Optimization of Drilling Parameters for Reducing the Burr Height in Machining the Silicon Carbide Particle (SiCp) Coated with Multi Wall Carbon Nano Tubes (MWCNT) Reinforced in Aluminum Alloy (A 356) Using Meta Modeling Approach

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Abstract –This paper explains the optimization of drilling parameters using meta modeling approach to reduce the burr height while machining Silicon Carbide Particle (SiCp) coated with Multi Wall Carbon Nano Tubes (MWCNT) and reinforced in aluminum alloy (A 356). The specimen is prepared by the combination of sonication and stir casting processes. The volume fraction of MWCNT used is 1.5% and the volume fraction of SiCp is 10%. The combination of input parameters for drilling the holes is designed using Taguchi experimental design technique. The input parameters chosen for drilling operations are spindle speed, feed rate and drill diameter. The ranges of input parameters are listed in Table 1. The tools used for drilling operation are made up of solid carbide drill bit. Meta model is a mathematical and statistical model whose second-order model can be fitted by factorial design. The optimization model can be improved significantly by the second-order model compared to the first-order model. Twenty - seven holes are drilled using vertical machining center in the prepared specimen (A 356/MWCNT coated SiCp). Desirability function shows the optimized values of input parameters to obtain minimum burr height. Meta modeling approach is used to design a model using input parameters and output response burr height. The residuals plot shows the predicted values are closer to the measured values. This plot explains that the Meta model is adequately used to predict the burr height. The optimized values of input parameters for obtaining minimum burr height are the combination of high speed, low feed and low drill diameter. The minimum value of burr height observed in this experiment is 0.002mm and it is obtained in the optimized combination of N_3, f1 and d_1.

Keywords: Burr Height; Desirability Function; Math Modelling; Taguchi Design;

1. Introduction

Burr is a small protrusion and it is produced during any machining process. Burr is formed due to the plastic deformation or tearing of materials. In drilling the burr formed around the hole edge which results in improper seating of fasteners for assembly purposes. Burr is removed by any of the finishing operation such as deburring and edge finishing. This finishing operation is about 30 % of total cost of material produced. The presence of burr in moving components results in unwanted friction and heat. Burr is reduced by the optimized values of input parameters [1].

T.Rajmohan and T.Palanikumar performed a drilling operation on hybrid metal matrix composites (A356/SiCp/Mica) using solid carbide tool. They discussed the use of Response Surface Methodology to minimize the burr height. They analyzed the optimized input parameters to obtain reduced burr height of 0.143mm. The optimized input values are low speed of 1000rpm, low feed of 50mm/min and high percentage (15%) of reinforcement [1].

Domingo and et al. conducted a drilling operation on thermoplastic polymeric material and polyether-ether-ketone reinforced with 30% glass fibers. The input values for machining chosen are drill bit speeds of 6000, 7000 and 8000 rpm, feed rates of 300, 400 and 500 mm/min and drill types of high-speed steel, tungsten carbide and diamond-tipped tungsten carbide. The author proved that the consumption of energy is reduced and the surface quality is improved at the drill bit speed of 7000 rpm and the feed rate of 400 mm/min by using tungsten carbide drill [2].

Jayaram and Mahesh Kumar performed a machining operation on AA6063 T6 alloy, the input parameters taken are spindle speed, feed and depth of cut and analyzed the inputs using Grey Relational Analysis(GRA). In the analysis, it is proved that the feed (57.365%) and depth of cut (25%) are majorly depends on the effect of output [3].

L.H. Manjunathan and P.Dinesh, fabricated a composite by mixing Multi Wall Carbon Nano Tubes with the base alloy in order to increase the strength of base metals [4].

Saravanakumarand P. Sasikumar conducted a drilling operation on hybrid aluminium composites using TiN coated solid carbide drill and analyzed the effect of drilling parameters on the burr height. They confirmed that the minimum burr height is obtained at the spindle speed of 3000rpm, feed of 50mm/rev and graphite percentage of 6. The output response burr height is greatly influenced by percentage of graphite [5].

Eder Silva Costa and et.al tested the micro alloyed steel and recorded the burr height. They proved that the burr growth depends on the tool wear. It is confirmed that the burr increase with drill wear and it grows after 64% of drill life at the cutting velocity of 45m/min. and the burr grows after 82%of drill life at the velocity of 60m/min [6].

Shanti Parkash and et.al conducted a drilling operation on Al-fly ash composites and verified the burr height. They presented the optimized input parameters to reduce the burr height. The optimized values of input parameters are low spindle speed of 60m/min, medium feed of 0.07mm/rev and low point angle of 100^o [7].

Nibir Saha and et.al performed a turning operation on an aluminium alloy and studied the burr formation using profile projector. They proved that burr height increased with the increase in input parameters. Burr height increased with feed values from 0.6mm/rev to 0.8mm/rev and it is decreased with the feed from 0.2 to 0.4 mm/rev. The minimum value of burr height is obtained at the optimized input values such as the depth of cut = 1mm, feed = 0.22mm/rev and cutting velocity = 235.5m/min [8].

Ravinder Kumar Chauhan used Taguchi method to obtain minimum burr height in drilling stainless steel AISI202 and obtained the optimized input parameters namely speed of 45m/min, point angle of 135^o and feed of 0.12mm/rev [9]

G.Vijaya Kumar and P.Venkataramaiah focused on minimizing burr height in drilling aluminium metal matrix composites using Desirable Fuzzy approach. They proved that the spindle speed, tool material and reinforcement material are greatly influenced the burr height [10].

From the above literature reviewed it is clear that in all experiments a composite material is fabricated and its burr height is minimized by analyzing the input parameters. The novelty of this paper is the treated ceramics. The ceramics are not reinforced directly in the base metal it is treated with multi wall carbon nano tubes and then it is reinforced.

2. Materials and methods

2.1 Materials
Base metal chosen for this experiment is A 356.Aluminium Cast Alloy (A 356). It has some unique properties such as excellent cast ability, weldability, good in pressure tightness, toughness and it has good resistance to corrosion, and it performs well in in the conditions of high temperature and pressure, making it ideal for various high-wear applications. A 356 has a specific application in the fields of automobile as cast wheel and in aerospace as inner turbo frame.Other applications are aircraft fittings, transmission cases, wheels, bridge parts, pump parts and control parts.
Silicon Carbide Particle (SiCp) has good thermal and chemical stability during the process of synthesis and under severe service conditions. Multi wall carbon nano tube (MWCNT) forms good interfacial bonding between the reinforcement and matrix and it reduced the surface roughness and tool wear while machining.

2.2 Methods

2.2.1 Sonication Process

Sonication process is the vibration process in which the silicon carbide particle is coated with multi wall carbon nano tubes in the presence of poly vinyl acetate as a sticking material. Various percentage of carbon nano tubes are coated on the silicon carbide particles such as 0.5%, 1%, 1.5% and 2%. The resultant product is verified under scanning electron microscope.
2.2.2 Casting Process

In casting process, the molten aluminium is mixed with coated silicon carbide particle by semisolid stir casting process.

In this experiment two muffle furnace are used. In one furnace the aluminium is melted to its melting point of700^{o}C and the melted aluminium mixed with preheated ceramics at 605^{o}C for five minutes. Then it is poured in to the preheated die to get a required shape.

2.2.3 D*rilling Process*

The fabricated specimen is subjected to drilling with input parameters spindle speed, feed rate and drill diameter. The spindle speed values ranges from 600 to 1860 rpm. The feed rate values ranges from 25 to 75 mm/min and the drill diameter ranges from 4 to 12mm.The drilling operation is carried out in Vertical Machining Centre. Figure. 1explains the experimental set up for drilling process and measuring of output response Burr Height.

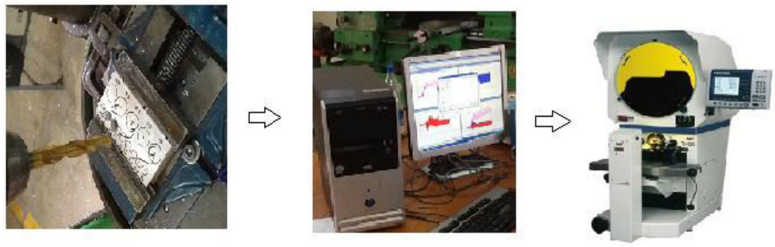

Figure1. Experimental set up for measuring Burr Height

2.2.3 Measurement of Burr height

In this experiment the hybrid metal matrix composite is drilled. Due to machining operation, some protrusion of material formed along the boundary. At high temperature, the tool material subjected to wear and cracks in workpiece which leads to burr. Burr height is the buildup edges due to rise in temperature and it results in poor surface quality. Burr height is measured using Profile Projector. The optimized combination of input parameters is obtained using Taguchi technique.

Table 1. Input parameters for drilling and their levels

Parameters	**Levels**		
	1	2	3
Spindle Speed, N (rpm)	600	1260	1860
Feed, f (mm/min)	25	50	75
Drill diameter, d (mm)	4	8	12

2.2.4 *Modeling of Burr Height using Response Surface Methodology*

Response Surface Methodology is an essential technique to find out the relationship between the process parameters. It is used to develop a mathematical relationship between the output response, Burr height and input parameters speed, feed and drill diameter.

Figure. 2 shows the normal probability plot of experiment values and predicted values. The points are closer to the lines and the deviations are less. This figure explains the good correlation between the experimental and model values.

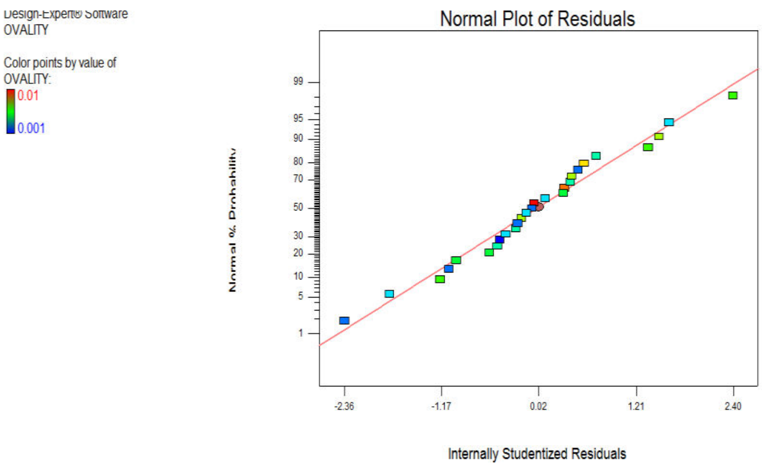

Figure 2. Normal probability Plot

2.2.5 Optimization of Burr height using Response Surface Methodology

Desirability based optimization is chosen in this experiment and it is mostly adaptable for multi performance objective. Desirability ranges between zero to one at the goal. For more than one output responses these goals are combined to form one desirability function.

3. Results anddiscussions

3.1 Results of Sonication

Results of sonication shows the equal distribution of carbon nano tubes over the ceramics. Figure. 3 shows the micro structure of multi wall carbon nano tubes, silicon carbide particles and resultant product of sonication.

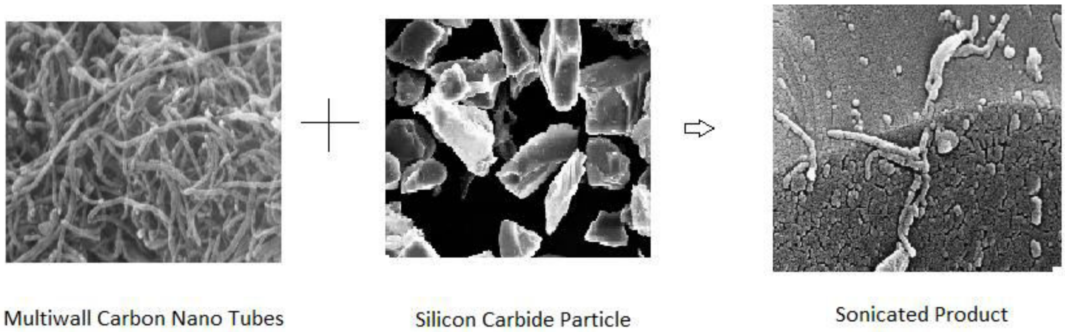

Figure 3. Mixing of multi wall carbon nano tube with silicon carbide particle and the resultant product of sonication

3.2 Results of Stir Casting

Results of stir casting shows the presence of carbon, silicon carbide particle and aluminium. Figure. 4 shows the micro structure of coated silicon carbide particle and aluminium alloy and the result of stir casting.

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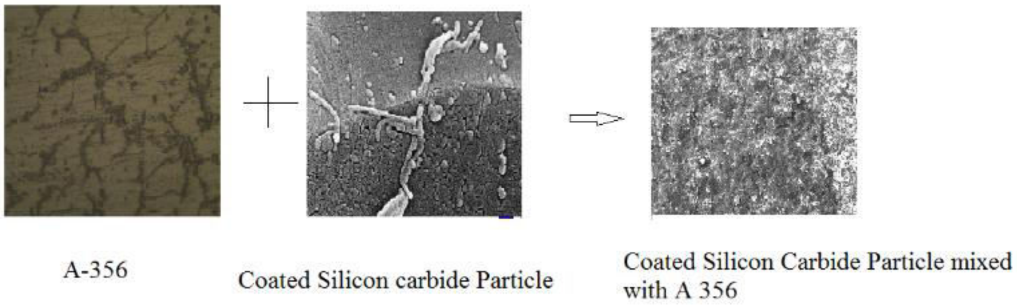

Figure 4. Mixing of aluminium, coated silicon carbide particle and the resultant product of stir casting

3.3 Modelling and Measurement of Burr Height

Burr height is observed and studied. Data analysis and interpretation using suitable modelling and optimization methodologies are made using Math modelling.

Table 2. Output response - Burr height obtained in the experiment with three input parameters designed based on l_{27} array

Speed(N)-rpm	Feed(f)-mm/rev	Diameter(d)-mm	Burr height-mm
600	25	4	0.004
600	25	8	0.005
600	25	12	0.008
600	50	4	0.004
600	50	8	0.004
600	50	12	0.006
600	75	4	0.009
600	75	8	0.031
600	75	12	0.159
1260	25	4	0.006
1260	25	8	0.08
1260	25	12	0.013
1260	50	4	0.004
1260	50	8	0.005
1260	50	12	0.012
1260	75	4	0.009
1260	75	8	0.005
1260	75	12	0.012
1860	25	4	0.003
1860	25	8	0.002
1860	25	12	0.009
1860	50	4	0.002
1860	50	8	0.003
1860	50	12	0.005
1860	75	4	0.003
1860	75	8	0.005

1860	75	12	0.009

Table.2 listed the output response burr height and they are measured using Profile projector in North Laboratory, Chennai.The second order polynomial response surface model for burr height is given below.

BURR HEIGHT =-0.010905+8.02344e005 * speed-1.99650e-003* feed rate+2.74018e-003 * drill diameter-9.74152e-007 * speed * feed rate-4.72998e-006* speed * drill diameter+1.18333e-004 * feed rate * drill diameter-4.20875e-009* speed^2+2.50667e005 * feed rate^2-1.04167e-005* drill diameter^2 (1).

3.4 Optimized Parameter Using Math Modelling

In this paper math modelling is used to determine the optimized values of process parameters. At this input conditions the reduced value of burr height is obtained. Tables 3 and 4 describes the goals and limits used for optimization and table displayed the best goal solution for optimization. The figures 5 and 6 describes the interaction of input responses plot and the main effects for burr height

Table 3. Goals Set and Boundary used for Optimization

Parameter and Response	Goal	Lower limit	Upper limit	Lower Weight	Upper Weight	Importance
Spindle Speed	Is in Range	600	1860	1	1	3
Feed rate	Is in Range	25	75	1	1	3
Drill diameter	Is in Range	4	12	1	1	3
Burr Height	Minimize	0.002	0.159	1	1	3

Table 4. Best Goal Solution for Optimization

No	Speed	Feed	Diameter	Burr	Desirability
1	1854.07	28.30	11.92	0.00164	1.000
2	813.35	33.20	4.01	0.00077	1.000
3	1442.68	64.02	4.01	0.00046	1.000

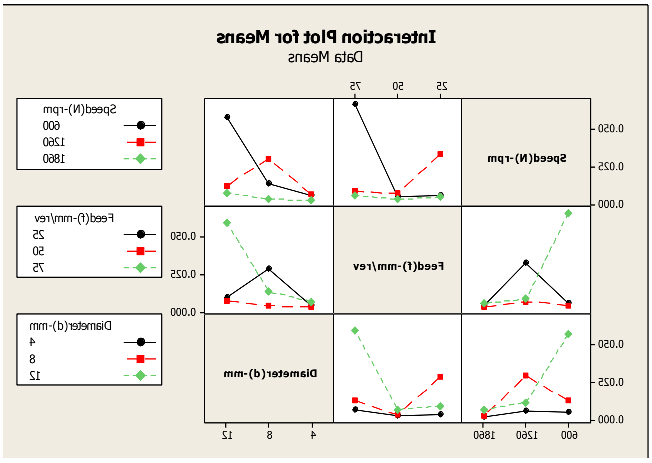

Figure 5. Interaction Plot for Means

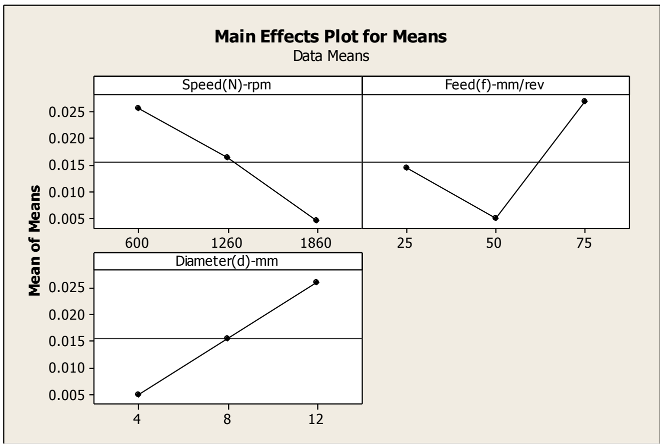

Figure 6. Main effect plot for Means

Table 5. Response table for means (Burr height)

Level	Speed(N)-rpm	Feed(f)-mm/rev	Diameter(D)-mm
1	0.025556	0.014444	0.004889
2	0.016222	0.005000	0.015556
3	0.004556	0.026889	0.025889
Delta	0.021000	0.021889	0.021000
Rank	3	1	2

Response table for means can be obtained using Minitab software and it describes that burr height is influenced mostly by feed rate followed by diameter and it is shown in table 5 The response table and the main effects graph describes that the output response burr height is greatly influenced by feed followed by drill diameter.

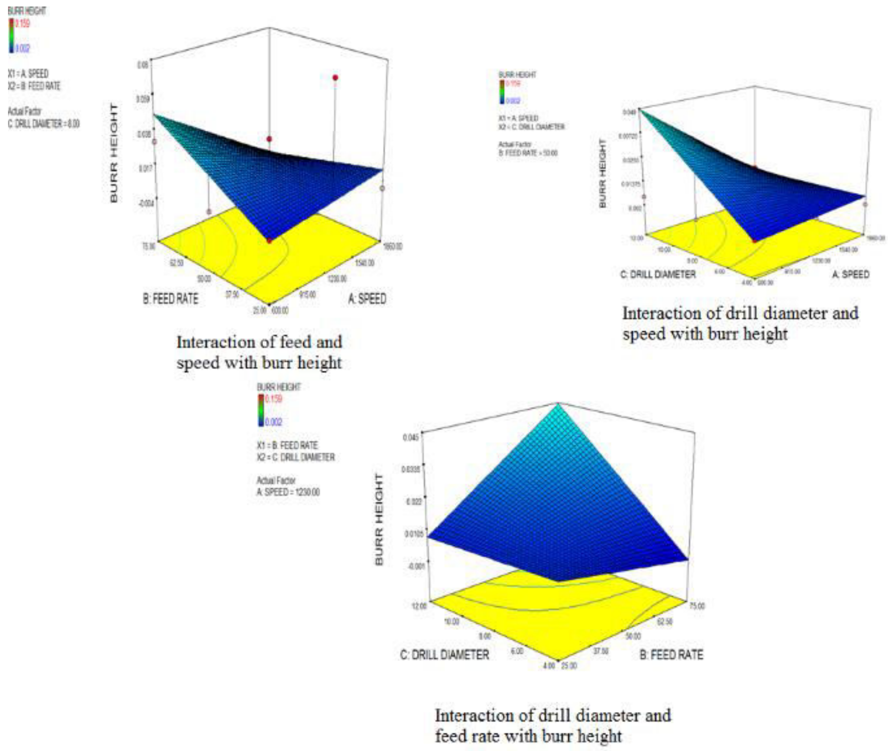

Figure 7. Interaction of input parameters with the Burr height

The figure 7 describes the variation of output, burr height with the interaction of input parameters. There is a rise of burr height with the increase of feed rate and drill diameter when compared to the spindle speed.

4. Conclusion

- Due to sonication process the clustering of nano particle is avoided
- Multi wall carbon nano tubes are evenly spread over the surface of ceramics

- Due to semi solid stir casting process there is a good interfacial bonding between the reinforcement and base alloy.

The output response burr height is obtained using Profile projector and analysed and this burr heightis highly affected by feed rate and drill diameter. As the feed increases the burr height increased and it decreased as the spindle speed increased.

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