to change the technology and environment within the industry; this can be achieved by proper knowledge sharing within the industry.

As Bhatt pointed out knowledge is an important factor for developing and conserving an organization's core capability [1]. Nonaka 1994 proposed knowledge as a justified belief which enhances the capacity for appropriate action [2]. Devenport and Prusak suggested that KM is a process of knowledge collection, sharing, and propagation [3]. According to Himanshu Joshi KM is about how organizations assemble, propagate, and pertain knowledge [4]. They described the utilization of KM in various organizations. KM has become an effective way of managing organizational intellectual [5]. The organizational goal cannot be achieved until we understand the knowledge sharing barriers [6].

The barriers which influenced the maximum number of barrier called the driving barrier and the barriers which are affected by other barriers are called dependence barrier or driven barrier. Hence, these barriers create a hindrance to the transfer of knowledge within the organization.

In this study, the interpretive structural modeling (ISM) methodology is being used to find out the intricacy of the barriers. By ISM, we found the hierarchy of the barriers based on their driving and dependence power. In the present research, there are 14 barriers is selected which is highly responsible for the hindrance of knowledge flow in the medium and small engineering industry. There are two barriers namely the "lack of top management commitment" and "KM is not well understood" which are the strongest driving power so managers should focus on these barriers while making

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the strategy. The opinion from experts is being used to develop the relationship matrix and ISM model.

The central theme of this paper is to establish a relationship between the chosen barriers with the help of ISM and find out their hierarchy which will be easy for managers to short out the problems. This paper structured into six segments in which the first segment contains an introduction, the second segment contains literature, the third segment contains the ISM methodology, the fourth segment contains ISM model, the fifth segment contains the categorization of KSBs, and sixth segment conclusion and future aspect of this research.

2 Literature Review

According to Nonaka 1995, knowledge is a factor of production [7]. Knowledge is defined as the information obsessed in the brain of an individual. It can be adapted or biased information regarding the facts, procedures, ideas, concepts, and judgments [8]. Knowledge originates and functional in the minds of the individual, so it is difficult to manage the knowledge [9].

KM is an inclusive concept covering people, process, and technological aspects [10]. Very few researches have been concluded on knowledge sharing barriers in Indian SMEs and their effectiveness with the help of ISM. Organizations that are investing to amplify potential gain of knowledge observe an increased efficiency in operation, better rates of innovations, and enhancement in the level of customer services [11]. Business objectives cannot be completed unless the Indian SMEs understand the KSBs and their mutual relationship [12].

Knowledge sharing barriers are categorized into three types as individual KSBs, technological KSBs, and organizational KSBs. This classification was given by Reige [13]. There are 14 barriers that are taken from various literature review and discussion with experts from industry and academia to implement KSBs in medium and small engineering industries for the successful running of the industry. These are discussed in given Table 1.

3 ISM Methodology

In 1973, J. Warfield first introduced the ISM [14–19]. ISM decides what the relationships among the variables are. ISM is a modeling technique in which a specific relationship is found between the variables and the overall structure is made into a graphical way.

Table 1 Literature review

S.No.	Knowledge sharing barriers	BP Sharma 2012	John Omgeafe 2014	Basant Kashyap 2015	A.S Kajure 2016	Saravanan Nadason 2017	Odor Ho 2018
1	Lack of technical support	✓			✓		✓
2	Lack of training	✓		✓	✓	✓	
3	Unrealistic expectation	✓			✓		
4	Lack of tolerance on mistakes	✓					
5	KM is not well understood	✓				✓	
6	Lack of transparent reward system	✓	✓		✓		
7	Lack of formal and informal space				✓		
8	Lack of top management commitment	✓	✓	✓	✓	✓	✓
9	Lack of trust in people	✓	✓		✓	✓	✓
10	Fear of job security	✓	✓				
11	Lack of time to share knowledge	✓	✓		✓	✓	✓
12	Age gap of employee	✓	✓		✓		
13	Underestimating of lower level		✓				
14	Resistance to change			✓			

3.1 Structural Self-Interaction Matrix (SSIM)

For the development of relationships among the knowledge sharing barriers, we discussed with the experts of industries, academician, and normal discussion with the group of engineers. For the developing SSIM, following four symbol, i.e., V, A, X, O, will be utilized to find the relationship among the knowledge sharing barriers. We use the notation “i” and “j” to understand the relationship between two knowledge sharing barriers (Table 2).

V IS USED WHEN KSB “I” IS RESPONSIBLE FOR KSB “J”.
A is used when KSB “j” is responsible for KSB “i”.
X is used when both the KSB is responsible for each other.
O is used when neither KSB “i” nor KSB “j” responsible for each other

3.2 Development of Initial Reachability Matrix

In the SSIM table where the relation is V, i.e., KSB “i” is responsible for the development of the KSB “j” would be change into 1 and the relation A, i.e., KSB “j” is responsible to the development of the KSB “i” would be changed into 0. Now the relation X in the SSIM table that means both the KSB are responsible to the development of each other would be changed into 1 and the last relation O, i.e., neither KSB “i” support to KSB “j” nor KSB “j” support KSB “i” would be changed into 0 (Table 3).

3.3 Development of Final Reachability Matrix

In the final reachability matrix, we remove transitivity between the relation we denote the transitivity by 1* and then find the driving power and dependence power of the barriers according to this driving and dependence power we find their rank. During counting, we consider both 1 and 1* and zeroes will not be count (Table 4).

3.4 Partitioning of Reachability Matrix

After the development of final reachability matrix, a set of positive relationships 1_s and 1_s^* in the row (reachability) and in column (antecedent) has been drawn to develop the series of partitioning. If the intersection set is similar to the reachability set, it will be removed from consideration and kept at level first in the hierarchy. This step will be repeated until the last level of KSBs. Partitioning of the final reachability matrix is completed in 14 iterations, shown in Table 5.

Table 2 Structural self interaction matrix

S.No.	Barriers	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	Lack of technical support	V	V	O	V	V	V	A	V	V	A	V	V	X	X
2	Lack of training	V	V	V	V	V	V	A	V	V	A	V	V	X	X
3	Unrealistic expectation	O	O	V	A	A	O	A	V	O	A	A	X		
4	Lack of tolerance on mistakes	O	V	V	V	X	A	A	V	O	A	X			
5	KM is not well understood	V	V	O	V	V	V	X	V	V	X				
6	Lack of transparent Reward	O	V	O	O	O	V	A	O	X					
7	Lack of formal and informal space	O	O	X	A	A	A	A	X						
8	Lack of top management commitment	V	V	V	V	V	V	X							
9	Lack of trust in people	X	V	V	O	V	X								
10	Fear of job security	A	V	V	V	X									
11	Lack of time to share knowledge	O	X	O	X										
12	Age gap of employee	A	A	X											
13	Underestimating of lower level	O	X												
14	Resistance to change	X													

Table 3 Initial reachabilty matrix

S.No.	Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Lack of technical support	1	1	1	1	0	1	1	0	1	1	1	0	1	1
2	Lack of training	1	1	1	1	0	1	1	0	1	1	1	1	1	1
3	Unrealistic expectation	0	0	1	0	0	0	1	0	0	0	0	1	0	0
4	Lack of tolerance on mistakes	0	0	1	1	0	0	1	0	0	1	1	1	1	0
5	KM is not well understood	1	1	1	0	1	1	1	1	1	1	1	0	1	1
6	Lack of transparent reward	0	0	0	0	0	1	0	0	1	0	0	0	1	0
7	Lack of formal and informal space	0	0	0	0	0	0	1	0	0	0	0	1	0	0
8	Lack of top management commitment	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	Lack of trust in people	0	0	0	1	0	0	1	0	1	1	0	1	1	1
10	Fear of job security	0	0	1	1	0	0	1	0	0	1	1	1	1	0
11	Lack of time to share knowledge	0	0	1	0	0	0	1	0	0	0	1	0	1	0
12	Age gap of employee	0	0	0	0	0	0	1	0	0	0	0	1	0	0
13	Underestimating of lower level	0	0	0	0	0	0	0	0	0	0	1	1	1	0
14	Resistance to change	0	0	0	0	0	0	0	0	1	1	0	1	0	1

Table 4 Final reachability matrix

S.No.	Barriers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	D.P.
1	Lack of technical support	1	1	1	1	0	1	1	0	1	1	1	1*	1	1	**12**
2	Lack of training	1	1	1	1	0	1	1	0	1	1	1	1	1	1	**12**
3	Unrealistic expectation	0	0	1	0	0	0	1	0	0	0	0	1	0	0	**3**
4	Lack of tolerance on mistakes	0	0	1	1	0	0	1	0	0	1	1	1	1	0	**7**
5	KM is not well understood	1	1	1	1*	1	1	1	1	1	1	1	1*	1	1	**14**
6	Lack of transparent reward system	0	0	0	1*	0	1	1*	0	1	1*	1*	1*	1	1*	**9**
7	Lack of formal and informal space	0	0	0	0	0	0	1	0	0	0	0	1	0	0	**2**
8	Lack of top management commitment	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**14**
9	Lack of trust in people	0	0	1*	1	0	0	1	0	1	1	1*	1	1	1	**9**
10	Fear of job security	0	0	1	1	0	0	1	0	0	1	1	1	1	0	**7**
11	Lack of time to share knowledge	0	0	1	0	0	0	1	0	0	0	1	1*	1	0	**5**
12	Age gap of employee	0	0	0	0	0	0	1	0	0	0	0	1	0	0	**2**
13	Under estimating of lower level	0	0	1	0	0	0	1*	0	0	0	1	1	1	0	**5**
14	Resistance to change	0	0	1*	1*	0	0	1*	0	1	1	1*	1	1*	1	**9**
	Dp. P.	**4**	**4**	**8**	**9**	**2**	**5**	**14**	**2**	**7**	**9**	**11**	**14**	**11**	**7**	

Table 5 Level partitioning

Barriers	Reachability set	Antecedent set	Intersection set	Level
1	1,2	1,2,5,8	1,2	VII
2	1,2	1,2,5,8	1,2	VII
3	3	1,2,3,4,5,8,9,10,11,13,14	3	II
4	4,10	1,2,4,5,6,8,9,10,14	4,10	IV
5	5,8	5,8	5,8	VIII
6	6	1,2,5,6,8	6	VI
7	7,12	1,2,3,4,5,6,7,8,9,10,11,12,13,14	7,12	I
8	5,8	5,8	5,8	VIII
9	9,14	1,2,5,6,8,9,14	9,14	V
10	4,10	1,2,4,5,6,8,9,10,14	4,10	IV
11	11,13	1,2,4,5,6,8,9,10,11,13,14	11,13	II
12	7,12	1,2,3,4,5,6,7,8,9,10,11,12,13,14	7,12	I
13	11,13	1,2,4,5,6,8,9,10,11,13,14	11,13	III
14	9,14	1,2,5,6,8,9,14	9,14	V

4 Development of ISM Model

ISM model development table shows that the age gap of employee and lack of formal and informal space are in the first level and "lack of top management commitment" and "KM is not well understood" are at last position. The barriers are at the last level are very powerful barriers these barriers affect other barriers. Figure 1 shows the ISM Model.

5 Categorization of KSBs

KSBs are classified on their driving and dependence power into four clusters. These are dependent, autonomous, independent, and, lastly, linkage KSBs. We arrange the KSBs into their driving and dependence power in a chart where on the abscissa is dependence power and at the ordinate, there is driving power. Figure 2 shows the MICMAC Analysis.

I. **Autonomous KSBs—**In our study, there is no one is autonomous barriers; these barriers are less driving power and least dependent barriers. Autonomous barriers have very less influence on the system.

II. **Dependent KSBs—**barriers such as lack of formal and informal space, age gap of employee, unrealistic expectation, lack of time for share knowledge, underestimating of the lower level, lack of tolerance on mistakes, and fear of job these barriers have weak driving power but highly dependent in nature.

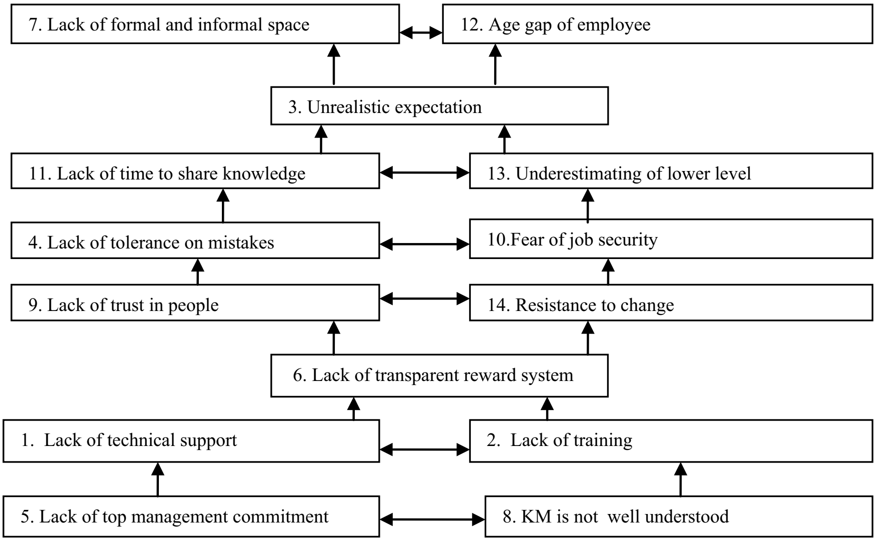

Fig. 1 ISM Model

These barriers have highly dependence power so during implementing other KSBs managers should focus on these barriers.

III. **Linkage KSBs—**there is no one in the linkage KSBs cluster. These obstacles have the highest driving power and the highest dependence power. These barriers are unstable.

IV. **Independent KSBs—**the barriers such as lack of top management commitment, KM is not understood, lack of training, lack of technical support, lack of trust in people resistance to change, and lack of transparent reward system are the primary cause of happening of other barriers.

6 Conclusion

Rapidly changing the demand and competition in the market industries should be focused on effective knowledge sharing in the industry which can meet the organizational demand. Framework of the barriers is developed on the basis of the survey and opinion of experts. With the help of ISM methodology, we develop a hierarchy of barriers that is based on the driving and dependence power. In this research, we found that lack of top management commitment and KM is not well understood has the highest driving power and lack of technology and lack of training are second highest driving power so managers should focus to eliminate these barriers. ISM is a primary tool used to develop the initial model. To check the statistical data, we can use LISREL software.

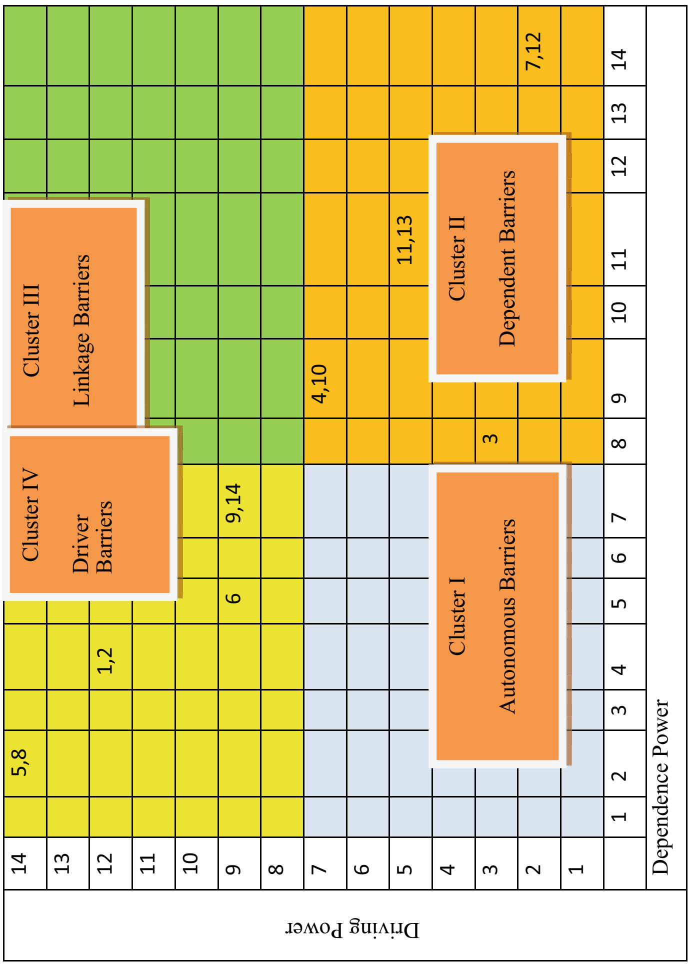

Fig. 2 MICMAC Analysis

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Simulation and Optimization of Flexible Flow Shop Scheduling Problem in an Indian Manufacturing Industry

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1 Introduction

In the real-time scenario, there exist many situations in manufacturing system like due date changes, unexpected job release, machine breakdowns, and more significant processing times, than estimated and expected. The scheduling has two aspects, forward scheduling, in which activities are planned from the date they become available to determine the due date, and backward scheduling, in which activities are planned for later as possible, to meet the due date [1]. The time estimate criterions such as minimizing the makespan, lateness, machine idle cost, inventory cost, and tardiness are identified [2, 3]. The objective is to increase the production efficiency, optimization of resources, minimizing production cost, and increase in competitive strength. The two- and three-stage production system with included setup times is specifying with a set of workstations [4]. The set of "*n*" jobs (different or same) are processed on "*m*" set of machines to minimize the given criterion [5].

1.1 Heuristics

Heuristics refers to as an approach to problem-solving, or discovery that employs a practical method not guaranteed to be optimal, but sufficient to obtain results. The flow shop scheduling problem (FSSP) has been solved with release and due dates to minimize maximum lateness [7]. The flow shop schedules have been framed for

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setup time estimates under uncertain situations [8]. Heuristic methods can rapidly process the problem giving a satisfactory solution.

1.2 Flow Shop Scheduling

In FSSP environment, each job has to go through a series of operations in the same order, implying that the jobs have to follow the same route or process sequence, but the processing time of each operation on a job will be different from that of other jobs. A job might need multiple operations at a phase (e.g., workstation). These operations require not to be done sequentially: operations of other tasks may be processed in among two following operations of a task. Preemption of the operations of a task is not allowed [8]. The hybrid flow shop environment is a group of $S \geq 2$ stages in which one of these stages has more than one workstations, that can process one job at a time [9]. Each operation of a task at a level has to experience some other activities that have no capacity at this level, but take an exhaustible amount of time. This time is independent of the job successiveness and required to be the same for all operations or tasks (Fig. 1).

2 Literature Analysis and Models

This section reviews the contributions made towards multi-objective FSSPs, sequence-dependent setup times problems, and backlogging problems in the past few years. As the flow shop environment is common practice in the manufacturing industries, hence essential to improve the productivity to achieve profit worthy

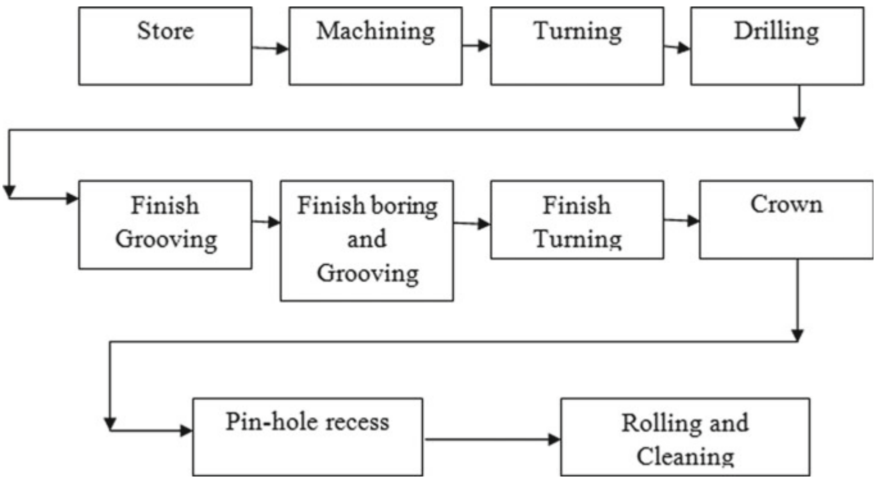

Fig. 1 The proposed flow process in a piston manufacturing industry (product. piston ring)

Table 1 Evaluation and reproduction phase on $12x_1 + 15x_2 \leq 90$

Substring 2	Substring 1	x_2	x_1	f(x)	F(x)	A	B	Rank
11001111	11100111	18.21	20.32	516.99	**0.001931**	0.09087	0.9087	1
100011001	111	24.72	0.615	378.18	0.002637	0.1241	1.241	5
111011001	100000101	41.61	22.96	899.67	0.00111	0.05223	0.5223	
11111	100011111	2.72	25.24	343.68	0.002901	0.1365	1.365	3
100110101	111011100	27.18	41.87	910.14	0.001097	0.05162	0.5162	
10101101	11101001	15.21	20.45	473.55	0.002107	0.09915	0.9915	
111100100	111111001	42.58	44.43	1171.86	0.000853	0.04014	0.4014	
10000101	101010	11.7	3.69	219.78	0.004529	0.21313	2.1313	2
10110101	1000101111	15.92	49.18	828.96	0.001205	0.0567	0.567	
1000100	11110011	5.98	21.38	346.26	0.00288	0.13553	1.3553	4
				Sum =	**0.021249**			
				Avg. =	**0.002125**			

status in the economy. Lots of these problems and principles of the heuristics algorithm are elaborated in this section, and the related surveyed literature is assigned in the upcoming section (Table 1). A heuristic procedure is presented to solve the hybrid FSSP in a flexible multistage batch production system to minimize makespan [9]. A particle swarm optimization (PSO) algorithm is proposed to solve flexible FSSP, which combines both flow shop and parallel machines in order to minimize the makespan so that multiprocessor system be executed with minimum length [10]. The dynamic programming algorithms for the scheduling problem of unit time jobs and batch production have been developed in a two-stage flexible flow shop environment [11]. A variable neighborhood search algorithm (VNS) for two-machine FSSPs is framed to minimize the makespan and constrained by blocking [12].

3 Model Formulation

In this paper, the process of design of heuristics is framed and checked its feasibility too. It is evaluated by software and shows the mathematical relationships for FSSP in the piston manufacturing sector. After extracting ideas from the literature review, the following problems need to be formulated:

i. The function of operation and production scheduling in the flow shop process is to identify the multi-objective tasks.
ii. Most of the papers on sequence-dependent setup time (SDST) for FSSP have been focused on the individual condition problem.

iii. A majority of broadly conceived performance measures are maximum flow time, total makespan, total tardiness, the total amount of tardy jobs, and maximum tardiness, etc.
iv. The FSSP with makespan condition is exceptionally significant in order to improve the productivity and maximization usage of resources and as well as in innovative manufacturing and function management.

4 Implementation of Heuristics Algorithm

Heuristics algorithm is proposed for the achievement of the optimal solutions to minimize the makespan of every machine and identify the best fitness function and prioritize accordingly.

4.1 Mathematical Analysis Using Heuristics for Optimization of Time Estimates

Consider the following assumptions as an important to solve the equation in genetic algorithm they are:

String length, $l = 10$
Population size, N = 20
Number of variables = 2
The dynamic probability of the *j*th string in the population is identified [6].

$$P_j = F_j / \sum_{j=1} n F_j \tag{1}$$

F_{j} = Fitness for the string j in the population, expressed as *f(x)*
P_i = Probability of the string j being selected,
n = Number of individuals in the population.

For the minimization of these problems, the fitness operation is a similar maximization problem is chosen so that the optimal point retains unaltered.

Usually, the linear mapping rule is used [8]:

$$X_i = \frac{X_i^{(LB)} + X_i^{(UB)} - X_i^{(LB)}}{2^{\mathrm{li}} - 1} \tag{2}$$

The iteration 1 sample of mathematical equation $12x_1 + 15x_2 \leq 90$ using the genetic algorithm is determined (Table 1).

Table 1 represents the values of $x_1 = 20.32$ and $x_2 = 18.21$. These are the solutions that are obtained by mathematical calculations only with two iterations. These values are the obtained values for the completion time of the third machine for two products in a total of eight machines. The values of these variables are chosen based on the highest fitness function, *F(x) = 0.001931*. The fitness function is calculated by the formula is given below as:-

$$F(x) = 1/1 + f(x) \tag{3}$$

4.2 Computation Analysis of Heuristics Algorithm Using MATLAB

From equation $12x_1 + 15x_2 \leq 90$, the first stages are an encoding of chromosomes and apply binary agency for integers. Therefore, 10 bits are applied to constitute integers up to 20. Let us put on that population size is 20. Give starting population at random. They are chromosomes either genotypes. Compute fitness value for particular and each one individually. Using MATLAB, Fig. 2 shows the $12x_1 + 15x_2 \leq 90$ is optimized and the results are described below: $x_1 = 3.436$ *and* $x_2 = 3.2252$ are the solutions that are obtained using optimization tool in the software. These values are the obtained values for the completion time of the third machine for two products in a total of eight machines. The variations of the two variables, best fitness value, selection, range, and best individuals' values are determined (Fig. 2).

4.3 Validation of Optimization and Simulation Model of Heuristics Algorithm for Flow Shop Scheduling

By comparing the actual data and optimized data, the optimized data are minimized, and the actual data, the values are decreased due to the genetic algorithm. By comparing the actual and optimized data using MATLAB, it denotes that for machine 1 to machine 8, the completion time of the products is reduced (Tables 2 and 3).

4.4 Cumulative Validation for Actual Data, Mathematical Data, and Optimized Data

The reduction in completion time they have obtained based on the factor of the fitness function, crossover, and mutation. The actual data that are determined in industry for machine 1 is 21 min, for machine 2 is 20 min, for machine 3 is 25 min, for machine 4 is 38 min, for machine 5 is 22 min, for machine 6 is 27 min, for machine 7 is 40 min, and for machine 8 is 30 min. After solving mathematically, i.e., by using

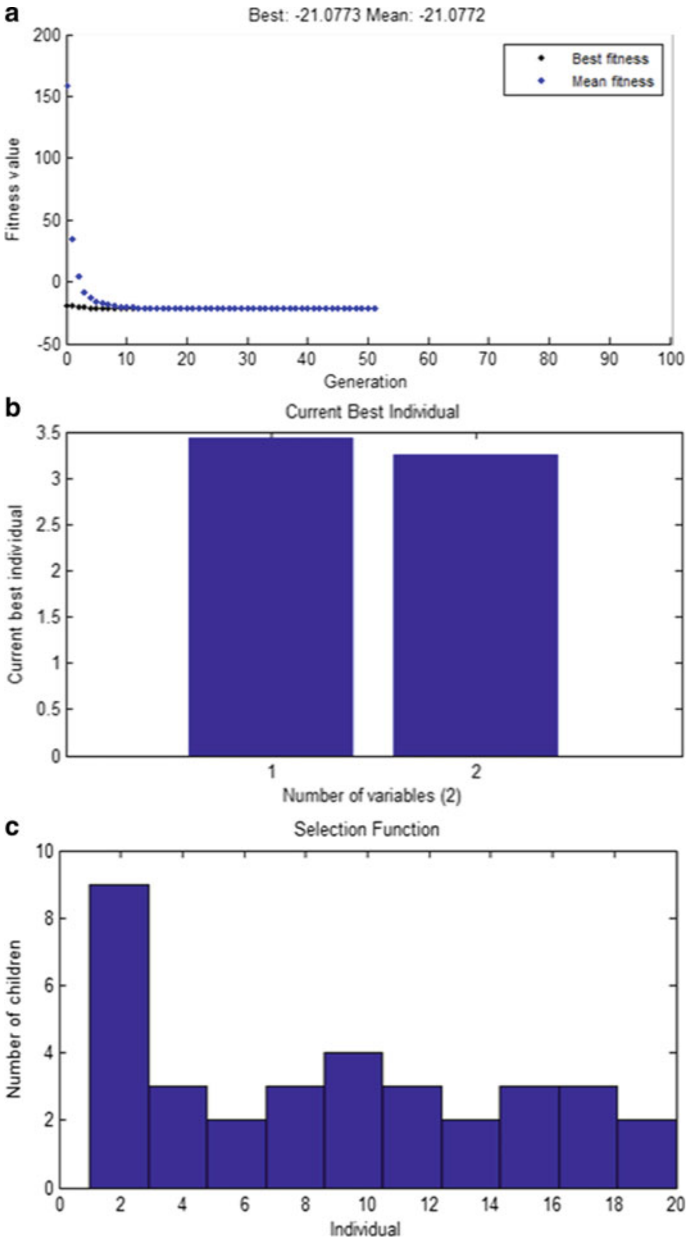

Fig. 2 **a** Variation of the best fitness function for equation $12x_1 + 15x_2 \leq 90$ **b** Variation of best individual function for equation $12x_1 + 15x_2 \leq 90$ **c** Variation of best selection function for equation $12x_1 + 15x_2 \leq 90$

Table 2 Analysis of actual data and optimized data for product 1

Product	Time per Process and Operation (min)							
	M1	M2	M3	M4	M5	M6	M7	M8
Actual data P1	11	11	12	19	11	15	19	15
Optimized data P1	2.452	4.197	3.436	2.119	2.027	4.157	1.562	3.653

Table 3 Analysis of actual data and optimized data for product 2

Product	Time per process and operation (min)							
	M1	M2	M3	M4	M5	M6	M7	M8
Actual data P2	12	11	15	21	13	14	24	17
Optimized data P2	2.753	3.985	3.252	2.845	2.9	4.117	2.514	3.835

genetic algorithm for machine 1 is 15 min, for machine 2 is 35 min, for machine 3 is 37 min, for machine 4 is 15 min, for machine 5 is 18 min, for machine 6 is 20 min, for machine 7 is 10 min, and for machine 8 is 12 min (Fig. 3).

Likewise, MATLAB optimized data are substituted in objective function and constraints, then the completion time for product 1 is 27 min and for product 2 is 30 min obtained in MATLAB is decreased to 3.5 times with 61 iterations; the reduction is due to the accuracy of the fitness function is 0.0035, population size is 25. So, this proves that by using MATLAB optimization tool gives more accurate results than the analytical data, and hence, this model is validated. This validated model can be implemented in the industry to minimize the completion time of the product, and the productivity can be increased.

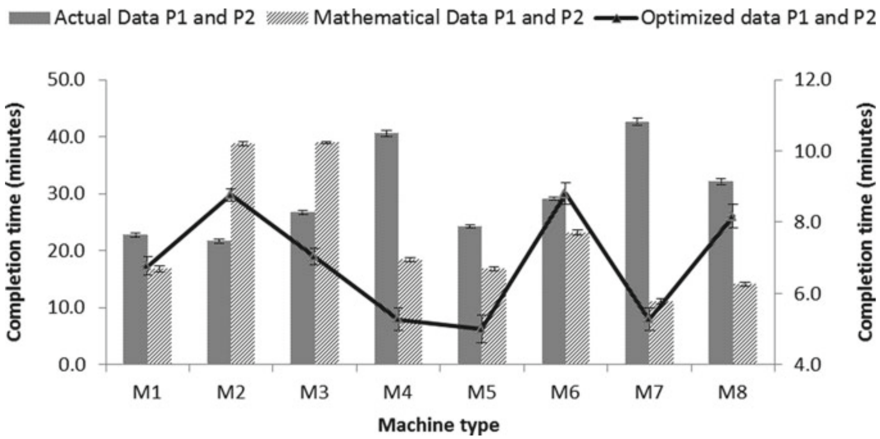

Fig. 3 Cumulative validation for completion time in a piston manufacturing industry

5 Conclusions and Future Interventions

It is observed from the result analysis that multi-objective sequence-dependent setup time FSSP has experienced little attention from the investigators. Efficient handling of SDST is one of the critical elements to increase manufacturing organization performance and experiences to be looked separately from the processing time. The actual data (processing time and makespan) determined from piston manufacturing industry is optimized using a genetic algorithm (GA). For machine 1, the processing times for two batches are 11 min after optimization and, consequently, the time as 3 min is reduced. The population size is 20, the length of the string is 20, each string consists of 10 bits and further, there are two variables in total. So there are 20 bits is the string length. The cumulative actual time taken for completion per cycle is determined as 239.9 min, while the analytical time is found as 178.5 min. Otherwise, the optimized time calculated by MATLAB per cycle is 55.1 min. Here, we can conclude that time efficiency of machine could be increased through the application of flow process (Fig. 3).

The performance of the proposed heuristics algorithm shows the most beneficial results and changes with the increase in the number of machines. Some major benefits are mentioned as (i) The hybridized GA gives the better environment of the modeling of any optimizing problem parameter and its interface is easier to understand the tool provided by the software which is easily available and also the fitness function gives good help to find suitable material to attach. (ii) It is also suggested that hybrid GA can be used for creating graphical user interface (GUI) in order to solve the minimization of transportation costs, delay time and cycle time of any kind of FSSPs. (iii) The proposed hybrid model proves to be a practical approach for optimizing multi-objective SDST FSSPs for any job and machine size. (iv) The proposed research would suggest the minimization of total transportation time, delay time, and also cycle time can be minimized using hybrid genetic algorithm (HGA), and the results can be compared with other heuristics algorithms. (iii) By using genetic algorithm, the processing time and the total makespan have been optimized. (v) Many products (jobs) and machines processing time can be minimized, and it can be easily optimized based on the string length. The grouping and cross-combination of modeling parameters and time estimates can be proposed for future scope of work. The transportation times between machines in the process shop floor and production facilities can be included by HGA, simulated annealing (SA), and PSO models.

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Computational Investigation on the Thermal Characteristics of Heat Pipe Using Nanofluids

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1 Introduction

Heat pipes are used in various applications, dealing with thermal cooling with highly effective heat transfer rate through evaporation and condensation of fluid. Because of its number of advantages such as small area, low cost and minimum maintenance make heat pipe more demanding. The heat pipe is an insulated container, which has wick and working fluid. Gravitational force plays an important role for bringing back the working fluid to the evaporator in wickless heat pipe. Heat pipe consists of three sections, which are evaporator, condenser and adiabatic section. In the heat pipe, the heat is applied to the evaporator section where working fluid is present in the liquid form. Because of the temperature and pressure inside the sealed container the liquid is vapourized and passed to the condenser section. Vapour near the wall of the condenser losses its heat by convection and condenses to liquid form. The condensed liquid is then returned to the evaporator due to the gravitational force [1].

Nanofluids are a type of fluid that is prepared by dispersing nanometer-sized particles such as nanoparticles, nanotubes, nanowires and droplets in base fluid such as water or oil. Nanofluids are two-phase systems with one phase solid and other phase liquid. Nanofluids increase the thermal conductivity as solid particles have larger thermal conductivity as compared to liquids [2–7].

Fadhl, Wrobel and Jouhara have numerically studied the investigation of two-phase thermosyphon. CFD model was developed in their work which allows performing the simulation of the phase change phenomenon in the thermosyphon. The appropriate source terms were implemented to the phase change material in the governing equations of the fluent. Finally, the source term has been linked to the fluent

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with the help of UDF code. Author validates his work using experimental results. The simulations' results show that VOF model in FLUENT was successful in evaporation–condensation mechanism in thermosyphon. Different heat flow power was applied to the evaporator section. Under these operating conditions average surface temperature and thermal resistance were calculated and found that thermal performance of thermosyphon improved above 172 W heating power input.

Alizadehdakhel et al. [1] have used CFD model and experimental measurement for heat as well as mass transfer phenomenon in two-phase closed thermosyphon. In their work they have used different heat input and different fill ratios of the working fluid for operation in thermosyphon. They have developed UDF subroutine to model phase change using FLUENT. Three fill ratios of 0.3, 0.5, and 0.8 and three inlet heat flow of 350, 500, and 700 W were considered. Under these operating conditions heat performance was calculated. The author found out that more heat energy applied to the evaporator section decreases the performance of the thermosyphon.

Raj et al. [8] computationally studied the thermal performance of heat using benzene as base fluid with titanium dioxide nanoparticles added. An increase in thermal conductivity was obtained by 3% at 300 K, with the addition of 1% nanoparticles by volume.

In these contexts, it is concluded that the addition of nanoparticles enhances the thermal performance of cooling devices, thereby increasing the heat transfer rate and achieving optimum performance. Hence, in the present work, computational model of the heat pipe is developed, which is operated with nanofluids in order to analyze the thermal characteristics to bring further clarity on the heat transfer mechanism.

2 Research Methodology

Numerical simulations for two or more phases are more difficult than single-phase flow. This is because the interface between the phases keeps on changing. Because of this reason, the volume of liquid (VOF) [9] strategy has been utilized to tackle these issues. Such scheme utilizes phase conservation in the control volumes, which equates to one. Moreover, for modelling fluid-flow dynamics, Navier–Stokes equation is solved by the solver FLUENT. In the present work, α_L is the volume fraction of working fluid phase that is liquid phase and α_G is volume fraction of the vapour phase.

The volume fraction of liquid α_L can be calculated as follows:

$$\alpha_L = \frac{\text{Liquid}}{\text{Liquid} + \text{Vapour}} \tag{1}$$

$$\alpha_V = \frac{\text{Vapour}}{\text{Liquid} + \text{Vapour}} \tag{2}$$

In the present work, the three cases are conceivable:

- $\alpha_L = 1$: the cell is completely filled by liquid,
- $\alpha_V = 1$: vapour completely occupying control volume,
- $0 < \alpha_L < 1$: interface between vapour and liquid phases.

2.1 Governing Equations

The movement of the working fluid in a thermosyphon relies on the three governing equations that are momentum, energy, and mass continuity as explained below. In the present work, the vapour is taken as a primary phase whereas the liquid is taken as secondary phase. According to the continuity equation, the governing equation can be written as

$$\nabla(\rho \vec{u}) = -\frac{d\rho}{dt} \tag{3}$$

In this equation density is denoted by ρ, velocity is represented by u, and time is represented by t.

Thus the continuity equation is expressed as

$$\nabla(\alpha_L \rho_L \vec{u}) = -\frac{d(\alpha_L \rho_L)}{dt} + S_M \tag{4}$$

where the S_M is the source term for mass and is used for calculating the mass transfer during the phase change process in the heat pipe.

In the present work, the vapour is taken as the primary phase. The above equations are not able to solve for the primary phase. The vapour volume fraction is calculated as the following:

$$\sum_{L=1}^{n} \alpha = 1 \tag{5}$$

The density of the mixture can be calculated as follows:

$$\rho = \alpha_L \rho_L + (1 - \alpha_L)\rho_V \tag{6}$$

Because of various forces acting in the fluid, such as gravitational, pressure, surface tension and friction, continuum surface force (CSF) model is applied to the momentum equation. In the CSF model surface tension coefficient is represented by σ_{LV} and surface curvature is represented by the following proposed model by Brackbill et al. [10].

$$F_{CSF} = 2\sigma_{LV} \frac{\alpha_L \rho_L C_V \nabla \alpha_V + \alpha_V \rho_V C_L \nabla \alpha_L}{\rho_L + \rho_V} \tag{7}$$

By considering the surface tension force, the momentum equation of VOF model can be written as

$$\frac{\partial}{\partial \mathrm{t}}(\rho\vec{u}) + \nabla(\rho\vec{u}\vec{u}) = \rho\vec{g} - \nabla p + \nabla\left[\mu\left(\nabla\vec{u} + \vec{u}^T\right) - \frac{2}{3}\mu\nabla\cdot uI\right] + F_{\mathrm{CSF}} \quad (8)$$

In the equation the pressure is denoted by p, unit tensor is denoted by I and g is acceleration due to gravity.

The moment equation depends on volume fraction of all phases. The dynamic viscosity μ is given by

$$\mu = \alpha_L\mu_L + (1-\alpha_L)\mu_V \quad (9)$$

The energy equation is expressed as [9],

$$\frac{\partial}{\partial t}(\rho e) + \nabla(\rho e\vec{u}) = \nabla(k\cdot\nabla T) + \nabla(p\vec{u}) + S_E \quad (10)$$

In this case, the energy source term is denoted by $S_E S_E$, which is used to find out the heat transfer when phase change process occurs. Thermal conductivity k is calculated as follows:

$$k = \alpha_L k_L + (1-\alpha_L)k_V \quad (11)$$

The internal energy e is expressed as

$$e = \frac{\alpha_L\rho_L e_L + \alpha_V\rho_V e_V}{\alpha_L\rho_L + \alpha_V\rho_V} \quad (12)$$

where internal energy of liquid e_L and vapour e_v are based on the specific heat c_p of the phases and the shared temperature, given by

$$e_L = c_{p,L}(T - T_{\mathrm{sat}}) \quad (13)$$

$$e_V = c_{p,V}(T - T_{\mathrm{sat}}) \quad (14)$$

In these equations, the T_{sat} is the saturated temperature. Above the saturation temperature the evaporation starts and below the saturation temperature the condensation starts.

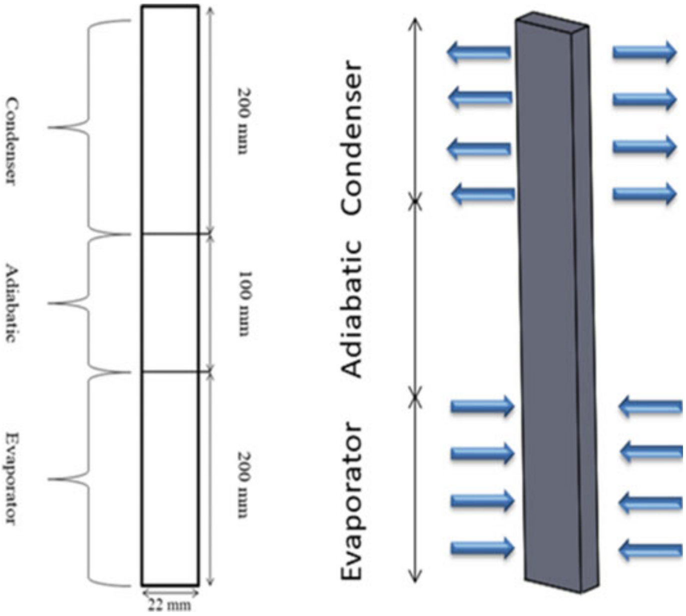

Fig. 1 Two-dimensional heat pipe geometry

2.2 Geometric Specification

A two-dimensional geometry was generated to model multiphase flow in the heat pipe. The heat pipe is shown in Fig. 1. The diameter of 22 mm is used in the heat pipe geometry. In the present simulation conditions, the heat pipe is segmented into three zones, namely, evaporator, adiabatic and condenser. Both upper and bottom sections have length of 200 mm where heat transfer occurs and middle section has 100 mm length where there is no heat flux. Adiabatic section is kept insulated by giving the value of heat flux equals to zero.

2.2.1 Boundary Conditions

For heating of the working fluid, a constant temperature of 425 K is applied at the walls of the bottom section which is the evaporator. A no heat flux is applied to adiabatic section; in the present study, the adiabatic section is insulated. The heat is lost from the working fluid by convection at the top most part of the geometry, which is the condenser. Body force is defined by giving the acceleration due to gravity of 9.8 m/s^2. The operating pressure of 101325 Pa is used. The working fluid used in heat pipe is water and density is the function of temperature which is calculated from the steam table as follows [9]:

Table 1 Commonly used correlations for metals and metals oxide

Thermophysical properties	Reference	Correlation
Thermal conductivity (W/m K)	Hamilton Crosser Model [11]	$k_{\text{eff}} = k_{\text{BF}} \frac{[k_p + (n-1)k_{\text{BF}} - (n-1)\varphi(k_{\text{BF}} - k_p)]}{[k_p + (n-1)k_{\text{BF}} + \varphi(k_{\text{BF}} - k_p)]}$
Specific heat (J/kg K)	Pak and Cho [12]	$C_{\text{PNF}} = \frac{(\rho_{\text{BF}} C_{\text{pBF}}(1-\varphi) + \rho_p C_{Pp}\varphi)}{(\rho_{\text{BF}}(1-\varphi) + \rho_p\varphi)}$
Effective density (kg/m^3)	Pak and Cho [12]	$\rho_{\text{NF}} = \rho_{\text{BF}}(1-\varphi) + \rho_P\varphi$
Viscosity (Pa-s)	Singh et al. [13]	$\mu_{\text{eff}} = \mu_{\text{BF}}(1 + 10\varphi)$

$$\rho_L = 859.0083 + 1.252209T - 0.0026429T^2 \tag{15}$$

Because of surface tension between the interfaces of the two phases, the following equation calculated from the steam table for surface tension is used [9]:

$$\sigma_{LV} = 0.09805856 - 1.845 \times 10^{-5}T - 2.3 \times 10^{-7}T^2 \tag{16}$$

Here T is the shared temperature. In the present work, the water vapour is used as a primary fluid and water is used as a secondary fluid. Initially, the volume fraction of water is 0.5 and is patched to the evaporator section.

2.2.2 Correlations for Thermophysical Properties

Metal oxide nanoparticles possess large surface area, along with chemical and thermal stability. Hence, in the present work, Al_2O_3, CuO, TiO_2 and SiC are selected as the class of nanoparticles for enhancing the thermal characteristics of heat pipes. Table 1 shows the correlations for estimating the effective thermophysical properties utilized. The correlations had been derived experimentally and are valid for the class of spherical nanoparticles utilized in the present work.

In the present work effective thermal conductivity of nanofluids is calculated by using the Hamilton crosser model. Where k_{eff} is the effective thermal conductivity of nanofluid and k_{BF} is the thermal conductivity of the base fluid and $n = 3$ for spherical nanoparticles (present case). The base fluid is taken as water. k_p is the thermal conductivity of the nanoparticles.

Similarly, C_{PNF} is the effective specific heat of nanofluid and C_{pBF} is the specific heat of base fluid, ρ_{BF} is the density of the base fluid and ρ_p represents the density of nanoparticles and C_{Pp} is specific heat of nanoparticles. The volume fraction is represented by φ.

Figure 5 shows the effect of Al_3O_3 concentration in the Al_2O_3-water nanofluids in the heat pipe operation after simulating the heat pipe for 5 s. It is observed from the graph that as the concentration increases from 1 to 5% of the nanoparticles the evaporator section which is from 0 to 0.2 m, 425 K is provided as the heating temperature. In the adiabatic region, this is from 0.2 to 0.3 m, temperature rise because of conduction from the evaporator section. Moreover, in the condenser section heat is released because of convection.

Figure 5 represents the effect of Al_2O_3 concentration in the Al_2O_3-water nanofluid in the heat pipe operation after simulating the heat pipe for 5 s. It is observed from the graph that as the concentration increases from 1 to 5% of the nanoparticles more temperature difference is seen because of the increase in thermal conductivity. In the evaporator section which is from 0 to 0.2 m, 425 K is provided as the heating temperature. In the adiabatic region which is from 0.2 to 0.3 m, temperature rise because of conduction from the evaporator section. Moreover, in the condenser section heat is released because of convection.

3 Results and Discussions

Figure 2 represents the variation of the liquid volume fraction with the evaporator, adiabatic and condenser section during 0, 10 and 20 s. It can be seen from the graph that at the initial state there is 0.5 volume fraction at the evaporator side. Similarly, the water volume fraction is zero at condenser and adiabatic section initially, which increases as the water starts evaporating because of heat temperature provided in the evaporator section.

Figure 3 represents the effect of CuO concentration in the CuO-water nanofluid in the heat pipe operation after simulating the heat pipe for 5 s. It is observed from the graph that as the concentration increases from 1 to 5% of the nanoparticles more temperature difference is seen because of increase in thermal conductivity. In the

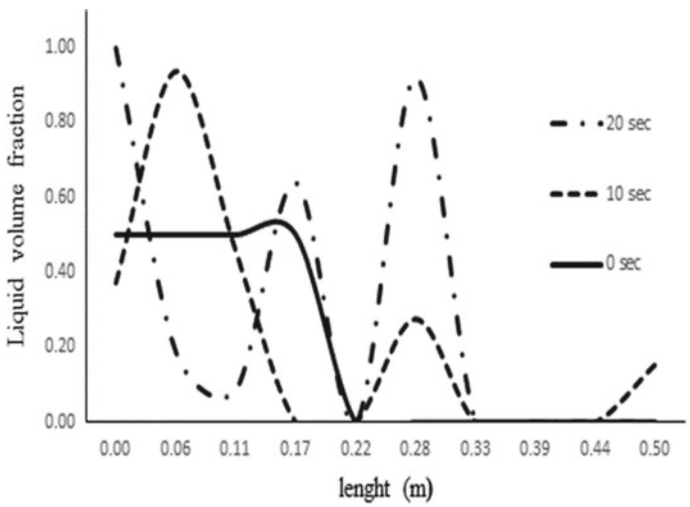

Fig. 2 Liquid volume fraction across various sections

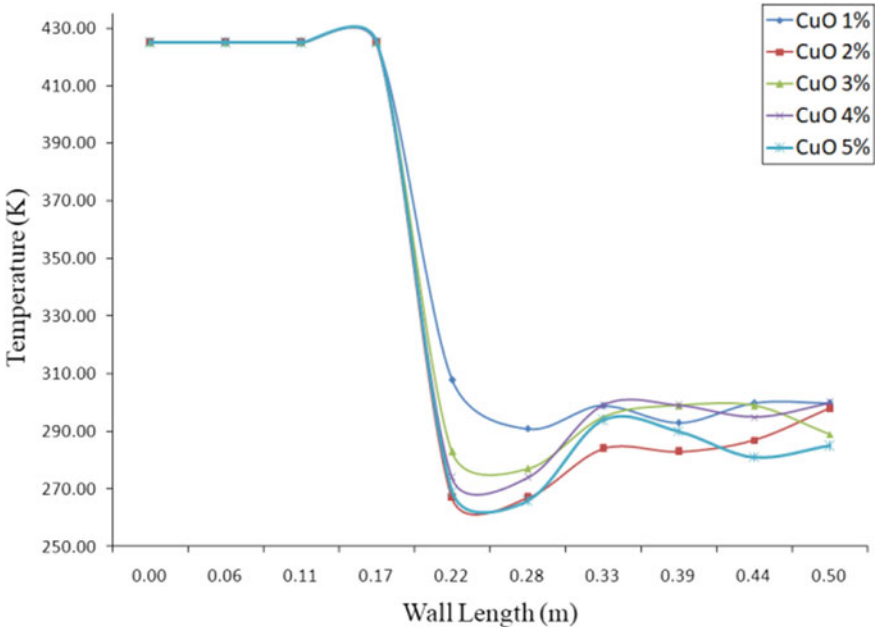

Fig. 3 Effect of CuO nanoparticles concentration on wall temperature

evaporator section which is from 0 to 0.2 m, 425 K is provided as the heating temperature. In the adiabatic region which is from 0.2 to 0.3 m, temperature rise because of conduction from the evaporator section. Moreover, in the condenser section which is from 0.3 to 0.5 m heat is released because of convection.

Figure 4 represents the effect of TiO_2 concentration in the TiO_2-water nanofluid in the heat pipe operation after simulating the heat pipe for 5 s. It is observed from the graph that as the concentration increases from 1 to 5% of the nanoparticles more temperature difference is seen because of increase in thermal conductivity. In the evaporator section which is from 0 to 0.2 m, 425 K is provided as the heating temperature. In the adiabatic region which is from 0.2 to 0.3 m, temperature rise because of conduction from the evaporator section. Moreover, in the condenser section which is from 0.3 to 0.5 m heat is released because of convection.

Figure 5 represents the effect of Al_2O_3 concentration in the Al_2O_3-water nanofluid in the heat pipe operation after simulating the heat pipe for 5 s. It is observed from the graph that as the concentration increases from 1 to 5% of the nanoparticles more temperature difference is seen because of increase in thermal conductivity. In the evaporator section which is from 0 to 0.2 m, 425 K is provided as the heating temperature. In the adiabatic region which is from 0.2 to 0.3 m, temperature rise because of conduction from the evaporator section. Moreover, in the condenser section heat is released because of convection.

Figure 6 represents the effect of SiC concentration in the SiC-water nanofluid in the heat pipe operation after simulating the heat pipe for 5 s. It is observed from the graph

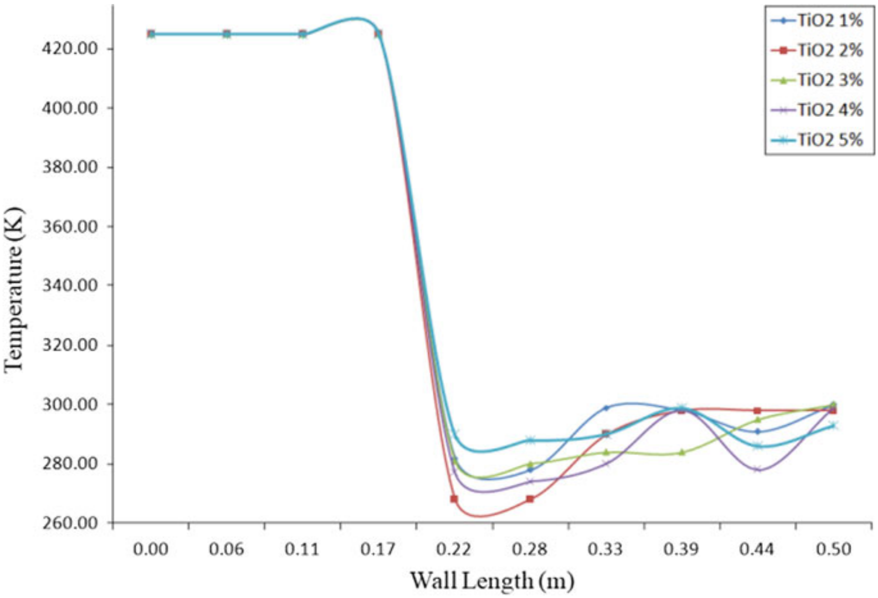

Fig. 4 Effect of TiO_2 nanoparticles concentration on wall temperature

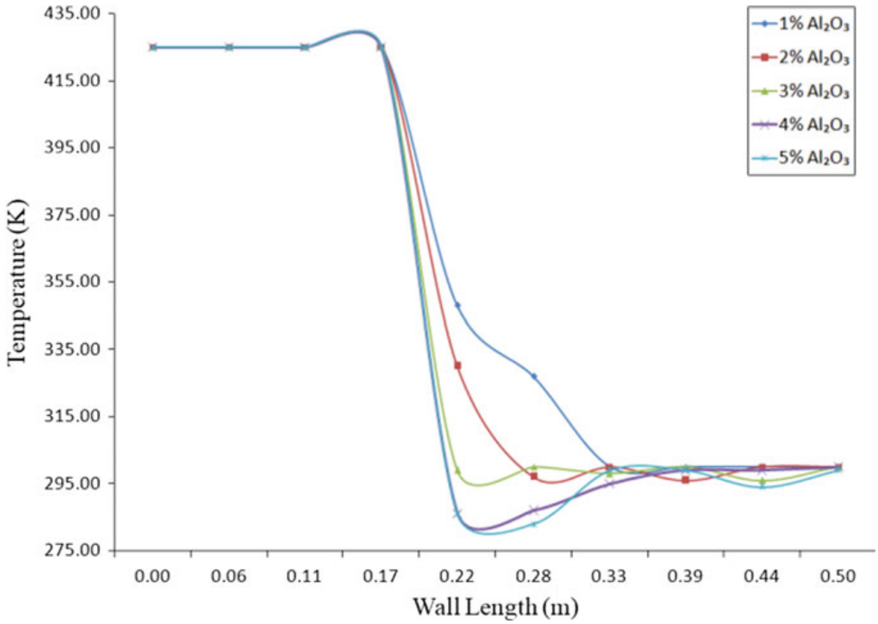

Fig. 5 Effect of Al_2O_3 nanoparticles concentration on wall temperature

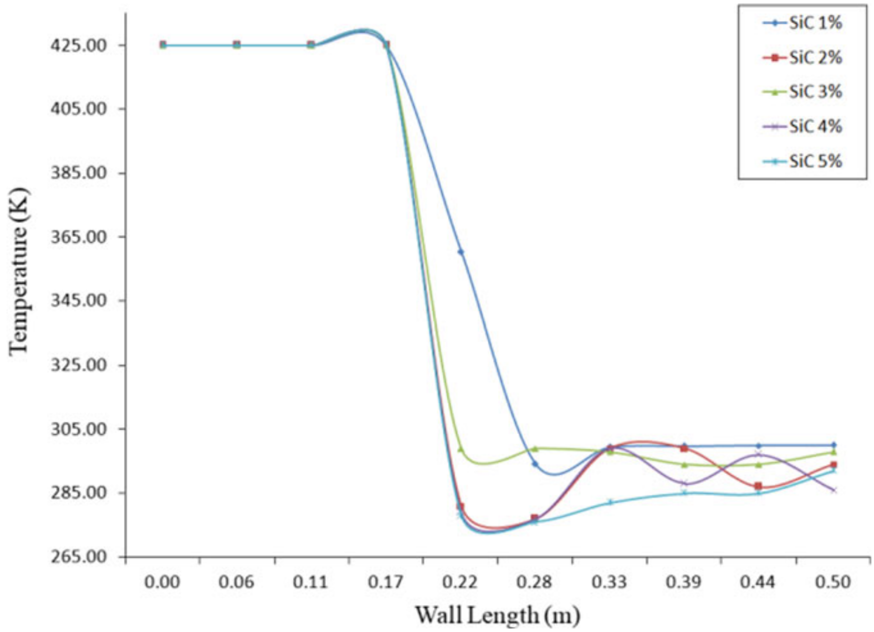

Fig. 6 Effect of SiC nanoparticles concentration on wall temperature

that as the concentration increases from 1 to 5% of the nanoparticles more temperature difference is seen because of increase in thermal conductivity. In the evaporator section which is from 0 to 0.2 m, 425 K is provided as the heating temperature. In the adiabatic region which is from 0.2 to 0.3 m, temperature rise because of conduction from the evaporator section. Moreover, in the condenser section which is from 0.3 to 0.5 m heat is released because of convection.

Figure 7 represents the effect of all the nanoparticles used in this work with concentration of 5% in water-based nanofluid in the heat pipe operation after simulating the heat pipe for 5 s. It is observed from the graph that CuO with 5% concentration has more temperature drop, which results in more condensation of the vapours in the condenser section. Because of this condensation more heat transfer takes place and higher thermal performance was observed.

4 Conclusions

The present analysis involved the study of thermal characteristics of wickless heat pipe using CFD. The results affirm that the incorporation of nanoparticles in water for thermal devices (heat pipe) enhances the heat transfer characteristics. Moreover, the conclusions drawn from the obtained results are as follows.

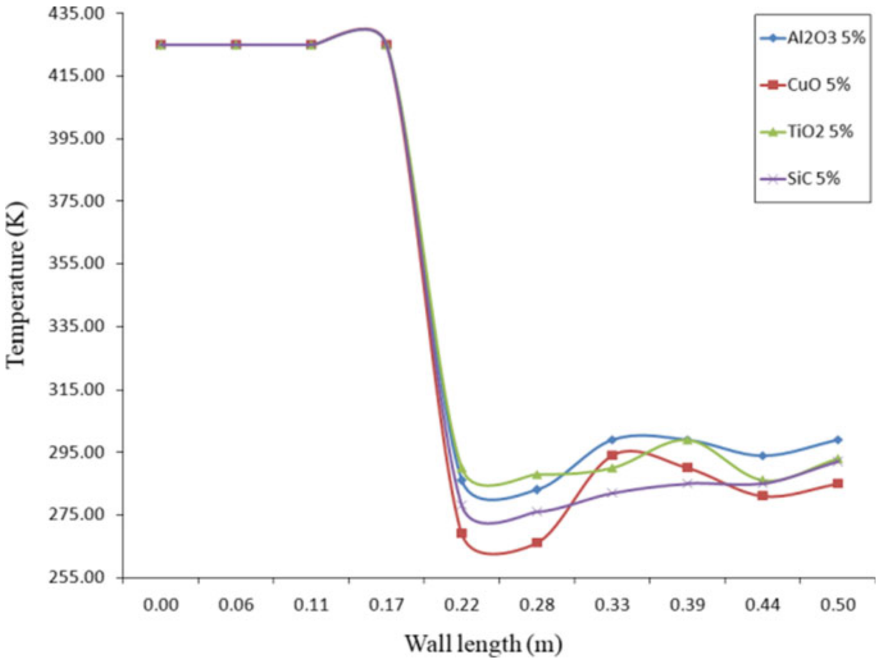

Fig. 7 Effect of different nanoparticles with 5% concentration on wall temperature

- The increase in concentration of nanoparticles ranging from 1 to 5% decreases the average temperature at the evaporator section, while an increase in average temperature is observed at the condenser section, implying the enhancement of heat extraction and cooling rate.
- For the nanoparticles used in the present work, no significant difference is observed at the wall of the evaporator section; however, at the condenser section, the highest average temperature is obtained for Al_2O_3, followed by TiO_2, CuO and SiC, respectively.
- Thermal characteristics are pronounced for 5% volume concentration of nanoparticles in water.

Hence, the present work demonstrates the use of nanoparticles that enhances the thermal dissipation and the CFD technique can effectively model the complex phase changing processes.

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Analysis of Barriers to Lean–Green Manufacturing System (LGMS): A Multi-criteria Decision-Making Approach

Rahul Sindhwani, Punj Lata Singh, Vipin Kaushik, Sumit Sharma, and Rakesh Kr. Phanden

1 Introduction

Operations management in the real sense aims at applying the concepts of business and management operations in the manufacturing of products. Management of Operations teams helps in processing and developing the methods of adaptation of inputs such as design, materials, and labor into outputs. One such strategy is Lean–Green Manufacturing System (LGMS). The idea of green and lean manufacturing is complementary to each other. Lean leads to reducing wastes whereas green leads to the use of less resources for production. Achieving lean manufacturing systems will automatically facilitate green manufacturing systems and vice versa. The benefits of combined lean and green can be obtained through LGMS.

The concept of Lean Manufacturing (LM) was first seen in Japan particularly in Toyota Production System. The concept of LM had gone under vigorous testing before it was implemented. LM means the system in which manufacturing is done without any waste. Wastes may occur in process, procedures and might also be hidden

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in policies and regulatory processes [40]. These wastes tie up cash and produce an undesired inventory, thus leading to certain unfavorable conditions. These resources can be used elsewhere in order to create some value-based operations and opportunities. The aim of LM is to eliminate the root cause of waste formation from the system and to extract the outputs at the cost of minimal possible inputs [3].

Green Manufacturing (GM) utilizes the concepts of reducing waste and reducing pollution toward the environment. It is a method that diverts our attention toward utilizing renewable energy resources and adopts the green methodology in choosing raw materials, processes, packaging, and logistics [33]. This method of manufacturing is gaining its importance day by day as the consumers are getting environmentally conscious. GM is the best resultant for conserving our resources and protecting the environment at the same time [7].

2 Literature Review

Congbo et al. [4] described GM is a type of current scenario manufacturing mode which mainly focusses on the resource optimization and environmental conservation. Reducing the emissions and the wastage of any kind is the ultimate goal to achieve in GM [44]. The relationship between green and lean manufacturing is debated earlier by researchers [13]. If we apply lean manufacturing initiative in organization, then most likely one thought comes in mind of environmental aspect, but [30] says that all processes of lean manufacturing are not positively related to green manufacturing concept.

The survey conducted by different researchers leads us to the findings that the firms adopting lean manufacturing produce a numerous kid of Volatile Organic Compounds (VOC) emissions which in turn is less in case of the firms which do not adopt lean manufacturing. Thus, this survey made us to think about a fact that these two systems can never be joined together [15]. So, there came a point of discussion for researchers to work on these shortcomings. The internal and external factors both work hand in hand to integrate the LM and GM [9].

3 Lean–Green Manufacturing Barriers

LM tends to reduce the wastage during manufacturing and GM tends to improve the environment by reducing the emission produced during manufacturing. So, both manufacturings are known as complementary to each other. The researchers globally tend to combine LGMS as a system of practices [30].

In this perspective, an effort has been made to recognize and examine the common barriers of LM and GM which are stopping to combine these two manufacturing systems. For measuring the barriers of LGMS, three main perspectives have been decided, i.e., Social Perspective (SP), Organizational Perspective (OP), and Governmental Perspective (GP). On the basis of three perspectives, these barriers will be ranked in Sect. 4. The following 08 barriers of LGMS are mentioned in Table 1 which was identified from the extant literature with the professionals from industry and academia.

Table 1 Barrier for Lean–Green Manufacturing Systems

No.	Barrier	References	Description
B1	Lack of Initial Investment	[6, 10, 11, 21, 22, 29]	It means to implement LGMS, high initial investment is required. Various green and lean technologies, designing, and setup costs are very high initially
B2	Lack of skilled worker	[5, 18, 19, 29, 35]	Workers in HR department of organization are less skilled workers
B3	Lack of Top Management Support	[8, 10, 14, 37, 41]	Top level management support is very essential for the implementation of LGMS
B4	Lack of Supplier Relationship	[12, 16, 36, 43]	In order to adopt "LGMS" and "clean" theory, organization needs to align the supplier toward them
B5	Lack of Resources Availability	[24, 32, 38, 42, 45, 46]	Limited technical resources, human resources, assets, money, *etc.* disturb the firms to implement new practices like Lean and Green Manufacturing system
B6	Opposition in Adoption of Technology	[11, 12, 23, 27, 34, 39]	Adoption of new technology according to the demand of customer is necessary for any organization. Opposition in it behaves like a barrier in implementation of LGMS
B7	Lack of Organizational structure	[12, 17, 20, 27, 28]	Organizational structure in any organization should be in flattened way rather than vertical way

4 Methodology

VIKOR method has been used for ranking the 07 barriers of LGMS. This method was introduced for solving decision-making problem with contradictory and no commensurable criteria [25]. It mainly deals with the favorable and the non-favorable ideal solution [26]. It is an effective MCDM tool, which is applied at such situations where the decision maker is in dilemma to assign the weightage or express the preferences at the commencement of any decision-making processes. The evaluation parameters of VIKOR method are easily understandable and provide an effective platform for specific calculations.

This approach has been magnificently used by several academicians and researchers in the fields of selection of suppliers [31], planning of land use [2], in deriving preference order of open pit mines [1], etc. The various steps, which lead to the development of model are illustrated below:

Step 1: Identify the barriers and evaluating criteria
Table 1 shows the 7 identified barriers to LGMS with description and 3 evaluation criteria viz. social perspective, organizational perspective, and governmental perspective.

Step 2: Rank all barriers with respect to all evaluating Criteria.
Table 2 shows the ranking of each barrier on Likert's scale 1–5, where 1 is for minimum effect and 5 is for maximum effect.

Step 3: Normalized all the data using equation

$$Xij = \frac{Xij}{\sum_{i=1}^{m} Xij} \ (j = 1,\ 2,\ 3 \ldots n) \quad \text{(i)}$$

Step 4: Calculate value of Ei, Fi, and Pi value by using the following Equation

$$\text{Ei} = \sum_{j=1}^{n} [(\text{Xij - Xijmin})/(\text{Xijmax - Xijmin})] \quad \text{(ii)}$$

$$\text{Fi} = \text{Maximum of} \left[(\text{Xij - Xijmin}) \big/ (\text{Xijmax - Xijmin})\right] (j = 1,\ 2 \ldots, n) \quad \text{(iii)}$$

$$\text{Pi} = \text{v}[(\text{Ei-Eimin})/(\text{Eimax - Eimin})] + (1 \text{ - v})[(\text{Fi - Fimin})/(\text{Fimax - Fimin})] \quad \text{(iv)}$$

As we assume VIKOR constant v = 0.5.

Table 2 presents the Ei, Fi, and Pi values for each barrier

Table 2 Application of VIKOR method

Barriers to LGMS	Ranking data			Normalized data			Ei	Fi	Pi
	SP	OP	GP	SP	OP	GP			
B1	2	3	2.5	0.26667	0.4	0.33333	1.499962	1	0.50002
B2	2	3.5	2.5	0.25	0.4375	0.3125	1.333333	1	0.3336
B3	3	2.5	4	0.31579	0.26316	0.42105	1.333333	1	0.3336
B4	2	4	2	0.25	0.5	0.25	1	1	0.00034
B5	3	4	4	0.27273	0.36364	0.36364	2	1	1
B6	3	3	4	0.33333	0.3333	0.4	0.99955	1	0
B7	1	3	1	0.2	0.6	0.2	1	1	0.0003

SP—Social Perspective
OP—Organizational Perspective
GP—Governmental Perspective

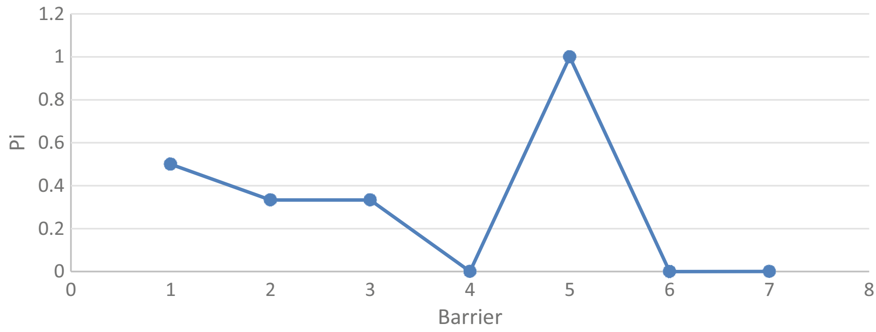

Fig. 1 Barrier Ranking

Step 5: Rank the Barriers using Pi values.

We plot the graph for ranking barriers from that we understand that how much one barrier is more effective than any other barrier in the recent scenario. The highest Pi value means more effectiveness and rank according to that (see Fig. 1).

5 Results and Conclusion

This research was oriented at identifying the barriers of LGMS with the help of thorough literature review and brainstorming with professionals from academia and industry. Barriers have been ranked with VIKOR method on the base of three perspectives, i.e., SP, OP, and GP. It found out that the two barriers had a huge amount of influence on the industrial application and adoption of LGMS.

Lack of initial investment and lack of resource availability were found out to be the two barriers which proved to be the major hindrance for implementation of LGMS. Requirement of huge initial capital and setup cost makes it very difficult for all the organizations to adopt this manufacturing system. Then the lack of finance and resources makes it very difficult for the sustainability of this combined approach. Hence, we need to work on these barriers in order to overcome them and adopt the efficient implementation of LGMS.

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Machine Learning Application for Pulsating Flow Through Aluminum Block

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1 Introduction

Heat exchange improvement is an imperative area of investigation because of its connection with heat dissemination issue from the workpiece. The fundamental point of the investigation in this field is to improve the heat exchange without expanding or reducing the facial zone. Due to enhancement in the electronic innovation, specialists need to allow extra capacities with diminishing the size of similar equipment. It can happen by placing a large density of chips on one plate. An upsurge in segment densities has the power dissipation prerequisite/issue of the component. Countless electronic disappointments are because of deficiency in temperature control. Effective evacuation of unnecessary heat is the critical necessity for trustworthy action of present-day electronics. Because of this reason, heat exchange improvement is a vital field of research from the most recent couple of decades [1, 2].

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An approach to take care of this issue is to raise the convective heat exchange by electronic device. In any case, scaling down of circuits significantly diminishes span of individual component. Hence, the course of action of numerous chips on a module is moving toward the circuit board. At the point when a chamber is set in the region of a barrier, the dynamic conduct and mean structure of wake fundamentally altered with the gap height, compared to a chamber in focal point of a channel [3, 4].

Other approach to tackle the current issue is to utilize heat exchange enhancement strategies. Numerous enhancement techniques have been distinguished which can be utilized to upgrade the heat exchange rate. Techniques can be assembled in two principle classifications like inert and Energetic/Forced approaches [5, 6]. Oscillating frequency is utilized to interrupt the flow. Current examinations are related to various fields [7–9].

Based on previous work, current research is used to assess the heat loss improvement from a heated square chamber by virtue of exciting flow. At last, the experimental outcome is evaluated using advance machine algorithm like support vector machine based on distinct kernel tricks. Some previous work has been reported based upon the use of support vector machine and advance algorithm in manufacturing and civil engineering [10–17]. A rare work is published on employing the support vector machine algorithm in thermal engineering [18].

2 Experimental Details

Various equipment is used for experimental setup, for example, temperature sensors, tunnel, axial fan, amplifier, heater, and anemometer.

During the investigation of various materials, aluminum is selected for current research work as shown in Fig. 1. The peculiarities of aluminum are shown in Table 1.

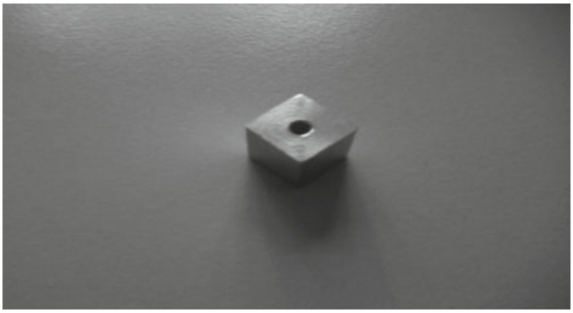

Fig. 1 Aluminum square workpiece

Table 1 Properties of aluminum

Density	Melting point	Boiling point	Thermal conductivity	Specific heat capacity
2.7 g/cm^3	660.32 °C	2519 °C	237 W/mk	24.2 J/mol.

Rectangular channel dimension is taken as 120 × 150 × 960 mm^3. Based on the measurement and work material, 24 W intensity heater is used. A circuit grid having four points is utilized for the woofer, fan, heater, and main. It has additionally RTD PT 100 thermocouples four in number with advanced presentation unit. An axial fan is utilized to supply the governed air to the workpiece. Woofer is utilized for the pulsating of stream. To gauge the stream speed, Anemometer of range 0.3–1.1 m/s is utilized.

2.1 Working Principle

The experimental setup diagram is shown in Fig. 2, individually. The examinations were begun by warming the heater and providing air inside the channel instead of oscillating flow. The thermally consistent condition is considered below at 0.10 C temperature for 10 min. Subsequent to achieving the stable condition, complete temperature information is noted. Further, the pulsating flow is forced by woofer. In the present tests, the pulsating frequency and velocity amplitude are changed and fixed from 0 to 60 Hz and 0.05. The flow velocity depending on time is estimated by hot wire anemometer amid the flow pulsating to decide the pulsating velocity amplitude and the Re number. Subsequently, attaining a consistent stage, temperature information is noted.

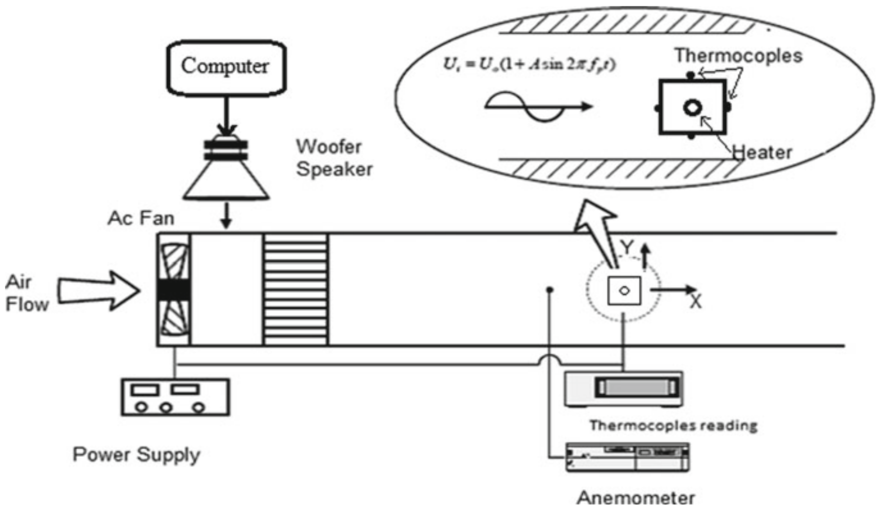

Fig. 2 Square cylinder placed in a rectangular channel

3 Results

3.1 Influence of Pulsation and RE Numbers on Temperature

Figure 3a demonstrates the change in outer temperatures of the work material at Re number 300. The temperature of various faces is diminished with an increment in the exciting frequency up to 30 Hz and after that, it starts to increase. The difference in temperature of faces is due to the different thickness of boundary layers. At Re 300 and 30 Hz frequency, the minimum temperature is recorded.

Figure 3b revealed the rapid decrement in temperature at exciting frequency 30 Hz in context of the previous case due to an increment in Reynolds number and the breakup of boundary layer. At Re 700 and 30 Hz frequency, the minimum temperature of 65.1 °C is recorded. Figure 3c revealed that, at Re 1100 and 30 Hz frequency, the minimum temperature of 64.3 °C is recorded. Figure 3d revealed that rate of temperature decline is large between Re 300–700 in comparison to the Re 700–1100. It demonstrates that more heat transfer takes place at low Re numbers.

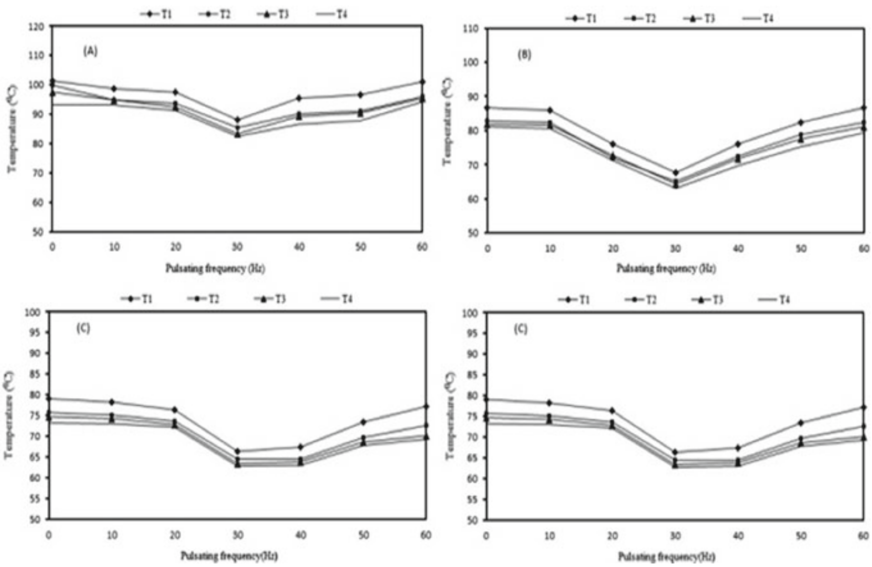

Fig. 3 Influence on external temperatures of work material at **a** Re 300 **b** Re 700 **c** Re 1100 **d** comparison

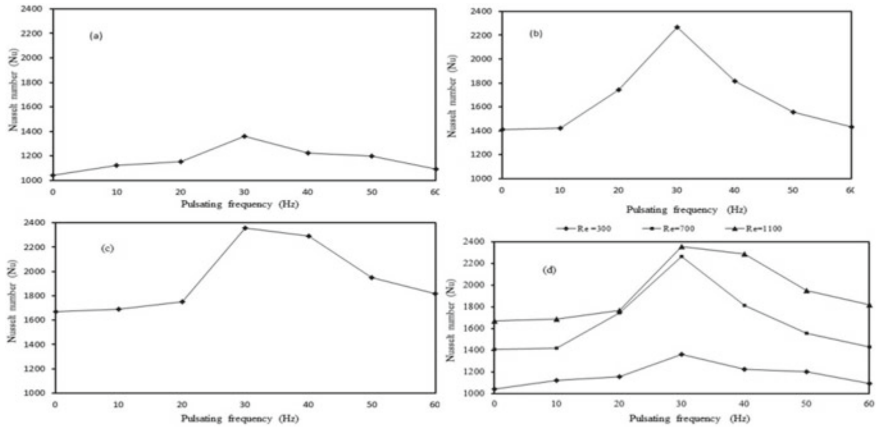

Fig. 4 Variations in Nusselt number at **a** Re 300 **b** Re 700 and **c** Re 1100 **d** comparison

3.2 Influence of Pulsation and Re Numbers on Nusselt Number

The gain in Nusselt number indicates the rise in convection heat transfer. Figure 4a reveals the change in Nusselt number at Re 300. Nusselt number 1361 is obtained with an upsurge in signal frequency up to 0 to 30 Hz and starts to decrease from 30 to 60 Hz. It demonstrates the gain in convective heat transfer due to oscillating flow.

Figure 4b revealed the sharp increment in Nusselt number for the same signal frequency due to upsurge in the value of Re number. The maximum Nusselt number 2267 is perceived at 30 Hz and Re 700. Figure 4c revealed that the same trends, and maximum Nusselt number 2355 is detected at 30 Hz frequency and Re 1100. Figure 4d revealed that more increase in convective heat transfer coefficient is achieved with an increase in Re 300–700 as compared to Re 700–1100.

3.3 Influence of Pulsation and RE Numbers on Enhancement Factor

Figures 5a revealed that highest enhancement factor1.28 is observed at 30 Hz signal frequency and Re 300. It indicates that more heat transfer takes place with pulsating flow. Figure 5b revealed that maximum enhancement factor 1.6 is observed at Re 1100 and 30 Hz frequency. The effectiveness of the process is increased with an increase in the enhancement factor. Figure 5c demonstrates that enhancement factor 1.4 is observed at 30 Hz frequency and Re 1100. Figure 5d revealed that high enhancement factor is observed in the range of 300–700 Re number in comparison to the Re number 700–1100.

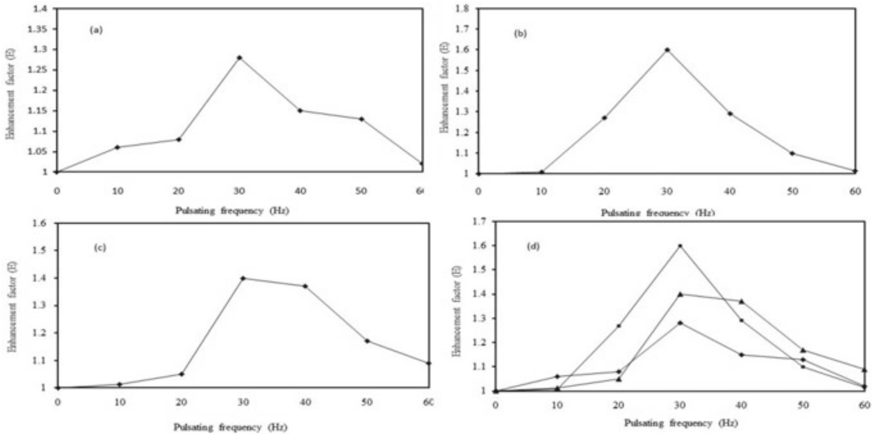

Fig. 5 Variations in enhancement factor at **a** Re 300 **b** Re 700 **c** Re 1100 **d** comparison

4 Support Vector Regression Modeling for the Temperature

This strategy was first proposed by Vapnik [19] and based on measurable learning hypothesis. Primary rule of SVM is ideal division of classes. From the detachable classes, SVM chooses the one which has least generalization error from infinite number of straight classifier or set maximum limit to error which is produced by minimization of structural risk. In this way, the greatest margin between two classes can be obtained from the chosen hyperplane and aggregate of separations of the hyper plane from the neighboring points of two classes will set the most noteworthy margin between two classes. Readers are asked to pursue the Smola [20] to get the comprehensive features of SVM. Cortes and Vapnik [21] proposed the concept of kernel function for nonlinear support vector regression.

The influence of distinct setting of Reynolds number and frequency on the workpiece temperature connected by four thermocouples at distinct place is evaluated using different kernels in SVM approach as shown in Eqs. (1–3). The 21, experiments have been performed which are repeated again to minimize the risk of error. Hence, total 42 experiments are performed. The complete data set is divided into training (50%) and testing (50%) set. The performance of each model is evaluated based upon the correlation coefficient (CC), root mean square value (RMSE), and root relative square error (RRSE). The predicted outcome of each model for training and testing sets of temperature T1, T2, T3, and T4 are given in Tables 2 and 3. The distinct kernel like normalized polynomial, radial basis function, and PUK kernels are used in SVM evaluation for temperature of the workpiece as shown in Eqs. (1–3) [16–18].

$$\text{Npoly} = K\left(X_i X_j\right) = \left\langle X_i, X_j\right\rangle / sqrt\left(\langle X_i, X_i\rangle\left\langle X_j, X_j\right\rangle\right) \tag{1}$$

Table 2 Predicted outcome of each model for training set of temperature of workpiece at four distinct places

Re	Fp (Hz)	T1 (C^0)	T2(C^0)	T3 (C^0)	T4 (C^0)	SVM Npoly T1	PUK T1	RBF T1	Npoly T2	PUK T2	RBF T2	Npoly T3	PUK T3	RBFT3	Npoly T4	PUK T4	RBFT4
300	0	101.5	99.8	97.4	93.1	101.487	101.47	84.739	99.747	99.011	81.139	97.388	97.337	79.764	93.08	93.04	77.846
300	20	97.8	93.9	92.2	91.6	97.787	95.313	84.665	93.851	90.857	81.065	92.188	91.039	79.692	91.573	90.454	77.781
300	40	95.2	90	89.6	86.8	97.787	93.936	84.587	93.851	89.236	80.987	92.188	88.976	79.617	91.573	86.797	77.712
300	60	101.1	96.1	95.4	94.1	97.787	101.073	84.506	93.851	96.053	80.906	92.188	95.357	79.537	91.573	92.634	77.639
700	10	85.9	82.7	81.4	80.8	76.003	83.353	82.256	72.408	79.298	78.656	71.225	79.514	77.352	69.926	78.027	75.639
700	30	67.9	65.4	64.7	63.3	76.92	71.738	82.177	72.382	68.348	78.577	70.091	68.738	77.275	69.373	67.08	75.569
700	50	82.1	78.5	77.2	75.5	82.1	82.162	82.1	77.426	78.496	78.5	74.957	77.195	77.2	74.434	75.553	75.5
1100	0	79.2	75.7	74.8	73.2	82.347	79.25	79.853	79.581	75.732	76.253	79.346	74.826	75.017	77.695	73.242	73.502
1100	20	76.7	73.8	72.5	72.1	76.003	73.942	79.769	72.408	71.217	76.169	71.225	70.761	74.935	69.926	69.544	73.427
1100	40	67.3	64.7	63.9	63.2	74.962	67.325	79.691	70.741	64.741	76.091	68.827	63.928	74.859	67.878	63.237	73.358
1100	60	77.4	72.4	70.1	69.4	76.92	77.416	79.62	72.382	72.415	76.02	70.091	70.158	74.79	69.373	69.41	73.295
300	10	98.8	95.2	94.7	93	97.787	98.841	84.703	93.851	95.217	81.103	92.188	94.726	79.729	91.573	93.023	77.814
300	30	88.1	85.3	83.1	82.7	97.787	92.98	84.627	93.851	88.328	81.027	92.188	88.43	79.655	91.573	87.2	77.747
300	50	96.8	89.8	90.5	88.1	97.787	97.235	84.547	93.851	92.38	80.947	92.188	91.854	79.577	91.573	89.231	77.676
700	0	87	82.8	81.8	81	82.347	87.046	82.296	79.581	82.813	78.696	79.346	81.806	77.39	77.695	81.053	75.674
700	20	75.7	72	73	71	74.962	75.716	82.217	70.741	72.031	78.617	68.827	73.021	77.313	67.878	71.057	75.604
700	40	75.8	72.5	71.7	70.2	79.607	75.748	82.139	74.954	72.433	78.539	72.516	71.641	77.237	71.927	70.156	75.534
700	60	86.7	82.2	81.1	79.5	84.181	86.638	82.062	79.53	82.231	78.462	77.079	81.037	77.163	76.589	79.456	75.466
1100	10	78.5	75.3	74.6	73.1	78.5	78.449	79.81	75.318	75.254	76.21	74.609	74.543	74.975	73.12	73.066	73.464
1100	30	66.3	64.6	63.2	62.8	74.917	67.385	79.729	70.968	65.051	76.129	69.374	64.684	74.896	68.262	63.875	73.392
1100	50	73.7	69.9	68.5	67.7	75.743	73.115	79.654	71.331	69.37	76.054	69.19	67.707	74.824	68.372	66.921	73.325

Table 3 Predicted outcome of each model for testing set of temperature of workpiece at four distinct places

Re	Fp (Hz)	T1 (C^0)	T2 (C^0)	T3 (C^0)	T4 (C^0)	SVM Npoly T1	PUK T1	RBF T1	Npoly T2	PUK T2	RBF T2	Npoly T3	PUK T3	RBFT3	Npoly T4	PUK T4	RBFT4
300	0	98.6	94.8	94.9	93.4	97.787	98.841	84.703	93.851	95.217	81.103	92.188	94.726	79.729	91.573	93.023	77.814
300	20	88.3	85.7	83.5	82.1	97.787	92.98	84.627	93.851	88.328	81.027	92.188	88.43	79.655	91.573	87.2	77.747
300	40	96.4	91.2	90.3	87.3	97.787	97.235	84.547	93.851	92.38	80.947	92.188	91.854	79.577	91.573	89.231	77.676
300	60	86.2	82.8	81.8	81	82.347	87.046	82.296	79.581	82.813	78.696	79.346	81.806	77.39	77.695	81.053	75.674
700	10	76.3	72.2	72.4	71.6	74.962	75.716	82.217	70.741	72.031	78.617	68.827	73.021	77.313	67.878	71.057	75.604
700	30	76.2	72.3	71.9	69.4	79.607	75.748	82.139	74.954	72.433	78.539	72.516	71.641	77.237	71.927	70.156	75.534
700	50	86.7	82.4	81.3	79.1	84.181	86.638	82.062	79.53	82.231	78.462	77.079	81.037	77.163	76.589	79.456	75.466
1100	0	78.1	75.1	74.2	73.1	78.5	78.449	79.81	75.318	75.254	76.21	74.609	74.543	74.975	73.12	73.066	73.464
1100	20	66.5	64.4	63.6	63	74.917	67.385	79.729	70.968	65.051	76.129	69.374	64.684	74.896	68.262	63.875	73.392
1100	40	73.1	69.7	68.7	68.1	75.743	73.115	79.654	71.331	69.37	76.054	69.19	67.707	74.824	68.372	66.921	73.325
1100	60	101.5	99.8	97.4	93.3	101.487	101.447	84.739	99.747	99.011	81.139	97.388	97.337	79.764	93.08	93.04	77.846
300	10	97.2	93.7	92.8	90.8	97.787	95.313	84.665	93.851	90.857	81.065	92.188	91.039	79.692	91.573	90.454	77.781
300	30	95.8	90.4	89.2	86.6	97.787	93.936	84.587	93.851	89.236	80.987	92.188	88.976	79.617	91.573	86.797	77.712
300	50	101.1	96.3	95.6	94.7	97.787	101.073	84.506	93.851	96.053	80.906	92.188	95.357	79.537	91.573	92.634	77.639
700	0	86.1	82.3	81.6	80.6	76.003	83.353	82.256	72.408	79.298	78.656	71.225	79.514	77.352	69.926	78.027	75.639
700	20	67.7	64.8	64.3	62.9	76.92	71.738	82.177	72.382	68.348	78.577	70.091	68.738	77.275	69.373	67.08	75.569
700	40	82.9	79.1	77.8	74.9	82.1	82.162	82.1	77.426	78.496	78.5	74.957	77.195	77.2	74.434	75.553	75.5
700	60	79.2	75.7	74.8	73.2	82.347	79.25	79.853	79.581	75.732	76.253	79.346	74.826	75.017	77.695	73.242	73.502
1100	10	76.3	73.4	73.1	72.3	76.003	73.942	79.769	72.408	71.217	76.169	71.225	70.761	74.935	69.926	69.544	73.427
1100	30	67.8	64.5	63.7	63	74.962	67.325	79.691	70.741	64.741	76.091	68.827	63.928	74.859	67.878	63.237	73.358
1100	50	77.2	73	70.3	69.2	76.92	77.416	79.62	72.382	72.415	76.02	70.091	70.158	74.79	69.373	69.41	73.295

where

$$< X_i, X_j > = \text{PolyKernel} = K(X_i, X_j) = ((X_i.X_j) + 1)^{d^*}$$

$$\text{RBF} = K\left(X_i, X_j^{'}\right) = \exp\left(-\frac{\left|X_j - X_i\right|^2}{2\sigma^2}\right) = \exp\left(\gamma\left|X_j - X_i\right|^2\right) \quad (2)$$

$$\text{PUK} = K\left(x_i x_j\right) = \frac{1}{\left[1 + \left(\frac{2\sqrt{x_i - x_j^2}\sqrt{2^{\frac{1}{\omega}} - 1}}{\sigma}\right)^2\right]^{\omega}} \quad (3)$$

4.1 Performance Appraisal of Distinct Models for Temperature T1, T2, T3, and T4

Three distinct models have been formulated using SVM approach based on different kernels. The scattering validation and error plot for the training and testing outcome of each model have been plotted for temperature T1 as shown in Fig. 6. The scattering plot for training and testing outcome of each model shows the dominancy of SVM model based on PUK Kernel against the SVM based on Npoly kernel and RBF kernel models. The SVM PUK kernel point is scattering more closely than others model to the agreement line as shown in Fig. 6.

The validation and error plot also purse the same behavior. The validation plot also indicates that SVM PUK line travels the approximate same path with actual line as shown in Fig. 6. The error plot also revealed that SVM PUK kernel model has the

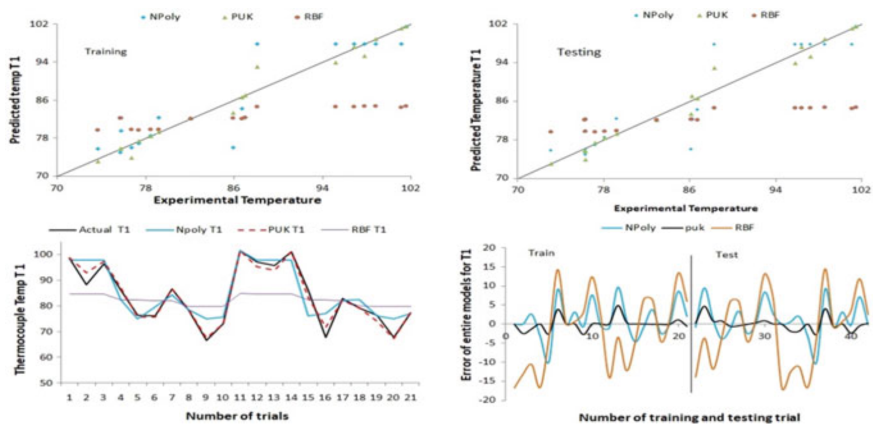

Fig. 6 Dominancy of SVM based on PUK model against the other models for temperature T1

least error against the other model as shown in Fig. 6. Therefore, the SVM based on PUK kernel proves its dominancy over the other models. The performance variables data also prove the significance of SVM based on PUK kernel over the other models as presented in Table 4. The highest value of correlation coefficient (CC) and least value of RMSE and RRSE also backed the dominancy of SVM based on PUK kernel model over entire models.

Similarly, the dominancy of SVM PUK kernel model against the other models is proved by scattering, validation, and error plot for each model for the temperature T2, T3, and T4. It has been observed that SVM PUK kernel presents better results against the other models for workpiece temperature T2, T3, and T4 as shown in Figs. 7, 8 and 9.

The Table 4 also revealed that the SVM PUK kernel model has the highest value for CC and least value for RMSE and RRSE against the other models for workpiece temperature T2, T3, and T4.

Table 4 Performance variables outcome of each model

Temperature						
	Training set			Testing set		
Model	CC	RMSE	RRSE	CC	RMSE	RRSE
SVM Npoly	0.9077	4.7989	43.2908	0.9097	4.7279	42.8972
PUK	0.9879	1.7205	15.5205	0.9878	1.7197	15.603
RBF	0.8457	9.5907	86.5177	0.8529	9.5091	86.2787
Temperature T2						
SVM Npoly	0.9191	4.2999	40.5188	0.9224	4.2507	39.5517 0.718
PUK	0.9886	1.5995	15.0722	0.9907	1.4857	13.8243 0.657
RBF	0.8499	9.1075	85.8214	0.8514	9.2442	86.0136 0.664
Temperature T3						
SVM Npoly	0.9185	4.2079	39.7712	0.9175	4.2419	39.9413
PUK	0.988	1.6577	15.668	0.9868	1.7281	16.2714
RBF	0.8611	9.1491	86.4731	0.8577	9.2128	86.7474
Temperature T4						
SVM Npoly	0.9106	4.2956	42.3515	0.9044	4.4585	43.9343
PUK	0.9872	1.6225	15.9968	0.984	1.8224	17.9576
RBF	0.8552	8.9352	88.0946	0.846	8.9293	87.9895

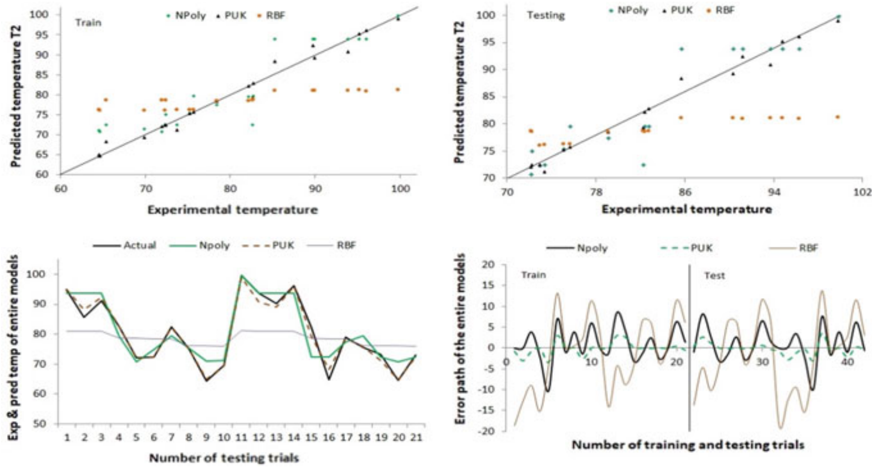

Fig. 7 Dominancy of SVM based on PUK model against the other models for temperature T2

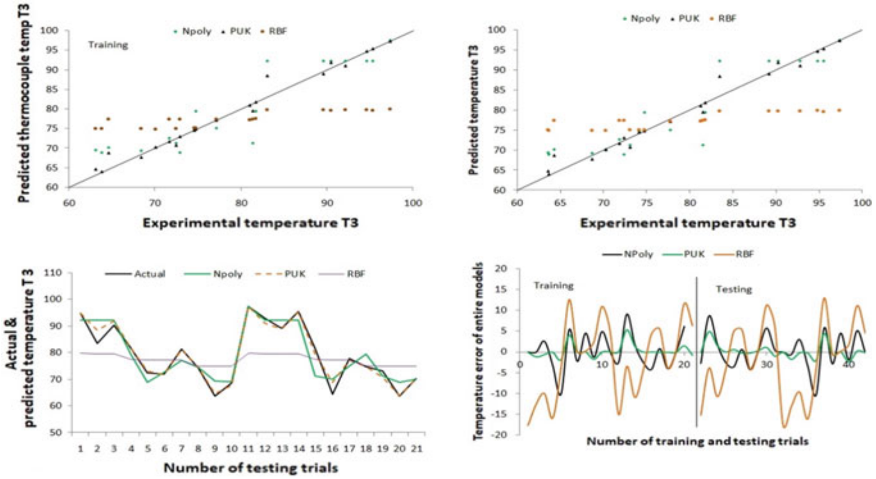

Fig. 8 Dominancy of SVM based on PUK model against the other models for temperature T3

5 Conclusions

The current research work is accomplished to examine the heat dissipation from a heated square cylinder in pulsating flow. The influence of oscillating frequency and RE number based on heat transfer enhancement is observed. The SVM approach based on distinct kernels is used to evaluate the workpiece temperature. Finally, the following outcomes are obtained:

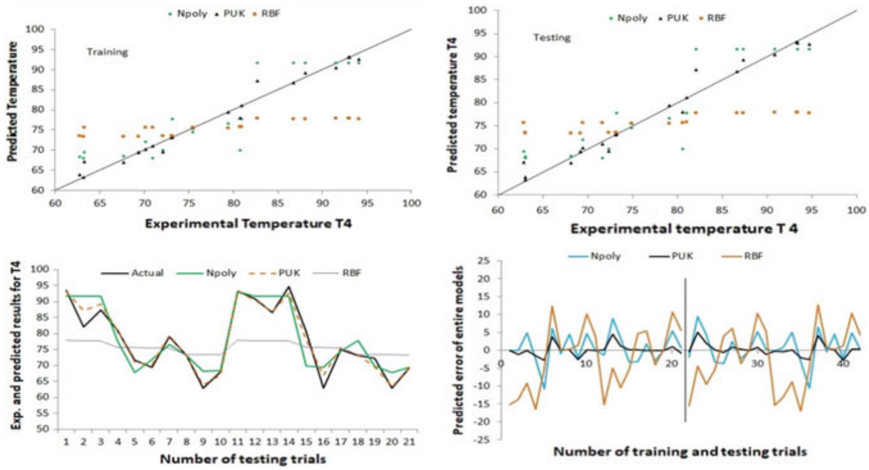

Fig. 9 Dominancy of SVM based on PUK model against the other models for temperature T4

- With the increase in RE number, the Heat transfer also increases.
- The difference in the temperatures at four distinct places is due to the creation of boundary layer and vortex behind the object.
- The increase in the signal frequency up to 30 Hz concludes the gain in Nusselt number and the Enhancement factor. Further enhancement in frequency from 30 to 60 Hz leads to decrease in Nusselt number and the Enhancement factor.
- "Lock-on regime" is observed where considerable growth in heat transfer takes place.
- All the models present the significant prediction results for the workpiece temperature T1, T2, T3, and T4.
- SVM PUK kernel model is the most dominate model.
- The decreasing order of the significant model is given as SVM PUK > SVM NPoly > SVM RBF.

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Ranking of Factors for Integrated Lean, Green and Agile Manufacturing for Indian Manufacturing SMEs

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1 Introduction

Considering advantage of industrial globalization across the world and competitive environment, we need to adopt new strategies that enhance manufacturing system by focusing on sustainability. The approach toward sustainable manufacturing practice and outcomes has impacted business organization to refine their environmental interpretation and efficiency. Economic aspect, ecological stability, and societal obligation are the three dominating bases which are unavoidable for attaining sustainability [1]. To assure poise development of society, there should be a congruous interaction between these parameters. The conjoint access to these dimensions is concluded as 'Tripartite Base Line' [2]. In the yesteryear these parameters have been considered separately, that's why the need to individually study the concepts of lean manufacturing, agile manufacturing or green manufacturing arises. Presently, in this era, it is

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essential to consolidate the concepts of lean manufacturing, agile manufacturing as well as green manufacturing to form a common platform [3].

The lean manufacturing, which helps to reduce waste in manufacturing system, also helps to reduce lead time, manufacturing space and some defects [4]; hence it improves the effectiveness of manufacturing system by acting at system level and reduces the cost of manufacturing.

Owing to modernization, there are a lot of environmental challenges, viz., emission, depletion of natural resources, and global warming. So it is necessary to adopt measures to protect the natural environment. GM provides a sustainable environment to society by minimizing waste and harnessing activity [5–8].

Agile manufacturing strategy provides flexibility in manufacturing system to satisfy the customer by fulfilling their demand and acting at the product level. Since many years, researchers were trying to explore LGAMS connectivity, to obtain efficient, economical, sociological and environmentally friendly manufacturing. To adopt LGAMS we need to obtain the parameter that hinders the faster execution of LGAMS. From comprehensive surveys, suggestions, and criticisms from academia and industrial profession, nine factors have been investigated for LGAMS. These factors are the basis which can be seen very useful in the establishment of LGAMS.

The remaining paper contains literature review, methodology section followed by results and discussion, and lastly the conclusion derived after a thorough analysis accompanied by acknowledgment along with references.

2 Literature Review

This part depicts an exploration of coeval literature of lean, green and agile manufacturing and united LGAMS. Moreover, effective implementation of such paradigms is carried out by containing and eliminating factors.

2.1 Lean Manufacturing

The emphasis of lean manufacturing relies on the reduction of different types of waste which ultimately will improve the production quality by reducing real time. Lean manufacturing is described as unified manufacturing system aimed at improving and maximizing effective utilization of available resource without the addition of cost in it and with the help of various techniques. It also reduces better inventories [9]. Lean manufacturing requires plenty of approaches which help this structure in implementation and also equip with aid system [10]. Lean manufacturing almost covers everything from product buildout to products distribution [11].

However, the foremost step to practice lean manufacturing is already taken, but on account of insufficiency of working capital, poor level of skill management, inadequacy of effective and relevant technological tools, and insufficient training, the rate of adaptation is slow. In addition, Reference [12] affirms the obtained results by reporting the adoption of novel techniques, with regard to increased competitiveness in the market by Indian manufacturing industries. The present situation of India in lean area of manufacturing is still in nascent stages and a lot is required to be done for taking an advance step [13]. Because of paucity of financial resources, the diffusion level of LM, as far as Indian machine tool sector is concerned, is still ranging from 'medium to low'. A report written by Mathur et al. [14] on an SME engaged in manufacturing of springs in India revealed that effectuation of LM is not fruitful from SMEs. In sectors like quality and that of process including process technology, Indian industries are performing very poorly reported by [15]. Moreover, Kumar et al. [16] stated that lean manufacturing practices area not easy to execute because of various aspects like absence of top managerial hands, absence of expert training and paucity of funds. In short, there doesn't exist any shortcut which provides a way for LM implementation in a successful manner. Hence, in this regard, it becomes indispensable that factors paving a way for effective lean decisions should be identified [7].

2.2 Green Manufacturing

The fast rate of exhausting and evacuating earth resources, increasing demand for energy, and enhanced awareness of customers regarding environmental factors demand expansion of green manufacturing exemplary. It mandates minimal impact of manufacturing on the environment and guarantees improved pollution control, decrement of employability of earth resources and building an image of green brand. As reported by a survey, execution of GM in SME can increase market share, competitive advantage and green brand image [17]. Luthra et al. [18] established green supply chain management (GSCM) operation with a poor fragment of assumption as far as a majority of Indian manufacturing industries are concerned and was given such a GSCM ranking so as to safeguard the improvements in environmental and economic sectors. However, many researchers demanded effective steps with regard to GM in the context of India because the current situation doesn't sound very positive [19, 20]. The aforementioned examination indicates that implementation of GM leads to an overall effective performance development and also maintained the need of strong efforts that are required to motivate SMEs to adopt GM strategies (Table 2).

2.3 Agile Manufacturing

Agile manufacturing enactment in any organization requires skills, understanding and affirmation from management and employees [21]. An organization couldn't obtain agility with the absence of all these factors [22]. The main goal of agile is individual customer satisfaction. The main aim is to integrate our organization, people and technology into a group. Agile manufacturing can be elucidated as the ability to sustain and flourish in an ambitious nature of continuous and uncertain change by responding rapidly and effectually to reforming markets, driven by customer-designed products and services [23].

2.4 Integrated Lean, Green and Agile Manufacturing

The above section shows the individual factors affecting lean, green and agile manufacturing. Now we integrate all the lean, green and agile manufacturing and find out the common factors affecting LGAMS. With the increment in customers' desires and environmental factors, it is necessary to hold newer manufacturing technology to compete against the manufacturer across the globe. Mainly, there are parameters that pertain to manufacturing systems of the modern world, viz., economic, social and environmental. To get an all-inclusive and such a manufacturing system which is most comprehensive, the present requirement demands consolidation of lean–green–agile manufacturing strategies (Table 4).

3 Research Methodology

Focusing on global market competition, industries experts have to continually renovate the manufacturing system. Hence there is a need to scrutinize various current tools and techniques of manufacturing. For the same, the decision maker must recognize sundry criteria along with better alternatives while making decisions for obtaining effective advancement in manufacturing sector. However, to make this job easy multi-criteria decision-making (MCDM) technique is used to take a decision. Weighted sum model (WSM), weighted product model (WPM), analytical hierarchy process (AHP), elimination and choice translating reality (ELECTRE), a technique for order preference by similarity to ideal solution (TOPSSIS), entropy method and so on are often used in conjunction with methods like MCDM for various purposes, thereby putting decision maker in a perplex situation to select suitable procedure [24, 25]. In the present work, entropy methodology is used to calculate the weight of the various criteria and VIKOR is used to make raking of a factor. Before discussion and application of this technique, here nine factors are obtained through various reviews of literature and discussions with experts in academia and industry, to analyze the factors affecting LGAMS. The description of nine factors is mentioned as follows:

- Leadership and Management (F1)
- Organizational Culture (F2)
- Technical Expertise and Skills (F3)
- Information Technology Integration (F4)
- Simplification and Standardization (F5)

- Product Lifecycle Management (F6)
- Innovation (F7)
- Empowered Worker (F8)
- Customer Feedback (F9)

Table 5 presents the six criteria which are divided into beneficial and non-beneficial for study in accordance to the factors affecting LGMAS implementation.

3.1 Entropy Approach

For the quantification of manufacturing flexibility, ENTROPY method is being used for evaluation. Entropy originates from the thermodynamic system and it is discovered by Shannon [26]. As the information entropy decreases, the weight of particular criteria is increased [27]. Entropy approach is very convenient in determining the significance of individual criterion which provides data and then handed to the decision maker [28, 29]. It is very advantageous as compared to another MCDM process as it is easy to understand and can be easily calculated with less mathematical error.

This technique is being used extensively. Different steps used in entropy weight assignment method are preferred by [30–32] and are described in the following:

Step 1: Normalizing of a matrix

There are following ratios which are frequently used to normalize avail ratio: Total ratio, Stopp ratio, Weitendorf ratio, Schärlig ratio, Körth ratio, Jüttler ratio and so on. For present calculation, we use total ratio. Equation for total ratio is:

$$\mathrm{Xij} = (\mathrm{j} = 1, 2, 3 \ldots..\mathrm{n}) \tag{1}$$

By using Eq. 1, normalized data of Table 1 is calculated and is shown in Table 6.

Step 2: Calculation of Nj value for each criterion

Equation for Nj value is

$$\mathrm{Nj} = -\mathrm{k} \sum_{i=1}^{n} xij * \ln(xij) \quad j = 1, 2 \ldots m \tag{2}$$

where

$$k = \frac{1}{\ln(n)} \tag{3}$$

Table 7 shows the calculated Nj value using Eq. 2.

Step 3: Weight for each criteria

Calculation of weight for ‘j’ criteria using Eq. 4 is shown in Table 3

Table 1 Factors affecting lean manufacturing

S. no.	Factors	Significance	References
01.	Leadership and management	For successful implementation of lean manufacturing, top management and leadership play a vital role. Having a poor and weak management would not lead to success	Saad et al. [33], Jeyaraman and Teo [34], Coronado and Antony [35]
02.	Communication	Effective and regular communications made guideline available to employees and retain the impetus in implementing lean toward regular upgrading efforts	Banuelas et al. [36]
03.	Financial capability	Needs significant investment, training material, resources	Saad et al. [33]
04.	Skills and expertise	Ensure company growth, success	Jeyaraman and Teo [34]
05.	Organizational culture	Changing employee's behavior, emotion, nature and political process that resemble lean culture	Banuelas et al. [36], Saad et al. [33], Hajmohammad et al. [37]
07.	Work standardization	This boosts the production rate and also the safety of the employees	Singh et al. [7], Panizzolo et al. [38]
08.	Employee empowerment	Need of such managers whose goal is to empower the employees with regard to decision making, thereby boosting their morale	Singh et al. [7], Dora et al. [22], Bakås et al. [39]
09.	Organizational culture	Positive supportive working environment	Singh et al. [7], Bakås et al. [39], Saad et al. [33]

$$\mathrm{Wj} = \frac{1 - N_j}{\sum_{j=1}^{n} \left(1 - N_j\right)} \quad \text{where } \mathrm{j} = 1, \ldots, \mathrm{n}. \tag{4}$$

3.2 VIKOR Analysis

The VIKOR method was coined by Serafim Opricovic in the year 1998 for solving problems related to multi-criteria optimization along with compromise solution [73]. Later on, it was modified by Opricovic and Tzeng in 2000. This method provides a multi-criteria ranking on the basis of approximation to the ideal solution [74]. This method is used to solve decision problem with clashing criteria provided that settlement is acceptable for conflict resolution. It provides solution near and closest

Table 2 Factors related to green manufacturing

S. no.	Factors	Significance	References
01	Leadership and management	Cooperate with the department to adopt green practices	Mittal et al. [40]
02	Information and technology Integration	Collects data regarding emission, hazardous substances	Sangwan and Mittal [41], Singh et al. [8]
03	Simplification and standardization	Define criteria for environment management system	Mohanty et al. [42]
04	Product lifecycle management	Facilitate sustainable development	Sangwan and Mittal [41]
05	Empowered employee	The employee should have some power to take a decision	Meyerson and Kline [43], Walton et al. [44]
06	Customer feedback system	Welcome customer's suggestion about green concept	Toke [45], Mittal et al. [40]
07	Green band image	Environmental respective image in the view of society CSR	Mittal and Sangwan [46], Bey et al. [47], Singh [8], Luken and Rompaey [6], Studer et al. [48], Arya and Zhang [49]
08	Customer focus	Close contact with customer giving feedback on quality, cost and delivery	Sangwan et al. [7], Mittal et al. [40], Dashore and Sohani [50]
09	Cost saving	Decrease in energy and resource consumption	Mittal and Sangwan [46], Ghazilla et al. [5], Mittal and Sangwan [51], Mittal et al. [46, 52], Walker et al. [53], Studer et al. [48]

value to the ideal solution. This idea of a compromise solution was introduced in MCDM by Lung Yu in 1973 and Milan Zeleny. This method is used to obtain the best solution from the set of feasible alternatives. This method is preferred by research just the way tools like green supply chain management, machine tool selection, project outsourcing and so on.

The first step is to normalize which is already been done earlier, and the subsequent steps are mentioned as follows:

Step 1: Calculation of difference between the ith *factors to obtain the positive ideal solution (F_i value). For beneficial criteria:*

$$F_i = \sum_{j=1}^{n} W_j \frac{X_{ij}\max - X_{ij}}{X_{ij}\max - X_{ij}\min} \tag{5}$$

For non-beneficial criteria:

Table 3 Factors for agile manufacturing

S. no	Factors	Significance	References
1	Organizational structure	Good organizational structure plays an important role in successful implementation of AIMS	Sindhwani and Malhotra [54]
2	Information and technology integration	Ability to produce product with minimum use of natural resources	Gunasekaran et al. [55, 56], Pan and Nagi [57]
3	Multi-lingual	They have many qualities like multi-functional, self-motivated	Gunasekaran [58], Sindhwani et al. [59]
4	Empowered worker	Knowledgeable worker can enhance growth of agile manufacturing	Gunasekaran [58], Speredelozzi et al. [60, 61]
5	Innovation	Developed framework on the basis of mathematical model to achieve agility	Gunasekaran et al. [55], McLendon et al. [62]
6	Product lifecycle management	Collect information over its entire cycle of product	Sindhwani and Malhotra [63, 64]
7	Leadership and management	It facilitates for building internal association	Pan and Nagi [56], Mishra and Mishra [65], Sindhwani and Malhotra [66]
8	Outsourcing	Adopt some technology and process from third parties if not available	Abdollahi et al. [67], Sindhwani and Malhotra [63, 64], Sindhwani et al. [68]
9	Agile workforce	Skill to produce the products with optimize use of resources and to decrease process lead time and cost	Pan and Negi [56], Gunasekran et al. [55], Sindhwani and Malhotra [63, 64]

$$F_i = \sum_{j=1}^{n} W_j \frac{X_{ij-}X_{ij}\text{min}}{X_{ij}\text{max} - X_{ij}\text{min}} \tag{6}$$

The calculated value of F_i using Eqs. 5 and 6 for each factor is shown in Table 6.
Step 2: Calculation of the negative ideal solution (H_i value)
For beneficial criteria:

$$H_i = \text{maximum of } \frac{W_j\left(X_{ij}\text{max} - X_{ij}\right)}{X_{ij}\text{max} - X_{ij}\text{min}} (\text{i} = 1, 2 \ldots.., \text{n}) \tag{7}$$

For non-beneficial criteria:

Table 4 Common factors affecting LGAMS

S. no.	Factor affecting LGAMS	Description	Reference
1.	Leadership and management	To implement LGA manufacturing in any industries, cooperation of top management is essential along with leadership	Saad et al. [33], Jeyaraman and Teo [34], Mishra and Mishra [65]
2.	Organizational culture	Obtaining better job satisfaction and professional development requires more teamwork, less bureaucracy, better communication.	Saad et al. [33]
3.	High technical expertise and skill	Technical expertise is required to implement LGA manufacturing and to ensure company success and growth	Sindhwani and Malhotra [69, 70]
4.	Information technology integration	For the success of LGA manufacturing, there is a requirement of accurate information, demand, material status, and product and process quality on a regular basis. If the software and software support system works at a good pace, it will be more beneficial	Mittal et al. [40], Sindhwani et al. [71]
5.	Simplification and standardization	Standardization helps to reduce production inefficiency by eliminating unwanted inventories and worker that would lower cost relating to production Simplification means the movement of work should be in right machine (person) in an appropriate way at the proper time	Mohanty et al. [42]
6.	Product lifecycle management	PLM means keeping the record of the product till its expiry. It is a method that helps industries to obtain its commercial goal of decreasing cost and enhancing quality and reducing time to market while making new products, services and business operation	Sindhwani and Malhotra [63, 64]
7.	Innovation	It is one of the basic methods of growth strategies for any new manufacturing system. It is not the only concern about the product but also related to marketing and organization	Young et al. [72], Choi and Li [1]

(continued)

Table 4 (continued)

S. no.	Factor affecting LGAMS	Description	Reference
8.	Empowered worker	With the help of learned workers such as computer operator, maintenance engineers and draftsman, design engineers can identify the root cause of problems and also we can, during production, avoid any loss to environment and society	Meyerson and Kline [43]
9.	Customer feedback	There are various stages of evolution; one of them is customer feedback. It initiates with simple data collection and ends with customer-driven, company-wide and continuous improvement process	Mittal et al. [40]

Table 5 Data collection

	Criterion		Favorable		Non-favorable	
Factors	C1	C2	C3	C4	C5	C6
F1	8	6	8	7	7	5
F2	9	7	5	6	7	6
F3	8	6	8	6	5	6
F4	7	7	7	5	7	4
F5	8	4	6	6	5	6
F6	6	9	6	6	8	8
F7	7	9	9	8	4	5
F8	9	7	6	7	6	5
F9	9	7	9	7	5	5

C1—Output (productivity) enhancement; C2—Emission retrenchment; C3—Customer fulfillment; C4—Monetary concern; C5—Resource concern; C6—Regulatory concern

$$H_i = maximum\ of\ \frac{W_j\left(X_{ij} - X_{ij}\mathrm{min}\right)}{g_{ij}\mathrm{max} - X_{ij}\mathrm{min}} (\mathrm{i} = 1, 2 \ldots\ldots \mathrm{n}) \quad (8)$$

Table 6 shows the calculated value of H_i using Eqs. 7 and 8 for all factors.

Step 3: Calculation of P_i value

$$P_i = v\left[\frac{E_i - E_{imin}}{E_{imax} - E_{imin}}\right] + (1 - \mathrm{v})\left[\frac{F_i - F_{imin}}{F_{imax} - F_{imin}}\right]$$

Table 6 Criteria weight calculation using entropy approach

Normalized matrix						
	C1	C2	C3	C4	C5	C6
F1	0.1126	0.0967	0.1250	0.1206	0.1206	0.0862
F2	0.1267	0.1129	0.0781	0.1034	0.1206	0.1034
F3	0.1126	0.0967	0.1250	0.1034	0.0862	0.1034
F4	0.0985	0.1129	0.1093	0.0862	0.1206	0.0689
F5	0.1126	0.0645	0.0937	0.1034	0.0862	0.1034
F6	0.0845	0.1451	0.0935	0.1034	0.1379	0.1379
F7	0.0985	0.1451	0.1406	0.1379	0.0689	0.0862
F8	0.1267	0.1129	0.0937	0.1206	0.1034	0.0862
F9	0.1267	0.1129	0.1406	0.1206	0.0862	0.0862

Table 7 The value of N_j and W_j

Result table						
	C1	C2	C3	C4	C5	C6
N_j	0.9962	0.9895	0.9915	0.9962	0.9520	0.9133
$1\text{-}N_j$	0.0037	0.0104	0.0084	0.0037	0.0479	0.0866
W_j	0.1399	0.3959	0.3211	0.1430	1.8121	3.2727

Here we assume VIKOR constant v = 0.5. The calculated value of P_i for each factor is shown in Table 7.

Step 4: Ranking the factors

Ranking of LGAMS is shown accordingly in Table 5. The LGAMS factor with low P_i value is more dominant, whereas the one with a large value is less dominant (Table 8).

Table 8 Criteria weightage

	C1	C2	C3	C4	C5	C6
F1	0.1951	0.1463	0.1951	0.1707	0.1707	0.1219
F2	0.2250	0.1750	0.1250	0.1500	0.1750	0.1500
F3	0.2051	0.1538	0.2051	0.1538	0.1282	0.1538
F4	0.1891	0.1891	0.1891	0.1351	0.1891	0.1081
F5	0.2285	0.1142	0.1714	0.1714	0.1428	0.1714
F6	0.1395	0.2093	0.1395	0.1395	0.1860	0.1860
F7	0.1666	0.2142	0.2142	0.1904	0.0952	0.1190
F8	0.1707	0.2195	0.1463	0.1951	0.1463	0.1219
F9	0.1627	0.2093	0.2093	0.1860	0.1162	0.1162

4 Problem Analysis and Results

The factors for integrated lean, green and agile manufacturing are identified, analyzed and ranked using entropy and VIKOR. This section discusses the result obtained from VIKOR analysis (Table 9).

Figure 1 presents the plot of P_i value. The lower value of P_i represents the best LGAMS factor, that is, the customer feedback system (factor 9) achieved 0, which is the lowest among other factors. Hence it comes at first rank against all other factors. After customer feedback system, factor 8 (empowered worker) gets P_i value as 0.0349, which is at second rank followed by factor 7 (innovation) that comes third rank among all factors. Factor 6 (product lifecycle management) has a maximum P_i value, which signifies that factor 6 is less effective among all factors.

Finally, with the help of Table 9, the following three factors customer feedback, empowered worker, and innovation. This ranking of LGAMS factors can be helpful in dealing with perfect plan for designing and implementation of LGAMS in any organization. The obtained value will now help the manager to properly use their

Table 9 The value of F_i, H_i, P_i and rank

Factors	F_i	H_i	P_i	Rank
F1	1.8885	1	0.2292	5
F2	1.9579	0.5	0.2407	6
F3	1.7236	1	0.2020	4
F4	2.1810	1	0.2775	7
F5	2.7174	1	0.3659	8
F6	3.5298	1	0.5	9
F7	1.1460	1	0.1068	3
F8	0.7105	0.7	0.0349	2
F9	0.4983	1	0	1

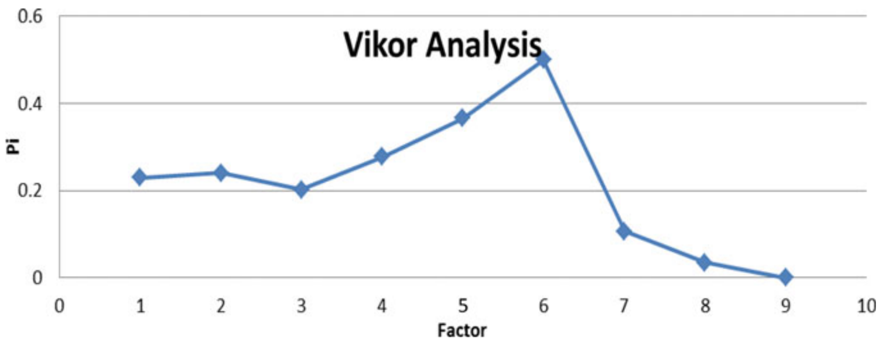

Fig. 1 Graph showing VIKOR analysis

resource to concentrate on more considerable and necessary factors. By applying this strategy an organization would attain competitor environment, customer fulfillment, and eco-friendly nature, which would lead to advanced manufacturing operation.

5 Conclusions

The prime objectives of any organization are: savings in terms of cost incurred, high profitability and increase in production rate with environmental awareness at the same time. Rapid exhaustion of earth resources, increased customer awareness with regard to green and natural products with implementation of enhanced technological tools serves the mandatory and important condition required to further the operational activities' transformation in sustainable activities.

However, this integration of LM, GM and AM and its implementation is pretty much challenging for any manager or owner belonging to any organization on account of deficiency of demanded skills along with paucity of finances. In this study, nine factors have been identified and short out with the help of literature reviews and experts, which include leadership and management, organizational culture, technical expertise and skills, information technology integration, simplification and standardization, PLCM, innovation, empowered worker and customer feedback. This study presents the use of entropy, VIKOR on LGAMS factors (which are nine) and recognizes from the study of literature and consultation from academia and industry experts the designated impact of factors, which is shown in Table 5. Since the integration of LGAMS is comparatively a new technique implemented, hence an initial survey of LGAMS factors will help the policymakers to analyze the importance of execution of LGAMS in any manufacturing setup. The present work offers the weight related to criteria and order of LGAMS supporter that assist while recognizing important factors, which must be primarily considered for the enactment of LGAMS in harmony with make any manufacturing setup efficiently.

Further deep study of factors by assembling numerical data obtained from academic experts, practitioners, including policymakers, would help in enhancing the field understanding. The feasibility with which statistical data is applied would examine tools like structural equation modeling, which can be inquired in such a way that LGAMS be effectively comprehended. Depending upon the results acquired, some actions are deemed to promote the implementation of LGAMS in studying the Indian manufacturing which is as follows:

The drafting of system in such a way that innovation and empowered worker lead to executing manufacturing in an easier way and also the system pertaining to customer feedback should work that will in a direct manner associated with those departments of organization which pertains to production and designing. This indicates the flexibility in the new drafting of running and upcoming products to incorporate the feedback obtained from the customers.

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