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Identification of optimal influencing parameters in milling of Al-7075 using grey relational analysis

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ABSTRACT

The quality of the surface plays a very important role in the performance of milling as a good quality milled surface significantly improves fatigue strength, corrosion resistance, or creep life. Surface roughness also affects several functional attributes of parts, such as, contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, load bearing capacity, coating or resisting fatigue. Therefore, the desired finish surface is usually specified and the appropriate processes are selected to reach the required quality. To achieve the desired surface finish, a good predictive model is required for stable machining. Generally, these models have a complex relationship between surface roughness and operational parameters.

In this paper, Grey relation has been used to identify the optimal combination of influential factors in the milling process. Milling experiment has been performed on AL7075 material, according to Taguchi orthogonal array, for various combinations of controllable parameters speed, feed, depth of cut and coolant. The surface roughness (R_q), power and cutting temperature are measured and recorded for each experimental run and analyzed using Grey relational analysis and the optimum controllable parameter combination is identified.

KEY WORDS
Analysis, AL-7075, Grey, Milling, Parameters.

1 INTRODUCTION

The challenge of modern machining industries is mainly focused on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact.

Roughness is often a good predictor of the performance of a mechanical component since irregularities in the surface may form nucleation sites for cracks or corrosion. Although roughness is usually undesirable, it is difficult and expensive to control during manufacturing. Decreasing roughness of a surface will usually exponentially increase its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

Increasing the productivity and the quality of the machined parts are the main challenges of metal-based industry. There has been increased interest in monitoring all aspects of the machining process. Quality of machining can be judged by surface roughness. Higher the surface finish higher will be the quality. Surface finish mainly depends on Cutting speed, Depth of cut and Feed. Most of the operators use trial and error method to find the appropriate cutting condition. It is not the effective way to find out optimal cutting parameters. So the main objective of the study is to find the optimum parameters (speed, feed, depth of cut) so that surface roughness is optimized. Aluminium has much application in industries. Also automotive aircraft and train companies need to replace steel and cast iron with lighter metal like aluminium. So it is important to know the machining behaviour of aluminium. There are various optimization techniques like genetic algorithm, artificial neural network, grey relational analysis, utility concept , response surface methods, taguchi technique etc. to find out optimum cutting condition. Grey relational analysis is used to understand and also suitable for analyzing the multi response problems.

2 LITERATURE REVIEW

Nihat Tosun & Hasim Pihtili performed the optimization of the face milling process of 7075 aluminium alloy by using the gray relational analysis for both cooling techniques of conventional [1] cooling and minimum quantity lubrication (MQL), considering the performance characteristics such as surface roughness and material removal rate. Experiments were performed under different cutting conditions, such as spindle speed, feed rate, cooling technique, and cutting tool material. The cutting fluid in MQL machining was supplied to the interface of work piece and cutting tool as pulverize. An orthogonal array was used for the experimental design. Optimum machining parameters were determined by the gray relational grade obtained from the gray relational analysis.

Dr. Mike S. Lou, Dr. Joseph C. Chen & Dr. Caleb M. Li [2] developed a multi-regression model that can predict the surface roughness on the surface of the specimen (Al-6061) on which end milling operation has been carried out using a CNC machine. They found out that feed rate is the most significant machining parameter used to predict the surface roughness in the multiple regression model.

Surasit Rawangwong, Jaknarin Chatthong, Romadorn Burapa, and Worapong Boonchouytan [3] investigated the effects of cutting parameters on the surface roughness in semi-solid AA 7075 face milling. The results of the research could be applied in the manufacture of automotive components. The study was conducted by using computer numerical controlled (CNC) milling machine with 63 millimeter diameter fine type carbide tool with twin cutting edge. For this experiment they have used factorial designs and the results showed that the factors affected the surface roughness were the feed rate and the spindle speed while the depth of cut did not affect the surface roughness. The result also indicates that lower value of speed and lower feed tended to decrease the surface roughness.

Mathew A. Kuttolamadom, Sina Hamzehlouia and M. Laine Mears [4] studied the effects of machining feed on surface roughness in milling Al-6061. A controlled milling experiment on 6061 aluminium depicted the relationship between feed and surface quality. These results were used to recommend machining practices for improved surface quality and hence minimizing cycle time, thus improving productivity. The contribution of each parameter was inferred, and a recipe prescribed, i.e., increases the feed up until a cutoff surface roughness limit is reached and then increases the speed within the roughness range, to maximize productivity.

3 OBJECTIVE OF PRESENT WORK

The objective of the present work is to obtain an optimal setting of milling process parameters (cutting speed, feed rate, depth of cut) resulting in an optimal value of the surface roughness, power and temperature when machining of Al-7075. The effects of the selected milling process parameters (Speed, Feed, Depth of Cut and Coolant) on Surface roughness, power and temperature, the subsequent optimal settings of the parameters have been accomplished using Grey Relational Analysis. The results obtained from Grey Relational Analysis are validated and optimal parameters are obtained.

4 PLANS OF EXPERIMENTAL WORKS

The present work has been done through the following plan.

Steps involved are:

1. Checking and preparing the milling machine ready for performing the machining operation.
2. Cutting Al-7075 Plate by band saw machine to get desired dimension of the work pieces.
3. Flattening the surface of work piece that is to be milled and arranging the milling cutter for the experiment.
4. Design the orthogonal array to conduct experiments by milling parameters.
5. Performing milling experiments as per design on specimens involving various combinations of process control parameters like spindle speed, feed and depth of cut.
6. Measure surface roughness with the help of a portable stylus-type Talysurf (Taylor Hobson, mitutyo).
7. Measure cutting temperature using the infrared thermometer at the interference of cutting tool and work piece
8. Measure the power consumed with respect to the feed rates and speed with the help of wattmeter
9. Tabulate these values in the L_{16} orthogonal array designed
10. Finding the optimum control parameters using Grey Relation so that minimum surface roughness, power consumed and cutting temperature is achieved.

4.1 Experimental details

Work material	- Al 7075.
Machine tool	- Universal milling machine.
Tool material	-HSS milling cutter.
Other equipment used	- Talysurf and support stand

4.2 Work material

The work piece material is Al-7075, which is extensively used in the aerospace industry. 7075 is widely used for construction of aircraft structures, such as wings and fuselages. Its strength and light weight are also desirable in other fields. Rock climbing equipment and bicycle components are commonly made from 7075 aluminium alloy. The chemical and mechanical properties of Al-7075 are shown in Table 1 respectively. The reason for selecting Al-7075 as work material is that it has the ability to produce greater surface finish than any other aluminium alloy in 7xxx series. In general 7xxx aluminium alloys produce good surface finish.

Zn	Mg	Cu	Fe	Si	Ti	Cr	Al
5.1–6.1	2.1–2.9	1.2–2.0	Max 0.5	Max 0.4	Max 0.2	0.18-0.28	87.2-91.4

Table 1.Chemical composition (wt %) of Al 7075 alloy

4.3 Machine tool

Milling tests were conducted on the Al-7075 specimen with the use of vegetable oil and diesel as lubricants. The experimental setup is shown in Figure 1.

Figure 1. Experimental setup of milling machine

4.4 The measurement of surface roughness

The surface roughness values of the machined surface were measured in order to analyze the surface finish quality. So Surface Roughness is measured with the help of Talysurf shown in figure 2.

Figure 2: Talysurf (surface roughness measuring machine)

In order to measure the surface roughness with good accuracy, a stand has been fabricated to support the Talysurf while taking the measurements. The support stand is shown in figure 3.

Figure 3. Support stand for Talysurf

4.5 The measurement of cutting temperature

The cutting temperature values at the interference of milling cutter and work piece were measured in order to analyze the wear of milling cutter. So [4] cutting temperature is measured with the help of Infrared Thermometer shown in figure 4.

Figure 4. Infrared Thermometer

4.6 The measurement of power consumed

The power consumed by the milling machine for various levels of feed rates and speed were measured in order to analyze quality of machine tool with respect to energy consumption. So power consumed is measured with the help of wattmeter.

4.7 Taguchi orthogonal array for experiments

In this experiment three controllable parameters with four levels have been considered.
Factors considered for present work are

1. Speed
2. Feed
3. Depth of Cut (DOC)
4. Coolant

L_{16} orthogonal array have been chosen for conducting experiments. Experiments are performed according to this design and the values of surface roughness are recorded for each experimental run. The responses are measured with the help of Talysurf.

5 GREY RELATIONAL ANALYSES

Milling tests have been performed on Al7075 work material by using milling machine with HSS cutter by considering different process parameter combinations. The surface roughness, cutting temperature and power are selected as indices to evaluate cutting performance in milling. Therefore this is considered as response characteristic in this study. Basically surface roughness, temperature and power should be minimized in any metal cutting process for better performance. In this experiment three controllable parameters are considered and each parameter is set at four levels. The parameters and its levels are shown in Table 2.

Factors considered for present work are

1. Speed
2. Feed
3. Depth of Cut (DOC)
4. Coolant

Table 2: process parameters and their levels

Levels	Factors			
	Speed	Feed	DOC	Coolant
1	450	315	0.4	Diesel
2	730	400	0.6	Vegetable oil
3	900	630	0.8	
4	1120	800	0.1	

For full factorial design, the experimental runs required are $(\text{levels})^{(\text{factors})}$ equal to $4^3 = 64$. To minimize the experimental cost, fractional factorial design is chosen, ie.$4^{3-1} = 16$ runs. Therefore Taguchi experimental design L_{16} is chosen for conducting experiments Table 3.

Table 3: L16 Orthogonal array

Expt. Run	Factors			
	Speed (rpm)	Feed(m m/rev)	DOC (mm)	Coolant
1	450	315	0.4	DIESEL
2	450	400	0.6	DIESEL
3	450	630	0.8	VEGOIL
4	450	800	1.0	VEGOIL
5	730	315	0.6	VEGOIL
6	730	400	0.4	VEGOIL
7	730	630	1.0	DIESEL
8	730	800	0.8	DIESEL
9	900	315	0.8	DIESEL
10	900	400	1.0	DIESEL
11	900	630	0.4	VEGOIL
12	900	800	0.6	VEGOIL
13	1120	315	1.0	VEGOIL
14	1120	400	0.8	VEGOIL
15	1120	630	0.6	DIESEL
16	1120	800	0.4	DIESEL

Surface roughness, Temperature and power values are analysed using Grey Relation analysis by applying lower is better as quality character. Data pre-processing is a means of transferring the original sequence [5] to a comparable sequence. Depending on the characteristics of a data sequence, there are various methodologies of data pre-processing available for the grey relational analysis.

When the “lower is better” is a characteristic of the original sequence, then the original sequence should be normalized as follows

$$x^*_i(k) = \frac{\max x^o{}_i(k) - x^o{}_i(k)}{\max x^o{}_i(k) - \min x^o{}_i(k)}$$

$$x^*_i(k) = \frac{x^o{}_i(k)}{x^o{}_i(1)}$$

Where *i*= 1…, *m; k*= 1…,*n..m* is the number of experimental data items and *n* is the number of parameters. $x^o{}_i(k)$ denotes the original sequence, $x^*{}_i(k)$ the sequence after the data pre-processing, max $x^o{}_i(k)$ the largest value of $x^o{}_i(k)$, min $x^o{}_i(k)$ the smallest value of $x^o{}_i(k)$, and x^o is the desired value.

5.1 Grey relational coefficient

In grey relational analysis, the measure of the relevancy between two systems or two sequences is defined as the grey relational grade. When only one sequence, x_o (k), is available as the reference sequence, and all other sequences serve as comparison sequences, it is called a local grey relation measurement.

After data pre-processing is carried out, the grey relation coefficient $\xi_i(k)$ for the K_{th} performance characteristics in the i_{th} experiment can be expressed as:

$$\Delta_{oi} = \| x^*{}_o(k) - x^*{}_i(k) \|$$

Where,$\Delta_{oi}$is the deviation sequence of the reference sequence and the comparability sequence $x^*{}_o(k)$ denotes the reference sequence and $x^*{}_i(k)$ denotes the comparability sequence. ζ is distinguishing or identification coefficient: $\zeta \in [0, 1]$ (the value may be adjusted based on the actual system requirements). A value of ζ *is* the smaller and the distinguished ability is the larger. $\zeta = 0.5$ is generally used.

5.2Grey relational grade

After the grey relational coefficient is derived, it is usual to take the average value of the grey relational coefficients as the grey relational grade. The grey relational grade is defined as follows

$$\gamma_i = \frac{1}{n} \sum_{k=1}^{n} \xi_i(k)$$

5.3 Response tables for the parameters

The response tables for the respective parameters is the average of the responses with respect to the parameter like speed feed depth of cut

Table 4: Response table for Power

Response table for Power			
Levels	Speed	Feed	DOC
1	250	237.5	237.5
2	187.5	275	275
3	225	262.5	250
4	350	237.5	250
Delta	162.5	37.5	37.5
Rank	1	2	2

Table 5: Response table for Temperature

Response table for Temperature			
Levels	Speed	Feed	DOC
1	39.7	54.275	51.475
2	48.175	53.95	7.75
3	60.075	54.475	6.75
4	69.275	54.525	7.75
Delta	29.575	0.575	44.725
Rank	2	3	1

Table 6: Response table for Surface roughness (Rq)

Response table for Rq			
Levels	Speed	Feed	DOC
1	0.0975	0.085	0.0825
2	0.085	0.0725	0.105
3	0.06	0.08	0.0725
4	0.085	0.09	0.0675
Delta	0.0375	0.0175	0.0375
Rank	2	1	2

From the above tables, Delta represents the range of the mean of corresponding factors and rank represents the influence of a particular factor over other factors. From table 4, the rank of factor 'speed' is 1, which means speed has a greater influence over output (Power) when compared with other factors like feed [6] and depth of cut (DOC). The level with delta is considered as optimal level for each factor in table 4

Similarly from table 5 delta is highest for Depth of cut and has rank 1 which means it influences the output response temperature over the speed and feed rates. Also from table 6 feed has the highest delta with rank 1 indicating that feed rate influences surface roughness (Rq) over speed and depth of cut.

5.4 Main effects plot for the responses

The main effects depict the ranking of the response and show which parameter influences the response the most

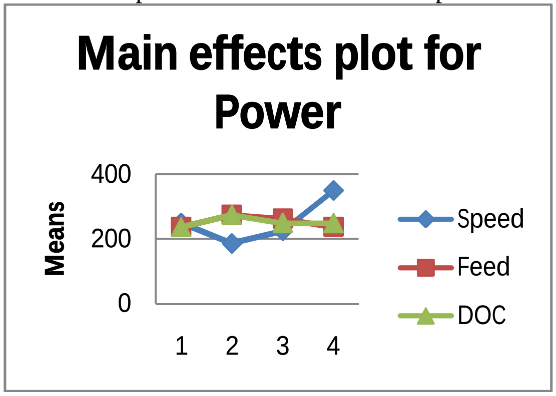

Figure 5: Main effects plot for Power

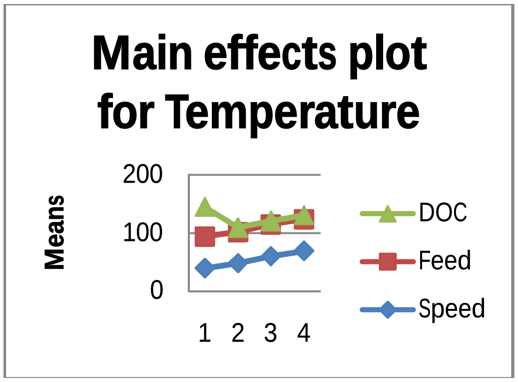

Figure 6: Main effects plot for Temperature

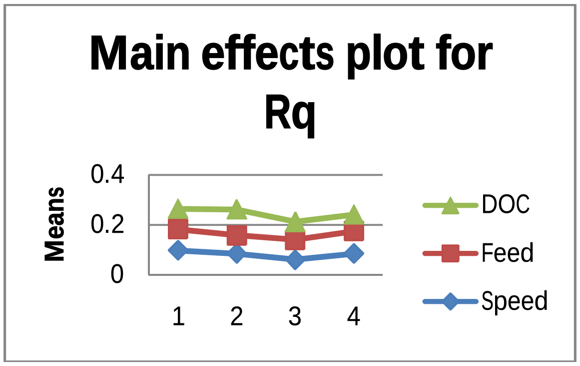

Figure 7: Main effects plot for R_q

5.5 Estimation of optimal levels of process parameters for responses

Optimal levels of parameters for responses are estimated by Grey relation analysis. Optimal levels of process parameters for multi [7] responses are obtained as follows

1. Determination of the mean grey relational grade for each level of the parameters.
2. Representations of mean grey relational grade values in response graph.

5.6 Determination of the mean grey relational grade

The procedure for calculating mean grey relational grade is as follows

a. Sum of the grey relational grades by parameter level for each column in the [8, 9] orthogonal array,
b. Calculate the average of previous step.

5.7 Response graph

The response graph is graph drawn between each level of the parameters and mean grey relational grades values. The optimal levels for Process parameter are identified from response graph i.e. corresponds to the highest grade value among the existing levels.

Table 7: Response table for Grey relation

Response table for grey relation			
Levels	Speed	Feed	DOC
1	0.35975	0.648302	0.595564
2	0.437112	0.676298	0.724098
3	0.597361	0.633551	0.722179
4	1.13731	0.573382	0.75
Delta	0.77756	0.102916	0.154436
Rank	1	3	2

From the table 7, speed has the highest delta and is ranked 1 which indicates that the parameter speed influences the output responses surface roughness (Rq), power consumed and cutting temperature over depth of cut and feed rates

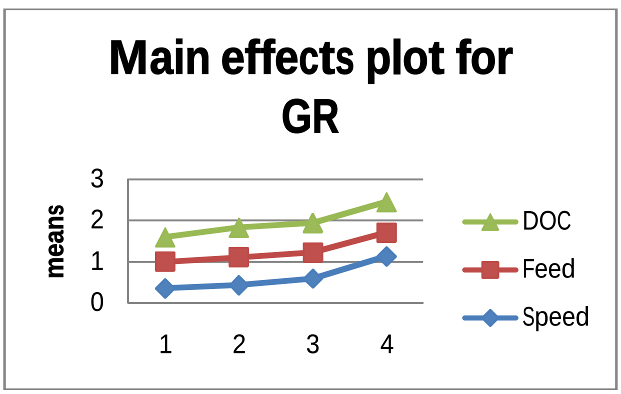

Figure 8: Main effects plot for Grey Relation

Table 8: Optimal combination of parameters

	Level	OP
Speed	4	1120
Feed	4	800
DOC	4	1

From table 8 and figure 8 the optimum combination of parameters is Speed(4), Feed(4) and depth of cut (4), if the confirmation test is performed then the optimal values of the surface roughness (Rq), power consumed and cutting temperature is obtained.

6 CONCLUSIONS

Aluminium alloys is one of the best materials out there which is best suited for high speed machining. Unlike steel, the surface finish improves with increase in speed. Out of all the factors taken, speed has the most influence on the surface roughness, cutting temperature and power consumed. Surface roughness, Temperature and power values are analysed using Grey Relation analysis by applying lower is better as quality character. Optimal levels of parameters for responses are estimated by Grey relation analysis. The response graph is graph drawn between each level of the parameters and mean grey relational grades values. The optimal levels for Process parameter are identified from response graph i.e. corresponds to the highest grade value among the existing levels.

In this work, effects of various cutting parameter in milling of 7075 Al alloy have been investigated on surface roughness, cutting temperature and power consumption. The following conclusions are drawn based on the above experimental work:

1. Feed rate is found the most significant effect on surface roughness. The increase of feed rates increases the surface roughness.
2. Grey Relation analysis shows that speed has a greater influence over Power when compared with other factors like feed and depth of cut (DOC).
3. Depth of cut influences the output response temperature over the speed and feed rates
4. Power Consumption is increased with increase in cutting speed, feed rate and depth of cut. Cutting speed is most effective parameter on power consumption
5. Cutting speed influences the responses surface roughness, cutting temperature and power consumed. The second factor which influences the responses is Depth of cut.

REFERENCES

[1] Saedon, J.B.; Jaafar, N.; Yahaya, M.A.; Mohamad Nor, N.H.; Husain, H., "A study on kerf and material removal rate in wire electrical discharge machining of Ti-6Al-4V: multi-objectives optimization," Technology, Informatics, Management, Engineering, and Environment (TIME-E), 2014 2nd International Conference on, vol., no., pp.111,116, 19-21 Aug. 2014.

[2] Yanmin Xie; Shiren Yin; Zhengzhi Luo, "Robust Optimization for Deep-Drawing Process of Sheet Metal Based on CAE with Grey Relational Analysis Method," Fuzzy Systems and Knowledge Discovery, 2008. FSKD '08. Fifth International Conference on, vol.4, no., pp.345,349, 18-20 Oct. 2008.

[3] Chen Yuqing; Wang Wenping, "Research on the service performance evaluation of the manufacturing enterprise's producer service value network based on ANP-GRAP," Grey Systems and Intelligent Services, 2013 IEEE International Conference on , vol., no., pp.344,348, 15-17 Nov. 2013.

[4] Jalil, I.E.A.; Muda, A.K.; Shamsuddin, S.M.; Ralescu, A., "Geometrical feature based ranking using grey relational analysis (GRA) for writer identification," Soft Computing and Pattern Recognition (SoCPaR), 2013 International Conference of , vol., no., pp.152,157, 15-18 Dec. 2013.

[5] Xinchun Huang; Dinghua Zhang; Zhenchao Yang; Changfeng Yao; Ying Mao, "Simulation of effect of milling parameters on milling force in High-Speed Milling of titanium alloy TC4," Mechanic Automation and Control Engineering (MACE), 2010 International Conference on , vol., no., pp.5291,5294, 26-28 June 2010.

[6] Yao Yunping; Li Ying; Chen Qi; Wang Sumei, "Optimize CNC Milling Parameters On-line," Measuring Technology and Mechatronics Automation (ICMTMA), 2010 International Conference on , vol.2, no., pp.856,859, 13-14 March 2010.

[7] Sousa, R.C.; Freitas, Paulo P., "Influence of ion beam milling parameters on MRAM switching," Magnetics, IEEE Transactions on , vol.37, no.4, pp.1973,1975, Jul 2001.

[8] Jian Tang; Wen Yu; Lijie Zhao; Heng Yue; Tianyou Chai, "Modeling of operating parameters for wet ball mill by modified GA-KPLS," Advanced Computational Intelligence (IWACI), 2010 Third International Workshop on , vol., no., pp.282,287, 25-27 Aug. 2010.

[9] Konrad, H.; Isermann, R.; Heintz, N., "Model based fault detection in milling by classification of estimated cutting parameters," Systems, Man and Cybernetics, 1995. Intelligent Systems for the 21st Century., IEEE International Conference on , vol.3, no., pp.2193,2198 vol.3, 22-25 Oct 1995.