Parametric Optimization in Drilling of Al–SiC Composite Using Taguchi Method

Manoj Modi, Gopal Agarwal, V.Patil, Umesh Bhatia, Rishabh Pancholi

Abstract-Optimization is one of the best techniques used in manufacturing industries for improving quality of product with lower cost. This report describes the effective approach for the single response optimization of drilling parameters based on the Taguchi's method. This research work also reported about the influence of input process parameters i.e. spindle speed and tool diameter on the material removal rate (MRR). Taguchi L_9 orthogonal array was used for planning and conduction of experiments. Analysis of Variance (ANOVA) was carried out to find which drilling parameters significantly affect the output response and it also determined the percentage contribution of individual parameter over the response.

Keywords: Drilling, Spindle Speed, MRR, Taguchi, and ANOVA etc.

1.Introduction

Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use of multi-point cutting tools called drills or drill bits. Drilling is a continuous machining process. Various cutting tools are available for drilling, but the most common is the twist drill. Wide varieties of drill processes are available to serve different purposes. With the rapidly growing technologies quality and productivity are the major concern. Productivity is concerned with the material removal rate (MRR) during machining operation and quality refers to the product characteristics. So the quality and productivity can be improved through parameters optimization. There are number of research works related to various drilling parameters optimization for achieving the performance responses. Among them surface roughness, material removal rate (MRR) and thrust forces on drill bit are the major performance responses. Material removal rate (MRR) is the primary response variable while considering productivity. The material removal rate depends on input parameters and the machine during drilling operation. So the primary objective of optimization analysis during drilling operation is to optimize the input parameters. Also material removal rate (MRR) play a major role in surface roughness. The primary objective in all the research works relating to drilling parameter optimization is to optimize the input parameters such as spindle speed, feed rate, drill bit diameter etc. Simply the optimization means improving the material removal rate and reducing the surface roughness value. The other aspect governing the drilling parameter optimization is quality of the product. Quality relating to the product characteristics like surface roughness, wear resistance, cost etc. Design of experiment and analysis of Experimental data play a significant role in parameters optimization and cost of optimization. Among all the design of experiment techniques Taguchi method is the simplest one. Analysis of variance (ANOVA) is used for analyzing the data obtained during experiment. Many of the researches in parameter optimization uses wide variety of design experiments and analysis focused on different performance, parameters and different materials. So this project concentrated on drilling parameters optimization in different material using Taguchi method.

[1]*Department of Mechanical Engineering, Acropolis Institute of Technology and Research, Indore, India.*

[1]**Corresponding Author E-mail: manojmnitjaipur1@gmail.com*

[2]*Department of Mechanical Engineering,, Malaviya National Institute of Technology, Jaipur, Rajasthan, India.*

[3,4,5,]*Department of MechanicalEngineering, Acropolis Institute of Technology and Research, Indore, India.*

2. Literature review

Rahul Bhole, R.S. Shelke [1], have considered the input parameters namely spindle speed, drilled hole depth and feed rate. Prediction were analyzed with actual data by conducting drilling experiments using the L9 orthogonal array on VMC drilling machine on material AISI 316L block using HSS twist drills and the measured results were analyzed by Minitab 16. Analysis of variance is used to determine most significant control factors affecting the surface roughness & MRR from Taguchi S/N ratio Analysis. Vignesh V. Sasikumar R. [2], have performed the experimental work and used the TM to optimize the rocess parameters such as cutting speed, feed & drill diameter to obtain the minimum surface roughness (Ra). Drilling experiments were conducted on a radial drilling machine using L9 orthogonal array. Analysis of Variance (ANOVA) was used to determine the most significant control factors affecting surface roughness. The results obtained showed that drill diameter was the most significant factor for surface roughness. M. Sundeep, M Sudhahar [3], have studied experimentally the behavior of Austenitic Stainless Steel (AISI 316) using L9 orthogonal array design of experiment of Taguchi methodology. The main objective of this work was to identify lowest thrust force and more Material Removal Rate (MRR) through experimental analysis by using ANOVA. The process parameters in this work are spindle speed, feed rate and drill diameter. The final results showed that more material removal rate occur at cutting speed 1250 rpm and feed rate 0.02mm using 8 mm drill bit tool. It is also observed in this work that cutting speed play a dominating role in SR and MRR. P. Singh and K. Bhambri [4], reported on optimization of drilling parameters of AISI D3 Steel using

Abrasive assisted HSS drill. The experiment included supply of silicon carbide abrasive having grain size 1200μm mesh size through abrasive slurry with coolant. Nisha Tamta, R.S. Jadoun [5], applied Taguchi Method for parametric optimization of drilling machining process parameters for minimization of surface roughness (Ra). The drilling operation was performed on CNC machine with Aluminum Alloy 6082 material and HSS tool. Spindle speed, feed rate & drilling depth are the input machining parameters in this experimental work. The effect of drilling parameters on material was concluded by using the S/N ratio and Analysis of Variance (ANOVA). The optimum parameter combination for these experiments to minimize surface roughness was obtained at spindle speed 3000 rpm, 15mm/min, feed rate with 9 mm drilling depth. Kurt et al. [6] optimized the surface finish and hole diameter accuracy in the dry drilling of Al 2024 alloy. They observed that the feed rate, cutting speed , and differently coated drills affect surface finish by 35.46%, 6.15%, and 53.84% and, the depth of drilling, feed rate , cutting speed and differently coated drills affect the hole diameter error of 8.18%, 74.09%, 6.04%, and 0.10% for the dry drilling of Al 2024 alloy. Kurt et al. [7] investigated the role of different coating, point angle, cutting speed and feed rate on the hole quality (hole size, surface roughness, roundness and radial deviation of produced hole) in drilling of Al 2024 alloy . Effective results have been obtained using low cutting speed and feed rate and the best hole quality obtained from near the bottom of the produced hole.

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3. Problem Definitions

On the basis of above Literature Review the drilling of Al-SiC composite material through drilling machine is the untouched area this is why the objective of this research work is to optimize the drilling machining process parameters for the maximization of Metal Removal Rate.

4. Methodology

4.1. Analysis Of Variance (ANOVA) -

The Analysis Of Variance (ANOVA) is a powerful and common statistical procedure in the social sciences. It is the application to identify the effect of individual factors. In statistics, ANOVA is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables. In its simplest form ANOVA gives a statistical test of whether the means of several groups are all equal, and therefore generalizes.

4.2 Taguchi Method

The Taguchi technique is a methodology for finding the optimum setting of the control factors to make the product or process insensitive to the noise factors. Taguchi's techniques have been used widely in engineering design, and can be applied to many aspects such as optimization, experimental design, sensitivity analysis, parameter estimation, model prediction, etc. The distinct idea of Taguchi's robust design that differs from the conventional experimental design is that of designing for the simultaneous modelling of both mean and variability. Taguchi based optimization technique has produced a unique and powerful optimization discipline that differs from traditional practices. While, traditional experimental design methods are sometimes too complex and time consuming, Taguchi methodology is a relatively simple method. Taguchi method uses a special highly fractionated factorial designs and other types of fractional designs obtained from orthogonal arrays (OA) to study the entire experimental region of interest for experimenter with a small number of experiments. This reduces the time and costs of experiments, and additionally allows for an optimization of the process to be performed. The columns of an OA represent the experimental parameters to be optimized and the rows represent the individual trials (combinations of levels). Traditionally, data from experiments is used to analyze the mean response. However, in Taguchi method the mean and the variance of the response (experimental result) at each setting of parameters in OA are combined into a single performance measure known as the signal-to-noise (S/N) ratio. Depending on the criterion for the quality characteristic to be optimized, different S/N ratios can be chosen:

- Smaller-The-Better
- Larger-The-Better
- Nominal-The-Best

Smaller – The –Better -
The Signal-To-Noise ratio for the Smaller-The-Better is:
S/N = -10 *log (mean square of the response)

$$S/N = -10*\log(\Sigma(Y^2)/n)$$

Larger – The – Better -
The Signal-To-Noise ratio for the bigger-the-better is:
S/N = -10*log (mean square of the inverse of the response)

$$S/N = -10*\log(\Sigma(1/Y^2)/n)$$

Where n = number of measurements in trial/row, in this case n = 1, 2…, 9 and Yi is the ith measured value in a run/row. i =1, 2………

Nominal – The – Better -
The S/N equation for the Nominal-The-Best is:
S/N = 10 * log (the square of the mean divided by the variance)

$$\frac{S}{N} = 10 * \log\left(\frac{\overline{Y}^2}{s^2}\right)$$

4.3 Experimental Setup

We conducted all the experiments on the drilling machine as per the experimental value displayed in the Table 2. The experimental setup of drilling machine is shown in Figure 1.

Figure 1: Experimental Setup of Drilling Machine

4.4 High Speed Steel (HSS)

Advent of HSS in around 1905 made a break through at that time in the history of cutting tool materials though got later superseded by many other novel tool materials like cemented carbides and ceramics which could machine much faster than the HSS tools. The basic composition of HSS is 18%.

4.5 Experimental plan

1) First of all we did research for the materials selection for the research work.
2) Procurement of Al material and SiC powder.
3) Make the pattern of the dimension 30*30*30 cubic mm.
4) Then we made the mould of greensand for casting.
5) Then we performed the steering die casting process to make composite material.
6) Then we have done surface finishing on shaper and milling machine.
7) Then we perform the drilling operation using different variants of cutting speed and different diameter of drill bit.

4.6 OBESERVATION TABLE

Table 1: Cutting parameters and their levels

FACTORS	LEVEL-1	LEVEL-2	LEVEL-3
CUTTING SPEED (RPM)	102.5	305.8	482.7
DRILL DIAMETER	4	5	6

Table –2: Experimental Plan and Response for Al-SiC Composite Material

Trial no.	Speed (RPM)	Drill Diameter (mm)	Material Removal Rate (MRR) gm/s
1	102.5	4mm	0.023
2	102.5	5mm	0.032
3	102.5	6mm	0.038
4	305.8	4mm	0.055
5	305.8	5mm	0.064
6	305.8	6mm	0.071
7	482.7	4mm	0.075
8	487.7	5mm	0.081
9	482.7	6mm	0.084

Table- 3 MRR value and S/N ratio value for the experiments

Trial no.	Speed (RPM)	Drill Diameter (mm)	Material Removal Rate (MRR) gm/s	S/N Ratio
1	102.5	4mm	0.023	-32.7654
2	102.5	5mm	0.032	-29.8970
3	102.5	6mm	0.038	-28.4043
4	305.8	4mm	0.055	-25.1927
5	305.8	5mm	0.064	-23.8764
6	305.8	6mm	0.071	-22.9748
7	482.7	4mm	0.075	-22.4988
8	487.7	5mm	0.081	-21.8303
9	482.7	6mm	0.084	-21.5144

Table-4: MRR response table for each level of the process parameters

Level	Speed	Drill Diameter
1	0.03100	0.05100
2	0.06333	0.05900
3	0.08000	0.06433
Delta	0.04900	0.01333
Rank	1	2

Table- 5: Analysis of Variance Results for MRR (Material Removal Rate)

Source of variation	DOF	Sum of Square (SS)	Variance (V)	F Ratio	P value	%
Speed	2	116.236	58.1181	116.83	.001	97%
Drill Diameter	2	1.846	0.9231	0.05	.954	1.65 %
Residual error	4		19.4134			1.5%
Total	8	0.244				

5. Results and Discussion

Minitab 16 is used for analyzing the experimental data. Taguchi Method is applied with larger-the-better criteria, for maximization of material removal rate. Fig. 3 displays main effects plot for S/N ratios corresponding to the input Parameter and Fig .2 shows the main effect plot for means. From the Fig .2, it is clear that 482.7 rpm cutting speed and 6 mm drill diameter have the higher S/N ration so that the optimum combination of process parameters in this experimental work is A_3-B_3 .Where A, B corresponding to Cutting Speed in RPM and drill diameter in mm respectively.

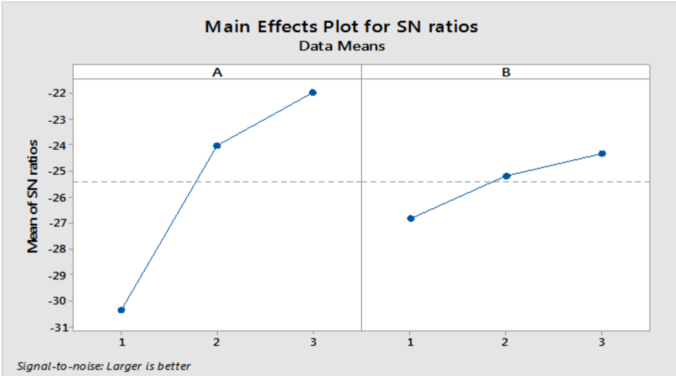

Figure 2: Main effects plot for SN ratio

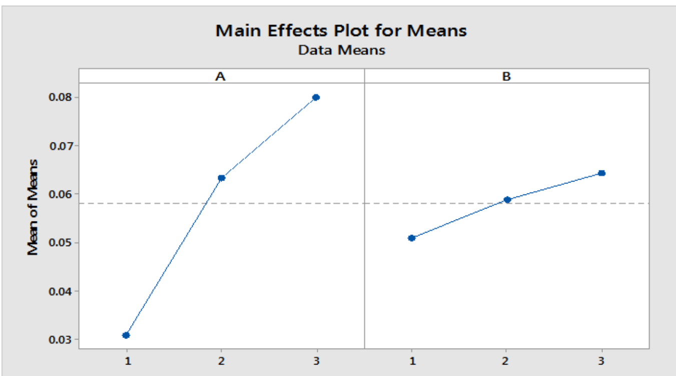

Figure 3: Main effects plot for means

6. Conclusions

In this research work, drilling of composite material (Al-SiC) is carried out with HSS drill bit. The input drilling parameters considered in this research are cutting speed and drill diameter, and the response is material removal rate. The drilling parameters are optimized with respect to single performance in order to achieve a maximization of MRR in the drilling of Al-SiC composite material .Optimization of the parameters was carried out by using the Taguchi Method. The following conclusions could be drawn based on the results and discussion, and interpretation of figures that MRR is increases with increases in cutting speed and MRR is also increases with increase in drill diameter.

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