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ORIGINAL ARTICLE

Process improvement: performance analysis of the setup time reduction-SMED in the automobile industry

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Abstract Flexibility and responsiveness to customer demands are very important for success. Generally additional time is needed for setup caused by poor design of equipment. At this point the terms continuous process improvement and SMED (single minute exchange of dies) as an approach of lean manufacturing come into play. A lean manufacturing system is part of corporate culture, like tools and approaches. In this research work, the process capability analysis technique is implemented by using MINITAB14 software to investigate the relation between SMED methodology and equipment design. The index C_{pk} has been used in this application study to provide a quantitative measurement of the equipment design by applying the SMED methodology in automobile manufacturing. The results of this research study indicated that SMED in other words "quick changeover" is still a suitable method not only for manufacturing improvement but also for equipment/die design development.

Keywords Single minute exchange of dies (SMED) · Process improvement · Process capability analysis (PCA) · Process capability index · Equipment design

1 Introduction

During the last decade, the need for shorter setup times has increased across all types of industries. Changing market demands brings high demands on flexibility and costs in part due to the transition from a seller's to a buyer's market and partly due to the globalization of markets. Market demands contain more product variants in parallel to customization. This evolution is not limited to certain types of industry, rather it is a general phenomenon. The real challenge in this lies in the combination with decreasing order/delivery sizes (as seen in just-in-time). Customers want short delivery times and a high delivery reliability. The most efficient way to accomplish this is to have short lead times in production [1, 2]. Otherwise, the only solution left is to provide inventories of the end products, which are large and costly. Companies have learned to identify and eliminate waste, increasing both production and quality.

The need for, and a focus on flexibility directly corresponds to lot sizes. A key question is, what is the smallest lot size that can be produced in an economic way. It can be easily shown that there is a direct relationship between lot sizes and setup times. The shorter the setup time, the smaller the lot size; therefore, it can be produced in an efficient way and the less important the actual order size. It is also possible to introduce a make-to-order production policy.

Manufacturers have to take the changing market demand into consideration. Shingo has considered product differentiation, high quality, and speedy delivery; thus, reasonable prices became important terms for customers [3]. They realized that flexibility and responsiveness to the customer demand is very important on the way to success. At this point the terms "continuous process improvement" and "lean manufacturing" come into play. Lean manufacturing systems must have the ability to achieve responsive, small batch manufacture so that they can meet rapidly changing market demands. In fact, the lean manufacturing system is a part of corporate culture, such as tools and approaches

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[4–6]. Strategy and high-level plans are important; however, the most important aspect is implementation. The most difficult phase is not in the planning but implementation of lean manufacturing culture. As stated by Eiji Toyoda, trust/respect of all employees is one of the fundamental principles behind the philosophy of lean manufacturing [7]. If there is no such philosophy, no employee would be willing to improve the company. Therefore, tools of lean manufacturing, given in Fig. 1, should be classified to improve the manufacturing process.

In the scope of lean manufacturing, an important problem needed to be solved. Because lean manufacturing required small batch sizes and high product variation a new method had to be developed to reduce the setup times during the rapid changeover of dies and equipment. In 1985, Dr. Shigeo Shingo introduced his methodology called single minute exchange of dies (SMED).

Rapid changeover is a fundamental technique for attaining just-in-time (JIT) production and for addressing the issues of quality, flexibility and responsiveness [2]. Because of the high variability in a process, which must be compared to the specifications and requirements for products to customers, it therefore can be used the process capability analysis.

1.1 Research objective

A process is understood as a series of activities or procedures in which raw materials or pre-machined parts or components are further processed to generate a finished product. A process capability study which has been developed to improve the production is prepared for new or changed production process. A process capability study has been developed to improve the production performance. A process capability study is conducted to determine total variability and process stability, and, thus, process optimization.

We often need to require compare the output of a stable process with the process specifications and make a statement about how well the process meets the specification. To do this, we compare the natural variability of a stable process with the process specification limits in this research work. PCA-process capability analysis focuses on the operators and on the processes. In this study, a variance of quality characteristics like air hole boring axis called “205 eksen” was investigated by using PCA-process capability analysis to reveal and explain the relation of SMED implementation and equipment to apparatus design. In this manner, a process capability study usually measures functional parameters on the product.

We implement an approach of measuring of SMED improvement in the manufacturing of automobile industry using the estimator of C_{pk} index and p-value for judging a process whether it is capable or not.

2 The setup reduction methodology-SMED

The SMED system is a theory and set of techniques that make possible to perform equipment setup and changeover operations under 10 minutes. SMED improves setup process and provides a setup time reduction up to 90% with moderate investments. Setup operation is the preparation or post adjustment that is performed once before and

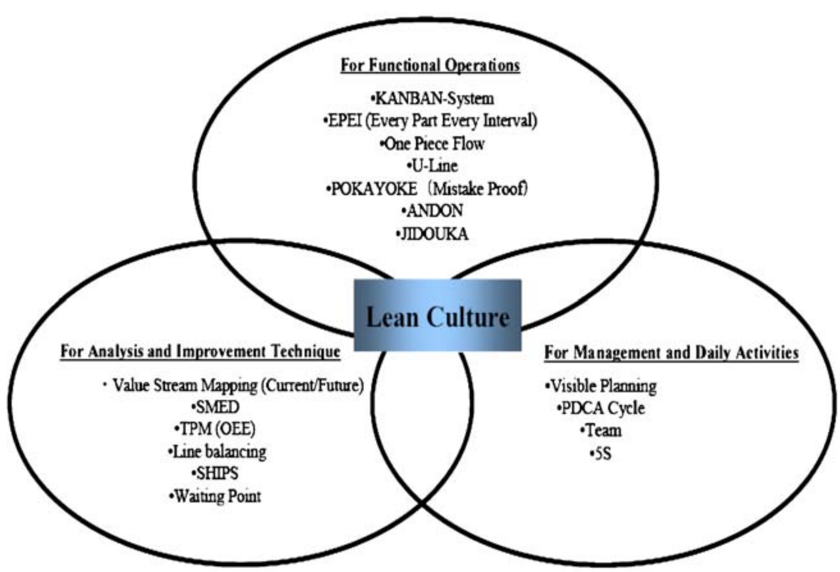


Fig. 1 Classification of tools-lean culture

once after each lot is processed [3]. Shingo divides the setup operation into two parts:

Internal setup The setup operation that can be done only when the machine is shut down (attaching or removing the dies).

External setup The setup operation that can be done when the machine is still running. These operations can be performed either before or after the machine is shut down; for example, getting the equipment ready for the setup operation can be done before the machine is shut down.

In Fig. 2, setup operation periods are shown. Set-up period is constituted by internal setup and external setup. During the internal setup there is no production. In the run-up period re-adjustments and trial productions are taking place. This period terminates when full output capacity is reached.

SMED system includes three main steps. These steps are as follows:

Step 1: Separating internal and external setup At this step an important question must be asked for each setup activity. "Do I have to shut the machine down to perform this activity?" The answer helps us in distinguishing between internal and external setup. This step can reduce the setup time by as much as 30% to 50%. The following are the three techniques that SMED uses at this step: checklists, function checks and improved transport of dies and other parts.

Step 2: Converting internal setup to external setup In order to achieve the single digit setup time objective SMED introduces this step. At this step internal setup activities were converted to external activities. So the total time that the machine is kept down will be reduced. Advance preparation of operating conditions, function standardization and use of intermediary jigs are the techniques to support the second step [7].

Step 3: Streamlining all aspects of the setup operation At this step "specific principles" are applied to shorten the setup times. Implementing parallel operations, using functional clamps, eliminating adjustment and mechanization techniques are used to further setup time reduction. All these steps are figured in Fig. 2.

2.1 The need for an improved SMED

In the literature the ways to improve and support the SMED technique are considered. The SMED technique is used as an element of "TPM" and "continuous improvement process" in efforts of reaching lean manufacturing [8–13]. Case studies about setup reduction at different manufacturing environments take place in some texts [14, 15]. In addition, the technique is evaluated about its sequential implementation approach [16]. An important lack of the SMED was the consideration and motivation of human factor. This issue is discussed in the academic texts [16, 17]. Another important discussion about the SMED technique in the literature is the impact of design on setup operations [16, 18–21].

Mileham shows the relationship between design and methodology-based improvements on setup times and their effects on cost in Fig. 3. From Fig. 3 "by methodology"

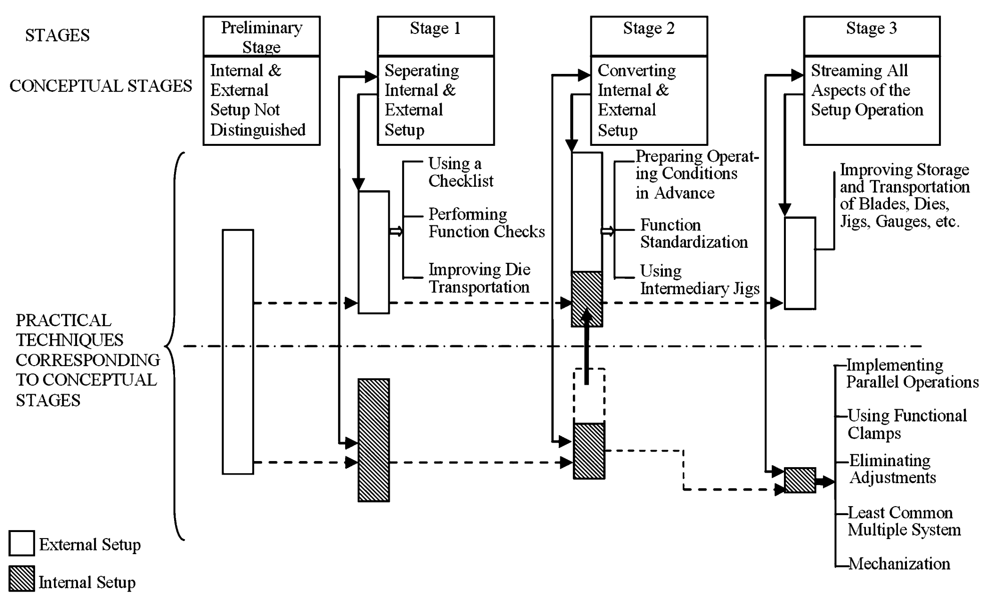


Fig. 2 SMED conceptual stages and practical techniques

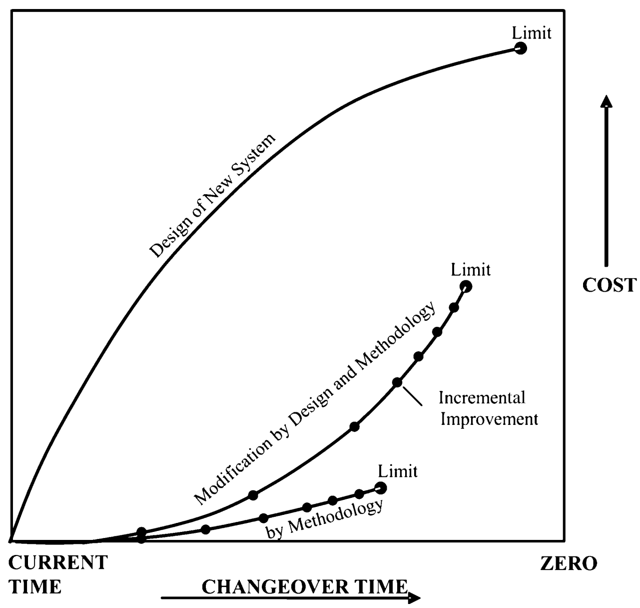


Fig. 3 Hypothesized limits and costs of changeover improvement strategies

based improvements are relatively cheap but their capacity of reducing changeover time is low. On the other hand, "designing of new system" is much more costly; however, significant setup time reduction can be achieved. Concurrent use of these two options (using modification by both design and methodology) can bring about optimal solution for companies' goal and resources.

According to Mileham, "The reduction of changeover times should take place within an overall methodology aimed at ensuring success and sustainability" [19]. So it can be said that success and sustainability are the performance measures for setup time reduction efforts. Thus, these two options (designing of new system or modification by methodology) must be evaluated on the basis of sustainability.

If a new system is designed to reduce the setup times, it would be costly as mentioned, but it would also be more sustainable. That means once the system is constructed and maintained to operate properly, it works as desired and no alteration is observed (for example a quick clamping system).

On the other hand, modifying an existing changeover operation by changing current methodology does not cost too much but is more difficult to sustain as methodology may change in time unless standardized and controlled. It must not be forgotten that preserving the success is as important as achieving it. Otherwise, all efforts to reduce changeover times may be worthless if one observes that the changeover times are rising to their previous value.

The sustainability objective can be achieved by creating a standardized method procedure. At this point Dirk Van Goubergen's diagnosis about setup procedure is so interesting. He notes that when new machinery or equipment is bought, the operating and maintenance instructions are given with it. So operators don't need to discover how this machine will be operated. But no one can find instructions about setup operations. So operators will develop their own way of working by trial and error [17, 19]. Especially, when complex changeover operations are encountered this "inspiration of moment" method must be changed with a "standardized setup method" that is prepared by the machine designers.

3 Relationship between equipment design and the setup time reduction

During the product design phase, setup minimization must be taken into account. Van Goubergen [18] defined the setup as the time the last product A leaves the machine until good products B comes out. He describes also the quality of a setup that is determined by three key elements: technical aspects of equipment and tools, the organization of the work and the method used. There is the additional time needed for the setup caused by poor design of equipment.

Especially when complex changeover operations are encountered this "inspiration of moment" method must be changed with a "standardized setup method" that is prepared by the machine designers [4, 7, 18]. Taking this into account, Asano defined it (standard setup) to reduce equipment waste by drawing attention to two important points to be followed: to invest and/or maintain the right capacity of equipment and to use equipment efficiently.

Short setup times are a necessity nowadays in all types of industries. There exists a good methodology to reduce these setup times in the existing situations. However, the experience of these processes should be used in the design phase of such equipment. Technical aspects of equipment and tools (namely equipment design) are to determine the concept and the construction of the machine. The awareness of the importance of having short setup times and some design principles or guidelines can help the designer to build setup friendly equipment. According to Asano, lean manufacturing reduces equipment waste, which means to invest and/or maintain the right capacity of equipment and to use it efficiently.

In practice, even for very modern and high technology equipment, there is much that can be improved about the technical concept of equipment to make it more setup friendly. From this point, new equipment and/or apparatus can be developed by using SMED setup time reduction methodology. During the observation of new equipment and/or apparatus after SMED implementation in the rims manufacturing, the data have been taken from rims product.

Van Goubergen approximately denotes also that within the SMED the followings can be improved:

- Use of bolts and nuts instead of quick fixtures (clamps, magnets, etc.)
- Modular design of machines
- Problems for setting the machine parameters:
  - Poor process capability of the machine
  - No appropriate measuring and re-adjusting tools on the machine
  - One product specification has to be set by more than one process parameter.

Van Goubergen and Van Landeghem, and Mileham et al. give a number of design rules such as securing; taking the mean of them; using manual clamps as a cheap and fast alternative to bolts and screws; using quick fixtures, hydraulic, pneumatic or electromagnetic fixtures. In this way, these rules can help the setup time reduction process and reduce the waste time.

Leading automotive manufacturers around the world has been challenged with applying fundamental design practices to sheet metal design and assembly. The goal behind this effort is to help achieve high quality product with minimal lead-time and development costs [21]. These practices include geometric dimensioning and tolerancing, variation simulation analysis, setting quality standard targets for process capability such as C_p, and C_{pk}. Methods, which are used by the automotive manufacturers, have had on sheet metal processes including the assignment of dimensional part tolerances, translating component designs into tools that can make them and predicting assembly conformance based on stamping capability.

Process capability analysis is a vital part of an overall quality-improvement program. Among the major uses of data from a process capability analysis are the following [22]:

- Predicting how well the process will hold the tolerances
- Assisting product developers/designers in selecting or modifying a process
- Specifying performance requirements for new equipment
- Planning the sequence of production processes when there is an interactive effect of processes on tolerances

4 Performance measuring of SMED with PCA

4.1 The process capability analysis

Statistical techniques can be helpful throughout the product cycle, including development activities prior to manufacturing, in quantifying process variability, in analyzing this variability relative to product requirements or specifications, and in assisting development and manufacturing in eliminating or greatly this variability. This general activity was called process capability analysis to estimate process capability by Montgomery [22]. Until now, the process capability analysis was frequently used for processes with quantitative characteristics. However, for process quality with the qualitative characteristic, the data's type and single specification caused limitations of using the process capability analysis [23]. A process capability study usually measures functional parameters on the product, not the process itself. When the analyst directly observes the process and controls or monitors the data-collection activity, the study is a true process capability study, because by controlling the data collection and knowing the time sequence of the data, inferences can be made about the stability of the process over time. In general, process capability analysis can be represented by using the process capability index.

Different capability indices have been developed in order to receive a numerical measure of the capability. These indices represent dimensionless functions of process parameters and product specifications and are designed to provide easily understood numerical values of the performance of the process. Process capability indices are quantitative measures of the process capability.

In determining the process capability indices, various formulae have been used [24]. The formulae to be used in the capability study are derived according to the distribution of data. The process capability indices, particularly $C_{p,}$ C_{pk}, and C_{pm} and C_{pmk}, have been widely used in various manufacturing industries providing measures on process potential and performance.

4.2 The process capability index

Process capability indices are used to measure the ability of an in-control process to manufacture products within the specified tolerance presented by the product designers or customers. These have been the focus of recent research in quality management and process capability study. Process capability indices like C_p, C_{pk}, C_{pm} and C_{pmk} have been used to establish the relationship between actual process performance and manufacturing specification tolerances [25–27].

There are various process capability indices that are used to describe the performance of a process, relative to the established specification limits presented by the designer [28]. Under the assumption that the measurement X comes from a stable process and arises from a normal distribution with mean μ and variance σ^2 then the following is the process precision index:

$$C_p = \frac{USL - LSL}{6\sigma} \tag{1}$$

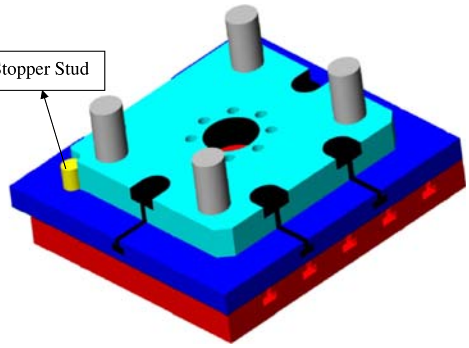


Fig. 4 New stopper stud design for the ease of centering process of die of air hole boring "205 Eksen"

where LSL and USL denote the lower and upper specification limits, respectively. The C_p index is designed to measure the degree of the overall process variation. Since the C_p index does not depend on the process mean, the C_{pk} index is then introduced to reflect the impact of μ on the process capability indices. The C_{pk} index is formulated as:

$$C_{pk} = \min\left\{\frac{USL-\mu}{3\sigma}, \frac{\mu-LSL}{3\sigma}\right\}. \quad (2)$$

To adopt the concept of the loss introduced by Taguchi, Pearn et al. [24] have provided a process capability C_{pm} index. This index provides indicators of both the process variability and deviation of the process mean from the target value T, and also provides a quadratic loss interpretation. The C_{pm} has been defined as

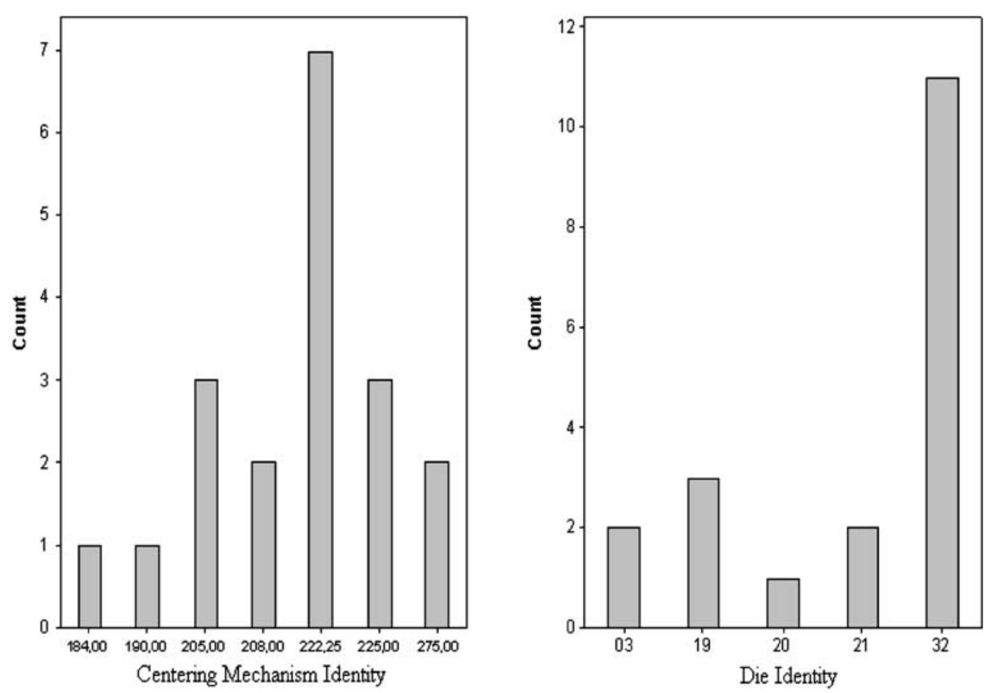
$$C_{pm} = \frac{USL-LSL}{6\sqrt{\sigma^2+(\mu-T)^2}}, \quad (3)$$

Pearn et al. introduced an alternative capability index C_{pmk}, which is a combination of C_{pk} and C_{pm}. The C_{pmk} index is much more sensitive to differences between the process mean and the target than the three indices C_p, ehic and C_{pm}. This index is defined as:

$$C_{pmk} = \min\left\{\frac{USL-\mu}{3\sqrt{\sigma^2+(\mu-T)^2}}, \frac{\mu-LSL}{3\sqrt{\sigma^2+(\mu-T)^2}}\right\}. \quad (4)$$

In recent years, the C_{pk} ındex is used more than any other capability index for judging whether a process is capable or not. From the definition equation of C_{pk}, it is apparent that C_{pk} quantifies capability for the worst half of the data. With the C_{pk} ındex , a larger value implies a better process distribution of the quality characteristic. Some commonly used values of C_{pk} are 0.50 (process is incapable), 1.00 (process is normally called capable), 1.33 (process is normally called satisfactory), 1.50 (process is normally called excellent), and 2.00 (process is normally called super).

Fig. 5 Centering mechanism and die usign frequencies



a Density of Use For Each Centering Mechanism **b** Density of Use For Each Dies

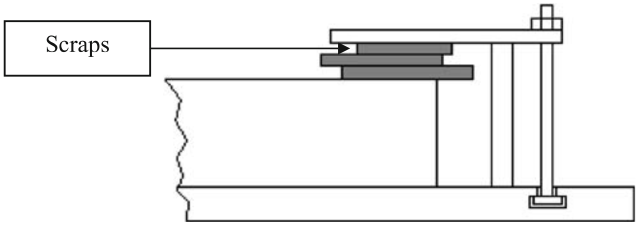


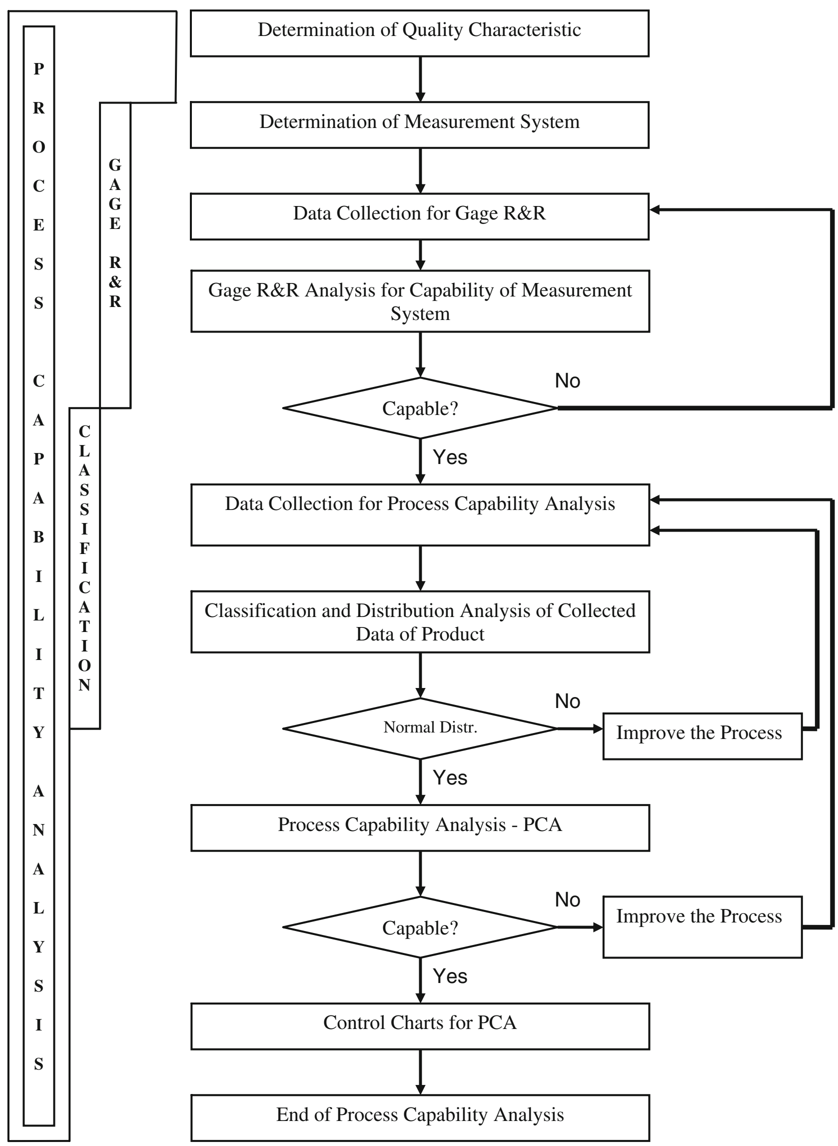
Fig. 6 The current method of die fastening in company ABC

4.3 Performance analysis study for SMED methodology

Automotive manufacturers and suppliers have struggled with the challenge of how to identify when a process is capable of producing dimensionally acceptable stamped parts of vehicle components [21]. In fact, no manufacturer has successfully achieved a C_{pk} of 1.33 on all part dimensions using the originally assigned specifications, particularly on the larger, thin material parts, etc. But on the thick material parts of vehicle like rims, the manufacturers achieve a C_{pk} over 1.33. Furthermore, achieving a high C_{pk} value alone is not necessarily a good predictor of final dimensional quality. Many factors such as the assembly locating process, and the clamp effects influence how rims build into an assembly. This research within the setup time reduction processes (SMED) will indicate that stamping variation of equipment (dies) is related to the following:

- Measurement fixture design (checking fixtures with more clamps tend to reflect lower variation)
- Part size, complexity and thickness (smaller, less complex and thicker parts have lower variation)

Fig. 7 Flow-chart of process capability



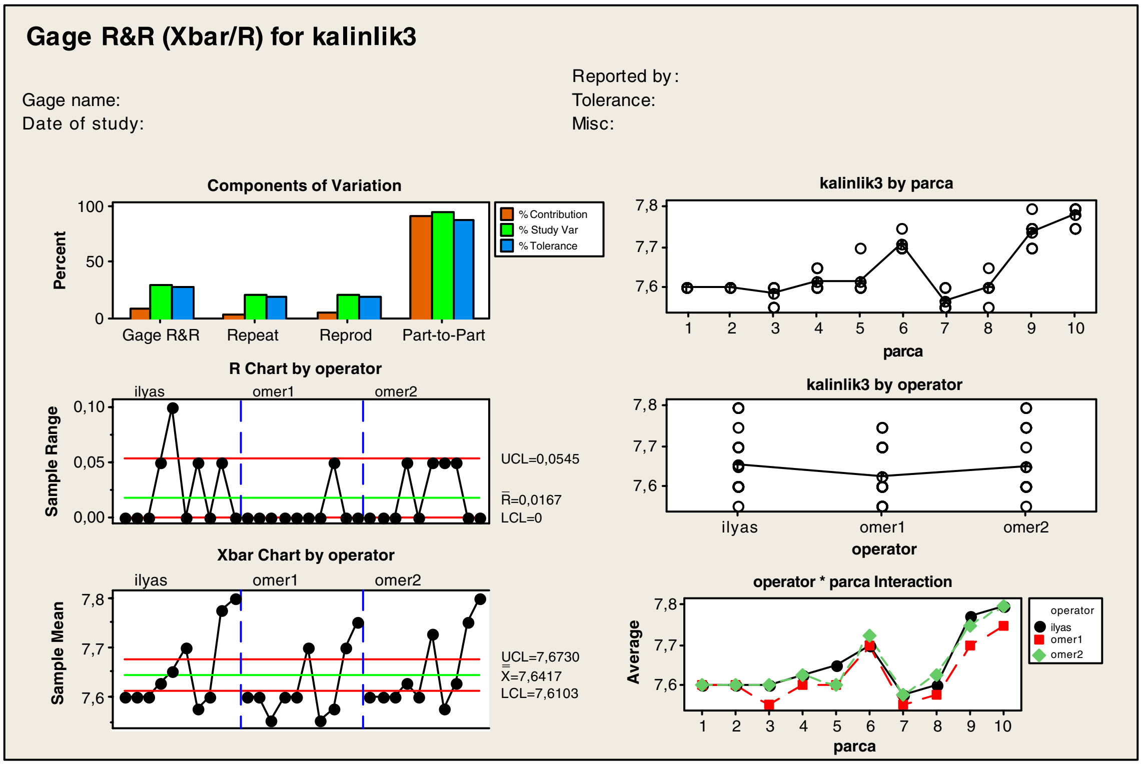


Fig. 8 Gage R&R Analysis for Process Capability Study of “205 Eksen”

- Shipping and handling (the shipping and handling of parts tends to increase variation and shift dimensions on the parts)
- Changes in stamping presses (for example, some dimensional shifts occur as dies are moved from a tryout press line to the home production press line)

Gage R&R Study - XBar/R Method

Source	VarComp	%Contribution (of VarComp)
Total Gage R&R	0,0004541	8,91
Repeatability	0,0002183	4,28
Reproducibility	0,0002358	4,63
Part-To-Part	0,0046423	91,09
Total Variation	0,0050964	100,00

Source	StdDev (SD)	Study Var (5,15 * SD)	%Study Var (%SV)	%Tolerance (SV/Toler)
Total Gage R&R	0,0213096	0,109745	29,85	27,44
Repeatability	0,0147754	0,076093	20,70	19,02
Reproducibility	0,0153554	0,079080	21,51	19,77
Part-To-Part	0,0681342	0,350891	95,44	87,72
Total Variation	0,0713888	0,367653	100,00	91,91

Number of Distinct Categories = 4

Gage R&R for kalinlik3

Fig. 9 The result of Gage R&R Analysis for Process Capability Study of “205 Eksen”

5 Problem definition

On the way to the optimal standardized changeover procedure, it was vital to choose the correct company. It should be noted changeover frequency defined as industrial choosing criteria which affects the method degree. So, high changeover frequency provides an available environment for high specialization and high level of method degree. It is clear that in heavy industries dies are used to form thick materials. So it was decided to find an industry, which uses thick materials in its production processes. Actual data collected from the factories were applied to investigate what the relationship between the SMED and equipment design was.

We present a case study on a rim manufacturing process. The research work which we studied was taken from an ABC Company, which is the manufacturer and supplier of rims for lorries and mid-sized trucks in western Turkey. The aim of SMED implementation at ABC Company was to improve rim production, which can be realized on the BPD–air hole boring machine. The ABC Company has a capacity of 1.2 million rims per year and has a large customer portfolio. Product types depend on rim dimension (57 different rim sizes), tire dimension (112 different sizes), number of holes for lug wrench (5, 6, 8, 10), lug types and sizes, weight (7.9 kg to 81 kg), internal/external offset sizes and maximum pressure values (750 kg to 5672 kg) that can be applied on the rim. High product variation and thick material usage (up to 18 mm steel) forces the company to

Table 1 Sample data of 140 air hole boring axis of die

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	205.04	205.05	205.08	204.97	204.95	205.04	205.18	204.97	205.01	205.06
2	204.99	204.99	205.05	204.99	205.04	205.09	204.98	204.96	204.97	204.93
3	205.04	205.03	204.93	205.08	205.03	204.86	205.01	204.96	204.94	204.90
4	205.07	205.03	205.04	205.02	204.96	205.01	204.99	204.97	204.89	204.94
5	205.04	205.03	205.10	204.97	204.92	204.88	205.06	205.03	205.04	205.02
6	204.96	205.01	204.99	205.03	204.89	205.01	204.88	205.06	204.87	205.01
7	204.93	205.03	205.04	204.97	204.89	205.02	204.99	205.09	204.92	204.92
8	204.94	205.04	205.13	205.10	204.97	204.92	204.98	205.06	205.01	204.87
9	204.93	205.04	205.04	205.10	204.98	205.01	205.01	204.99	205.02	205.04
10	204.97	205.13	205.05	205.06	204.94	204.96	204.88	204.99	205.01	204.95
11	205.07	205.07	204.97	204.89	204.88	205.06	204.87	204.93	205.04	205.13
12	205.01	205.01	205.01	205.01	205.11	204.81	205.04	204.90	204.93	204.89
13	205.10	204.99	204.98	204.81	205.01	205.03	204.94	205.17	204.88	205.13
14	205.07	204.98	205.07	204.93	205.05	204.83	205.12	204.97	204.98	204.96

make changeovers frequently. Huge machines (5 meters high) are used to cut and form the steel and huge dies are used for these operations. Setting up these machines take a long time, and the company has to reduce setup times. A pilot approach is applied in this study, and one of the five disk production lines is selected for the study [7]. There are 18 machines on the line. BPD machine is an air hole boring machine. It shows the problematic area that must be focused on. In this case this is BPD machine (the die of air boring machine displayed in Fig. 4). ABC Company decided to apply SMED to reduce the setup times on BPD machine.

There were five different kinds of dies for BPD machine. Besides that, for each die there were seven different centering mechanisms that hold materials that have different radius. So, 35 different products could be produced at this machine. In order to define the busiest dies and centering mechanism frequency tables were developed (Fig. 5a,b).

Because die and clamp heights were different, the operator used to use scraps to fasten the die at the desired height. The operator used to put one scrap then try to fasten the die. If the heights were not matched then he used to put one more scrap (Fig. 6). All of these motions were unnecessary motions and had to be eliminated. They were time consuming. Moreover it was impossible to standardize these motions of the operator. Therefore clamps and die heights were standardized.

6 An application

We consider a numerical example to illustrate how to apply the designed procedure to calculate process capability and

Table 2 New sample data of 140 air hole boring axis of die

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
1	205.01	205.05	205.08	204.97	204.98	205.04	205.09	205.04	205.09	204.98
2	204.96	204.97	204.93	205.04	205.03	204.93	204.97	205.01	205.06	204.99
3	204.99	205.05	204.99	205.04	205.09	204.98	204.96	204.97	204.93	205.04
4	205.03	204.93	205.08	205.03	204.86	205.01	204.96	204.94	204.90	205.07
5	205.03	205.04	205.02	204.96	205.01	204.99	204.97	204.89	204.94	205.04
6	205.03	205.10	204.97	204.92	204.88	205.06	205.03	205.04	205.02	204.96
7	205.01	204.99	205.03	204.89	205.01	204.88	205.06	204.87	205.01	204.93
8	205.03	205.04	204.97	204.89	205.02	204.99	205.09	204.92	204.92	204.94
9	205.04	205.13	205.10	204.97	204.92	204.98	205.06	205.01	204.87	204.93
10	205.04	205.04	205.10	204.98	205.01	205.01	204.99	205.02	205.04	204.97
11	205.13	205.05	205.06	204.94	204.96	204.88	204.99	205.01	204.95	205.07
12	205.07	204.97	204.89	204.88	205.06	204.87	204.93	205.04	205.13	205.01
13	205.01	205.01	205.01	205.11	204.81	205.04	204.90	204.93	204.89	205.10
14	204.99	204.98	204.88	205.01	205.03	204.94	205.17	204.99	205.02	205.07

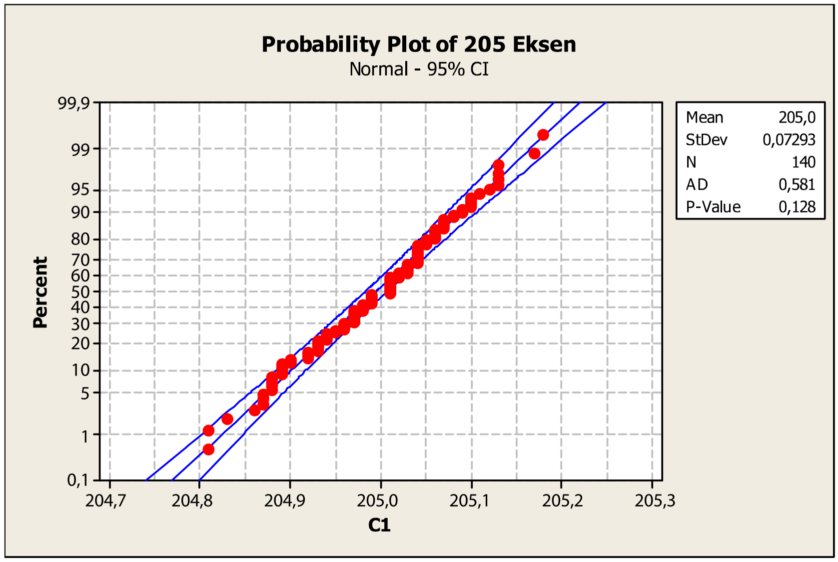


Fig. 10 The normal probability plot of the sample data of 205 Eksen in Table 1

determine whether a given process for the improvement of quick changeover is capable. The study concerns capability of SMED on the rims production line called "BPD-air hole boring machine line", in the ABC company. The quality characteristic of rims is the axis of air hole axis called "eksen" (see Fig. 4). After the SMED process of BPD-air hole boring machine line, process capability analysis procedure for assessing C_{pk} index can be represented according to the flow-chart as shown in Fig. 7.

Step 1 The capability requirement is defined as $C_{pk}>1.33$, that is, C=1.33. On the thick materials parts of vehicle like rims, the manufacturers achieve a C_{pk} over 1.33 (see chapter 3.3). We set also α-risk at 0.05 if the p-value is less than the chosen risk á, then it is concluded that the process is capable, otherwise, we would not have enough information to conclude that the process is capable.

Step 2 To research if the measurement tools is capable or not, the Gage R&R study has been conducted. Ten pieces have been examined [25, 29, 30]. All pieces have been measured two times by three operators as seen in Fig. 8 R&R. From the results of Gage R&R graphics, we concluded the following: The measurement tool is capable of measuring the length since Gage R&R 29.85 % is less than 30% displayed in Fig. 9.

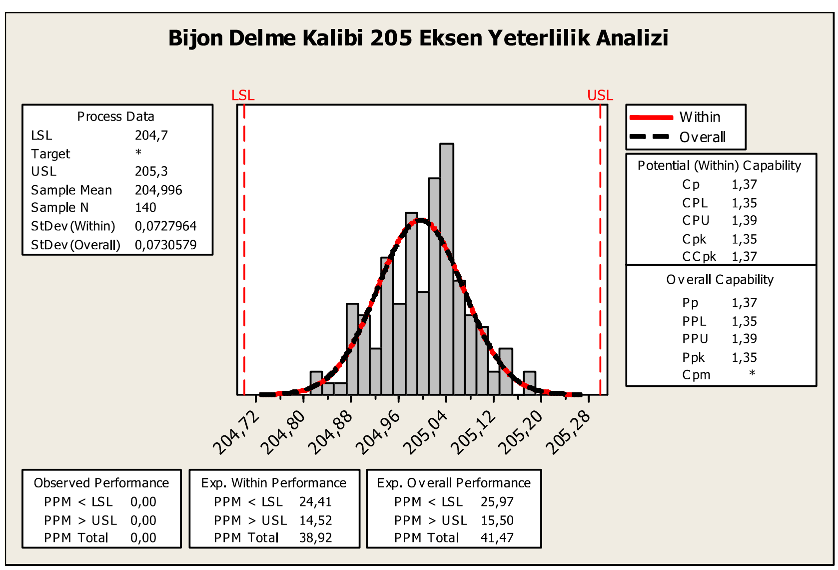


Fig. 11 Process capability analysis of die from air boring machine, "205 EKSEN"

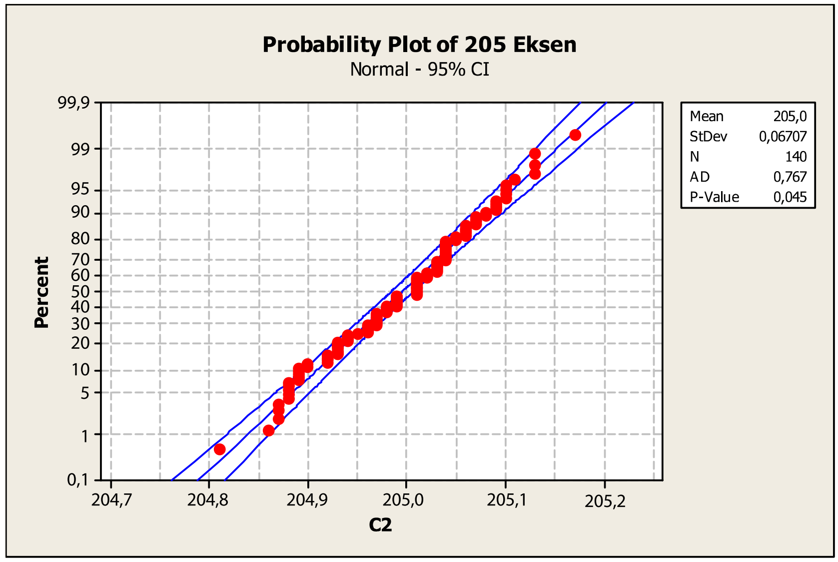


Fig. 12 The normal probability plot of new sample data of 205 Eksen in Table 2

Step 3 Random samples of size 140 after the SMED improvement is achieved are given in Table 1 and in Table 2. First of all, we can obtain the p-value=0.128 (see Fig. 10) and C_{pk}=1.35 (see Fig. 11) acc. to the data of Table 1.

Step 4 Since the p-value=0.128 > α-risk=0.05 (see Fig. 12), we can not conclude that the process can satisfy the capability requirement. Accordingly, some quality improvement activities are necessary before checking whether the adjusted process will be satisfactory again. A new sample data of 140 from the process is collected and displayed in Table 2. Then, we can obtain the p-value less then α-risk and C_{pk} index 1.43 (see Fig. 13).That means the adjusted SMED process that is improvement of die can satisfy the capability requirement, C_{pk}>1.33.

7 Conclusion

Short setup times are a necessity nowadays in all types of industries. There exists a good methodology to reduce these setup times in the existing situations. However, experiences of these processes should be used in the design phase of such equipment. In this paper the need for setup time reduction (SMED) and product design efficiency along with lean manufacturing is illustrated from the point of view of relation between both the setup time reduction (SMED) and

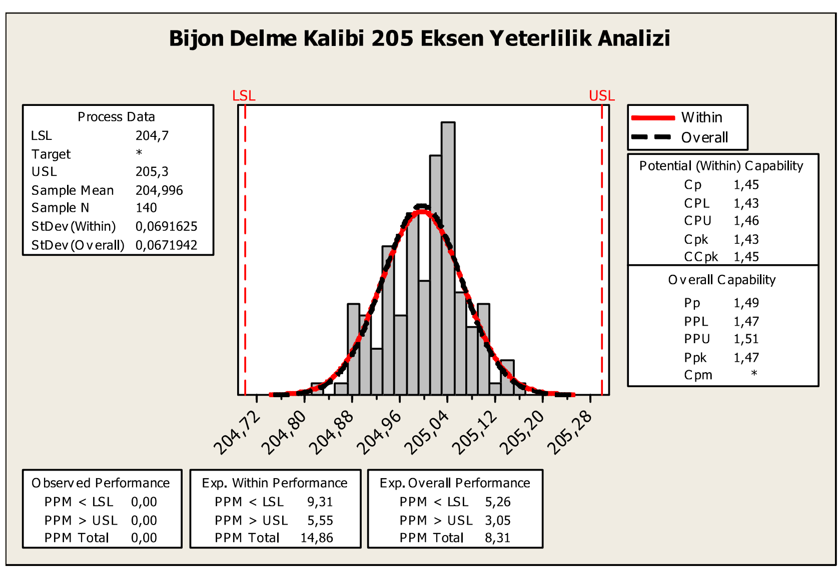


Fig. 13 Process capability analysis of die from air boring machine-205 EKSEN

product design efficiency. A key question was, how the relation between the SMED (changeover process) and equipment efficiency should be revealed. This can be showed quantitatively by using a proposed solution, a kind of quality control technique, and process capability analysis. To illustrate this and how the C_{pk} index can be applied to actual data collected from the dies of BPD-air hole boring machine, we presented a case study on a rims manufacturing process in the automobile industry. As a conclusion, it can be stated that SMED "single-minute exchange of die" in other words "Quick Changeover" is still a suitable method not only for manufacturing improvement but also for equipment/die design development.

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