Investigation of Al 6061 Metal Matrix Reinforced With FLY ASH in CNC Turning Process Using Design of Experiments

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Abstract- *The present work is focusing on an optimization of the CNC turning process for the metal matrix composite. Metal matrix composite (MMCs) are one of the widely known composites because of their superior properties such as high strength, hardness, stiffness, and corrosion resistances. Al 6061 metal matrix is reinforced with fly ash which widely used in automotive industries and aerospace industries. The present work is focusing on multi response optimization of CNC turning process for Al6061 composite. The study provided to minimize the damage events occurring during CNC turning process for composite material. A statistical approach used to analysis experiment data. Taguchi method with grey relational analysis was used to optimize the machining parameters with multiple performance characteristics in machining MMC Al6061-Flyash .The results shows that the maximum feed rate, low spindle speed are the most significant factors which affect the drilling process and the performance in the drilling process can be effectively improved by using this approach.*

Keywords- MMC, Surface Roughness,Grey relational analysis ,Stir Casting , Taguchi method

I. INTRODUCTION

The technological advances in various sectors have created demand for newer materials, where they are required to perform in stringent conditions - high pressure & temperature, highly corrosive environments, with high strength requirement, which the conventional materials failed to service. This has triggered the development needs for engineering materials to cater to customized needs. Industry has recognized the ability of composite materials to produce high-quality, durable, cost-effective products.

Light-metal matrix composites which have been employed in the automotive and aircraft manufacturing industries consist of mostly aluminium as their main matrix. The components which are produced there consist of hardness and wear resistance and also give a high degree of damage tolerance.

Ajay Singh et al Examined the behavior of aluminium cast alloy (6063) with alumina composite produced by the stir casting technique for different percentage of alumina powder was used as reinforcement phase in Matrix metal. Various mechanical tests like tensile test, hardness test, and impact test were performed on the samples of AMMC. It is also proved that the experimental studies reveal the increase in percentage of alumina in aluminium matrix improves the strength of the matrix material. Since uniform distribution of alumina particles in aluminum matrix improves the hardness of the matrix material.[1].A.A. Premnath et al In this literature, aluminum (Al6061) alloy reinforced with aluminium oxide (Al_2O_3) particle using various sixe (25,50& 80 microns) with constant volume fraction of about 10% is fabricated by stir casting method. The variation in mechanical properties such as hardness, tensile strength with respect to increase in particle size of alumina was investigated. The investigation shows that the results illustrate the hardness and yield strength increases with decrease in particle size of alumina.[2].

M K Surappa et al this paper deals with the fundamentals of composite and their classification. An elaborate review on Aluminum matrix composites, their types, properties, applications and opportunities are given, which provides a basic foundation for the research on AMC.[3]

Rathod Abhik et al investigated the mechanical and wear behavior of Aluminum 2014 Reinforced with fly ash for brake pads. In this Al MMC with fly ash Provides the better strength & wear resistance compared to grey cast iron.[4].S.K.Rhee et al examined the wear property for polymers sliding against metal surfaces. In this property of the Al6061 & fly ash is greater when compared to grey cast iron and steel.[5]. Y.Sahin et al Investigated the wear behavior of aluminium alloy and its composites reinforced with fly ash particles were analyzed using statistical analysis. In this the aluminum and fly ash wear behavior were analyzed.[6]

Guo.H Fuzzy (1985)[7]Use The grey relational analysis for optimizing the drilling process parameters for the work piece surface roughness and the burr height is introduced. Various drilling parameters, such as feed rate, cutting speed, drill and point angles of drill were considered. An orthogonal array was used for the experimental design. Optimal machining parameters were determined by the grey relational grade obtained from the grey relational analysis for multi-performance characteristics (the surface roughness and the burr height). Experimental results have shown that the surface roughness and the burr height in the drilling process can be improved effectively through the new approach. Stein and Dornfeld [8] presented a study on the burr height, thickness, and geometry observed in the drilling of 0.91-mm diameter through holes in stainless steel 304L. They presented a proposal for using the drilling burr data as part of a process planning methodology for burr control. To minimize the burr formed during drilling, Ko and Lee [9] investigated the effect of drill geometry on burr formation. They showed that a larger point angle of drill reduced the burr size. Sakurai et al. [10] have also tried to change the cutting conditions and determined high feed rate drilling of aluminum alloy. The researchers examined cutting forces, drill wear, heat generated, chip shape, hole finish, etc. Gillespie and Blotter [11] studied experimentally the effects of drill geometry, process conditions, and material properties. They have classified the machining burrs into four types: Poisson burr, rollover burr, tear burr, and cut-off burr. Valuable review about burr in machining operation provided important information. [12].

II. MATERIALS AND METHODS

Al6061 metal matrix composite reinforced with flyash is produced by stir casting method . the chemical compostion of Al6061-Flyash is tabulated in table 1.

Table 1 Composition of ZnGr

Component	Al6061	Fly ash
Amount (% of volume)	90	10

Grey Relational Analysis

The black box is used to indicate a system lacking interior information. Nowadays, the black is represented, as lack of information, but the white is full of information. Thus, the information that is either incomplete or undetermined is called Grey. A system having incomplete information is called Grey system. The Grey number in Grey system represents a number with less complete information. The Grey element represents an element with incomplete information. The Grey relation is the relation with incomplete information. Those three terms are the typical symbols and features for Grey system and Grey phenomenon. There are several aspects for the theory of Grey system:

1.Grey generation: This is data processing to supplement information. It is aimed to process those complicate and tedious data to gain a clear rule, which is the whitening of a sequence of numbers.

2. Grey modeling: This is done by step 1 to establish a set of Grey variation equations and Grey differential equations, which is the whitening of the model.

3. Grey prediction: By using the Grey model to conduct a qualitative prediction, this is called the whitening of development.

4. Grey decision: A decision is made under imperfect countermeasure and unclear situation, which is called the whitening of status.

5. Grey relational analysis: Quantify all influences of various factors and their relation, which is called the whitening of factor relation.

6. Grey control: Work on the data of system behavior and look for any rules of behavior predict future's behavior, the prediction value can be fed back into the system in order to control the system.

This study will adopt all six above- mentioned research steps to develop a vendor evaluation model based on Grey relational analysis, and apply to vendor evaluation and selection. All details will be discussed in the following sections. The Grey relational analysis uses information from the Grey system to dynamically compare each factor quantitatively. This approach is based on the level of similarity and variability among all factors to establish their relation. The relational analysis suggests how to make prediction and decision, and generate reports that make suggestions for the vendor selection. This analytical model magnifies and clarifies the Grey relation among all factors. It also provides data to support quantification and comparison analysis. In other words, the Grey relational analysis is a method to analyze the relational grade for discrete sequences. This is unlike the traditional statistics analysis handling the relation between variables. Some of its defects are: (1) it must have plenty of data; (2) data distribution must be typical; (3) a few factors are allowed and can be expressed functionally. But the Grey relational analysis requires less data and can analyze many factors that can overcome the disadvantages of statistics method.

III. DESIGN OF EXPERIMENT

The experimental layout for the machining parameters using the L_9 orthogonal array design the drilling machine is used for the in this study. The radial drilling machine was adapted to drilling process and HSS tool with dia of 8 mm was used. The surface roughness (SR) and material removal rate (MRR) are two essential part of a product in any drilling machining operation. The theoretical surface roughness is generally dependent on many parameters such as the tool geometry, tool material and work piece material. The array having a three control parameter and three levels are shown in table 1. This method, more essentials all of the observed values are calculated based on the maximum the better and the minimum the better. In the present study spindle speed depth of cut feed rate have been selected as design factor. While other parameter have been assumed to be constant over the Experimental domain. This Experiment focuses the observed values of MRR and SR were set to maximum, intermediate and minimum respectively. Each experimental trial was performed with three simple replications at each set value. Next, the optimization of the observed values was determined by comparing the standard analysis and grey relational analysis.

Table 2 CNC Turning parameters and levels

Designation	Parameters	Level 1	Level 2	Level 3
A	Spindle Speed(rpm)	1500	2000	2500
B	Feed Rate (mm/min)	0.3	0.6	0.9
C	Depth of cut (mm)	0.10	0.15	0.20

IV. RESULT AND DISCUSSION

The algorithm of grey relational analysis coupled with principal analysis to determine the optimal combinations of the cutting parameters for rough cutting process in high-speed drilling operation is described step by step as follow:

1) Convert the experimental data into S/N values.
2) Normalize the S/N ratio.
3) Calculate the corresponding grey relational coefficients.
4) Calculate the grey relational grade using principal component analysis.
5) Select the optimal levels of cutting parameters.
6) Conduct confirmation experiments.

Optimal combination of the cutting parameters

The performance characteristics obtained from the experimental results are initially converted into S/N ratio to search for a desirable result with the best performance and the smallest variance. Thus, metal removal rate is of higher-the-better type. As for surface roughness, it can be clearly recognized as one of lower the-better type. The experimental results are substituted into Equation 1 to calculate the S/N ratios of surface roughness and metal removal rate shown in Table 4.

$$S/N=-10\log 1/n\sum y_i^{2} \qquad (1)$$

All the original sequences of S/N ratio in Table 3 are then substituted into Equation 2 to be normalized. The outcomes result is shown in Table 4 and denoted as Z_i and Z_j for reference sequence and comparability sequence respectively. In order to objectively the relative importance for each performance characteristic in grey relational analysis, principal component analysis is specially introduced here to determine the corresponding weighting values for each performance characteristic. The elements of the array for multiple performance characteristics listed in Table 5 represent the grey relational coefficient of each performance characteristic.

$$Z^*_{ij}(k) = z_{ij}(k) - \min z_{ij}(k) / \max z_{ij}(k) - \min z_{ij}(k) \qquad (2)$$

Table 3 S/N ratio for MRR and SR

Trials	A	B	C	S/N ratio for MRR	S/N ratio for SR
1	1	1	1	38.0138955	-3.045766888
2	1	2	2	34.8639216	-2.60667537
3	1	3	3	33.0873818	-6.444385895
4	2	1	2	37.8940731	-3.806633963
5	2	2	3	39.0384015	-5.343434568
6	2	3	1	33.1162099	-4.760922063
7	3	1	3	35.7591225	-1.138097027
8	3	2	1	36.5963638	-2.383728154
9	3	3	2	32.6633071	-5.845121427

Table 4 Normalized values of S/N Ratio for MRR and SR

Trial No	Normalized values of S/N Ratio Z_{ij}	
	MRR(Z_i)	SR (Z_i)
1	0.839295555	0.359511
2	0.345189325	0.276762
3	0.06652054	1
4	0.820500156	0.502901
5	0.999999995	0.79252
6	0.071042523	0.682742
7	0.485610906	0
8	0.616940927	0.234746
9	0	0.887065

Table 5 Grey Relational Coefficients for MRR and SR

Trial No	Grey Relational Coefficient		Grey Grade
	MRR	SR	
1	0.3733306	0.581726	0.477528
2	0.5915834	0.6436979	0.617641
3	0.8825805	0.3333333	0.607957
4	0.3786444	0.4985538	0.438599
5	0.3333333	0.3868414	0.360087
6	0.8755915	0.4227465	0.649169
7	0.5072996	1	0.75365
8	0.4476512	0.6805071	0.564079
9	1	0.3604733	0.680237

The response table of Taguchi method is employed here to calculate the average grey relational grade for each cutting parameter level. It is done by sorting the grey relational grades corresponding to levels of the cutting parameter in each column of the orthogonal array, and taking an average on those with the same level. Using the same method, calculations are performed for each cutting parameter level and the response table is constructed as shown in Table 6. Basically, the larger the grey relational grade is the better the corresponding multiple performance characteristic. From the response table for the grey relational grades shown in Table 05, the best combination of the cutting parameters is the set with spindle low speed, high feed rate and middle depth of cut.

Table 6 Optimum Level for Drilling Parameter

	Factors	1	2	3
A	Spindle Speed	0.567709	0.482618	**0.665989**
B	Feed Rate	0.556592	0.513936	**0.645788**
C	Depth of Cut	0.505951	**0.624922**	0.585443

V. CONCLUSION

In this study the optimum condition for CNC Turning process of Al6061-FlyAsh find out by design of experiments(DOE) by using Grey Relational Analysis .The optimum conditions for minimization of surface roughness and maximization of metal removal rate is maximum spindle speed(2500 rpm) ,maximum Feed rate(0.9 mm/min) and nominal Depth of cut (0.20 mm).

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