Multi-response Optimization of Machining Simulation Approach Using Grey Relational Analysis

Mohd Amran Md Ali[1(✉)], Sivarao[1], Zulkeflee Abdullah[1], Raja Izamshah[2], Mohd Shahir Kassim[2], and Ahmad Shahir Jamaludin[3]

[1] Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal, Melaka, Malaysia
mohdamran@utem.edu.my

[2] Advanced Manufacturing Centre, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, 76100 Durian Tunggal, Melaka, Malaysia

[3] Faculty of Manufacturing and Mechatronic Engineering Technology, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia

Abstract. This study is to find the multi-response optimization of machining by finite element analysis simulation software using the grey relational analysis approach. The parameters selected are cutting speed, feed rate, and depth of cut towards the responses that are velocity, displacement, and temperature. Stainless steel was selected as workpiece and carbide material as cutting tool. L4 orthogonal array was implemented as an experimental design. In pre-processing the experimental result was normalized followed by determination optimization parameters from the highest value. It is found that optimum parameters for all responses are 150 m/min of the cutting speed at level 1, 0.5 mm of the depth of cut at level 1, and 0.3 mm/rev of the feed rate at level 1. Analysis result shows that the cutting speed is the significant factor that affects all responses followed by feed rate and depth of cut.

Keywords: Multi-response · Grey relational analysis · Machining

1 Introduction

Finite Element Analysis (FEA) is an engineering simulation program that is used to evaluate different manufacturing processes, providing an important analysis method for an industrial application study. According to Prasad et al. [1], various Computer-Aided Engineering (CAE) simulation software such as DEFORM-3D, ABAQUS, ANSYS, etc. are Finite Elements Method (FEM) approach that are used to evaluate the various formation processes employed by steel shaping sectors and similar ones. By simulating fabrication processes make designers and engineers decreasing the need for costly shop floor trials and redesign of tooling and processes [2].

The machining process parameters that most affected the machining characteristics are cutting speed, feed rate, and depth of cut. The suitable material and machining

© The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2022
M. F. B. Abdollah et al. (Eds.): ICE-SEAM 2021, LNME, pp. 154–157, 2022.
https://doi.org/10.1007/978-981-19-3179-6_27

process parameter needs to be investigated so that the optimum parameters can enhance the quality for the machining characterization [3].

In this paper, the finite element analysis of DEFORM 3D software was used. The cutting parameters are cutting speed, feed rate, and depth of cut meanwhile the selected responses are velocity, displacement, and temperature. The main objective of this paper is to find the most significant parameters and optimize the parameters by multi-response optimization using the grey relational analysis.

2 Experimental Work

Three independent variables machining parameters are selected which are cutting speed (150 m/min to 250 m/min), depth of cut (0.5 mm to 0.6 mm), and feed rate (0.3 mm/rev to 0.5 mm/rev) while the responses are velocity, displacement and temperature. Machining parameters of cutting speed, depth of cut, and feed rate were set up in the process setting in DEFORM 3D software. Next, the carbide cutting tool insert was loaded in the program then generated mesh. The selection 316 L stainless steel was chosen as a workpiece then generated mesh on the workpiece. After the command bar shows the complete process for turning simulation. Data can be analyzed by selecting types of the variable for the response. Choose types of response that are required for velocity, displacement and temperature. The determination of grey relational analysis (GRA) method was followed from the previous researcher approach [4].

3 Multi-response Optimization Result and Discussion

3.1 Grey Relational Analysis

The result from the experiment was taken for analysis by Grey Relational Analysis (GRA). Application of the GRA approach to identify optimum levels of parameters of significance. The outcome of the confirmation test indicated that the optimal combination of parameters that have been determined effectively increases the cutting speed performance of the product properties [5].

Table 1. Result of grey relational analysis (GRA).

Runs	Velocity (mm/sec)	Displacement (mm)	Temperature (°C)	GRA of velocity	GRA for displacement	GRA of temperature
1	5070	40.5	1600	0.8435	0.5526	1
2	3450	57.3	2020	1	0	0.8667
3	5680	35.0	4750	0.7850	0.7336	0
4	13800	26.9	3630	0	1	0.3556

The smaller the better characteristic was used for calculation the GRA for each run as shown in Table 1. The table shows that run number 1, 2 and 4 has a different high result from one to another with a value of 1 for each answer that is velocity, displacement, and temperature. The result shows when used the smaller the better for experiment result with value zero was run numbers 2, 3, and 4. The value for displacement was 0 value at run number 2, meanwhile run number 3 shows 0 value for temperature.

3.2 Grey Relational Coefficient (GRC)

Next, analyze using GRC where the maximum value of process parameters is evaluated using the higher GRG. Higher values of mean grade values of GRG are selected as the optimal multi-response, therefore as shown in Table 2, run number 1 is the optimal run of multi response optimization for the three responses.

Table 2. Data of GRC and GRG.

Runs	Cutting speed (m/min)	Depth of cut (mm)	Feed rate (mm/rev)	GRC of velocity	GRC of displacement	GRC of temperature	Grey Relational Grade (GRG)
1	150	0.5	0.3	0.7616	0.5278	1	0.7631
2	150	0.6	0.5	1	0.3333	0.7895	0.7076
3	250	0.5	0.5	0.6989	0.6524	0.3333	0.5615
4	250	0.6	0.3	0.3333	1	0.4369	0.5901

3.3 Ranking the Most Parameters Affected on Responses

The response factor diagram is shown in Fig. 1 which shows the parameters main effect plot of speed, depth of cut, and feed rate versus the data means.

The result indicates that the optimum level of parameters of cutting speed is 150 m/min at level 1, meanwhile for depth of cut is 0.6 mm at level 1and for the feed rate is 0.3 mm/rev at level 1. The result shows the multi-response optimization fall under run number 1. From the figure it shows that cutting speed is the most influence factor follow by feed rate and depth of cut. The result similar report by Hadzley et al. [2] that the cutting speed higher the influence of velocity, displacement and temperature very sensitive due to as the cutting speeds increases the strain rate increases at shear zone thus more heat is generated rapidly with respective to speed.

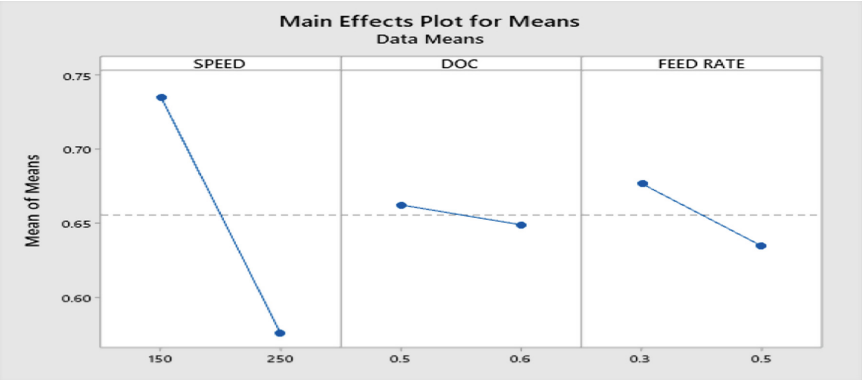

Fig. 1. Parameters main effect plot of speed, depth of cut, and feed rate.

4 Conclusion

It can be concluded that the response factor shows that the Gray Relation Analysis (GRA) was obtained. This result indicates that the optimum parameters of multi-response are 150 m/min of the cutting speed at level 1, 0.5 mm of the depth of cut at level 1, and 0.3 mm/rev of the feed rate at level 1. From this result, using multiple responses shows that cutting speed is the most parameter that affected all responses.

Acknowledgement. The authors gratefully acknowledge Universiti Teknikal Malaysia Melaka (UTeM) for providing facilities for this research work done. This research work was support through FRGS/2018/FKP-AMC/F00377 research grant.

References

1. Prasad, K.K., Tamang, S.K., Chandrasekaran, M.: Comparative study on cutting force simulation using DEFORM 3D software during high speed machining of Ti-6Al-4V. Key Eng. Mater. **856**, 50–56 (2020)
2. Hadzley, A.M., Azahar, W.W.M., Izamshah, R., Shahir, K.M., Amran, A.M., Afuza, A.: Response surface methodology approach on effect of cutting parameter on tool wear during end milling of high thermal conductivity steel-150 (HTCS-150). IOP Conf. Ser. Mater. Sci. Eng. **114**(1), 1–7 (2016)
3. Bakar, M.H.A., et al.: Surface integrity of LM6 aluminum metal matrix composite when machined with high speed steel and uncoated carbide cutting tools. J. Mech. Eng. Sci. **6**, 854–862 (2014)
4. Md Ali, M.M., et al.: Multi-response optimization of plastic injection moulding process using grey relational analysis based in Taguchi method. J. Adv. Manuf. Technol. **12**(1), 87–98 (2018)
5. Izamshah, R., Husna, N., Hadzley, M., Amran, M., Shahir, M., Amri, M.: Effects of cutter geometrical feature on machining polyetheretherketone (PEEK) engineering plastic. J. Mech. Eng. Sci. **6**, 863–872 (2012)