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Optimizing surface roughness of AZ91/SiC composite during machining

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Abstract

From past numerous years lightweight materials like magnesium are upgrading their use in a few applications and enterprises. This rising need of magnesium moves numerous scientists to take in its utilization in various practices. In the present paper, the statistical investigation on surface roughness of magnesium alloy (AZ91) metal matrix composites using Taguchi technique has been reported. The composites reinforced with SiC of average size 37 µm were processed by stir casting route. Surface roughness of AZ91-SiC composites were measured under dry turning conditions at different spindle speed (275, 350, and400 rpm), feed rate (rate 0.1, 0.2, and 0.4 mm.), and composition (0, 2, and 3.5 wt pct of each of SiC). The design of experiments approach using Taguchi technique was employed to statistically analyze the surface roughness of the composites. Signal-to-noise ratio and analysis of variance were used to investigate the influence of the parameters on the surface roughness.

Keywords: AZ91 *Magnesi*um Alloy, Taguchi, Turn*ing process, surface roughness*

INTRODUCTION

The thickness of magnesium (1.74 g/cm3) is 35.6% lower when contrasted with aluminum which makes it perfect for light weight applications. Because of its low thickness, magnesium based materials discover applications in car and aviation ventures [1]. However low flexibility, durability and firmness are the first downsides of magnesium based materials when contrasted with aluminum based materials. It was accounted for that the work of break and flexibility of magnesium can be expanded by utilizing fortifications [2]. So it is generally accepted by the analysts that presentation of fitting strengthening materials has control over to take out the beforehand expressed property slacks of magnesium materials. Magnesium matrix materials reinforced with hard ceramic particles possess enhanced hardness and abrasive wear resistance [3]. Further, it is a well known fact that particle reinforced metal matrix composites institute extensive applications owing to its low cost and improved isotropic properties. These property upgrades make them as a hopeful material for substitution of iron and steel in many applications [2]. Among the different fortifications like SiC, Al2O3, AIN utilized as a part of MMCs, SiC is one of the low thickness support accessible in vast amounts. In later past, because of high quality, modulus, wear resistance and weakness resistance AMMCs with SiC fortifications have generally discovered their applications in aviation, military, common, fabricating businesses, and so on [4, 5]. Al–SiC composites hold the best guarantee for future development accordingly of their custom fitted properties, great shaping attributes, ease viability and high volume creation strategies [6]. Consequently, SiC reinforcements are introduced to the magnesium matrix also. Strength and stiffness of the magnesium alloys improved significantly while adding SiC particles. Facilitate it was found that the Mg-SiC composites prepared through blend throwing course are financially savvy other than promising broad applications in the said zones and enterprises [7].This study involves preparing magnesium based composite through stir casting method wherein SiC used as reinforcements. Because surface roughness is the important functional property of the material for its successful applications in automotive and aerospace industries, the effect of spindle speed, feed rate and composition of reinforcement on surface roughness were analysed in detail.

METHODOLOGY

Taguchi technique: The design of experiments (DOE) approach using Taguchi technique has been successfully used by researchers in the study surface roughness of aluminum-based metal matrix composites.[6,7] Taguchi technique drastically reduces the number of experiments required to model the response function compared to the full factorial design of experiments[1-4]. A major advantage of this technique is to find the possible interaction between the parameters.[10] The DOE process consists of three main phases: the planning phase, the conducting phase, and the analysis phase[5-7]. A major step in the DOE process is the determination of the combination of factors and levels which will provide the desired information. Analysis of the experimental results uses a signal-to-noise ratio to aid in the determination of the best process designs. The Taguchi technique is a powerful design of experiment tool for acquiring the data in a controlled way and to analyze the influence of process variable over some specific variable which is an unknown function of these process variables and for the design of high-quality systems. The experimental results are analyzed using analysis of means and variance to study the influence of parameters. A multiple linear regression model is developed to predict the surface roughness of the composites. Thus, the major aim of the present investigation is to analyze the influence of parameters like feed rate, spindle speed, and composition on surface roughness during dry turning of AZ91-SiC metal matrix composites using Taguchi technique.

EXPERIMENTAL DETAILS

Materials and Preparation of composites

In the present study the AZ91 magnesium alloy having chemical composition as given in Table I was reinforced with SiC. The alloy was prepared by melting together the required quantities of commercially available elemental pure Mg, pure Al, and pure Zn master ingots. Melting was carried out at 953 K (680 _C) in mild steel crucible. The reinforcement percentage of silicon was varied from 0 to 3 wt. pct each in steps to prepare the composite. The vortex method was used to prepare the composite specimens. During the process, the uncoated and preheated reinforcement were introduced after defluxing into the vortex created in the molten alloy under inert atmosphere[8-10].

Machining and Surface roughness Test

A HMT NH26 lathe with a maximum speed of spindle 2300 rpm was used for experiments. The turning process is done in dry machining condition without any cutting fluid. Tools used in the research were HS steel. The rods with 0%, 2% and 3.5 % SiC are further divided into three slots on which turning process is done. The three rods are shown in **Fig. 1**.

The surface roughness of AZ91-SiC composite was investigated by stylus type surface roughness tester [11-15].

Fig 1 *Sample for suface roughness test*

Experimental Design

The experiments were conducted as per the standard orthogonal array. The selection of the orthogonal array is based on the condition that the degrees of freedom for the orthogonal array should be greater than, or at least equal to, the sum of those of roughness parameters. The roughness parameters (control factors) chosen for the experiment were composition (A), spindle speed (B), and feed rate(C). Table.1 presents the factors and their levels. In the present investigation, an L9 orthogonal array was chosen, as shown in Table2. In the Taguchi method, the experimental results are transformed into a signal-to-noise (S/N) ratio, which are used to calculate the quality characteristics. In this study, 'the-lower-the-better' quality characteristic was adopted for investigation of the wear rate of the magnesium hybrid composites since minimum values of wear rate are required. The S/N ratio for each level of the process parameters was computed based on the S/N analysis. Moreover, a statistical analysis of variance was performed to identify the statistically significant parameters. The optimal combination of the test parameters can thus be predicted.

The S/N ratio for wear rate using 'the-lower-the-better' characteristic, given by Taguchi [11], is as follows:

S/N ratio for $R_a = -10\log_{10} 1/n\sum(y^2)$

where n= no. of observations, y= observed data (R_a)

The 'lower-the-better' characteristics along with the S/N ration transformation is suitable for minimization of wear rate. A statistical analysis of variance (ANOVA) is performed to identify the statistically significant control parameters. ANOVA along with S/N ratio make it possible to predict the optimal combination of wear parameters to an acceptable level of accuracy. Table 3, 4 represents that the response for signal- to-noise ratios shows the average of selected characteristics for each level of the factor. This table includes the ranks based on the delta statistics, which compares the relative values of the effects. S/N ratio is a response which consolidates repetitions and the effect of noise levels into a single data point. Mean-response graphs were plotted using Minitab-17- software, and the percentage of contribution of testing parameters was determined by the ANOVA analysis.

RESULTS AND DISCUSSION

The basic objective of the realized experiment was to find the most influential factors and the combination of factors which have maximum influence on the surface roughness, in order to reduce its value to a minimum. Experiments were conducted based on the L9 orthogonal array, which relate the influence of the composition, spindle speed, and the feed rate at 3 levels as shown in table 1 and Table 2. It is these parameters which influence the process and define the surface roughness of the composite. The study of above experimental data was conceded by software named MINI-TAB 17. It follows from Table 3 and Table 4, based on the S/N ratio, that the dominating factor which influences the surface roughness, is spindle speed, followed by feed rate and lastly by the composition. Figure 3 and 4 shows the main effects plots for means and S-N. This observation is in accordance with the one reported by the authors in a sequel paper [12] which deals with the experimental analysis and where similar observations were made and suitable explanation has been provided.

Table1: *Three factors with three levels*

Level	Composition of SiC (A) in wt. %	Feed rate(B)in mm/rev.	Spindle speed(C)in rpm
1	0	0.1	275
2	2	0.2	350
3	3.5	0.4	400

Table 2: *Outcomes of experiment*

No. of experiment	Composition of SiC (wt. %)	Feed rate(mm)	Spindle speed(rpm)	Ra
1	0	275	0.1	1.07
2	0	350	0.2	2.27
3	0	400	0.4	10.30
4	2	275	0.2	2.20
5	2	350	0.4	13.05
6	2	400	0.1	1.46
7	3.5	275	0.4	7.96
8	3.5	350	0.1	1.50
9	3.5	400	0.2	1.89

ANOVA and the Effect of Factor

The experimental results were analyzed by the Analysis of Variance (ANOVA), which is used for investigating the influence of parameters, like the composition, spindle speed and feed rate as well as their optimal levels. By performing the analysis, it is possible to determine the influence of the individual factors on the surface roughness and also the

Table 3: *Response Table for Signal to Noise Ratio*

Level	A	B	C
1	-11.507	-11.062	-10.356
2	-14.671	-9.847	-16.716
3	-5.4261	-10.633	-4.546
Delta	9.112	1.246	12.197
Rank	2	3	1

Table 4: *Response Table for Means*

Level	A	B	C
1	4.987	5.621	4.061
2	7.437	4.613	8.495
3	1.916	4.137	1.723
Delta	5.535	1.463	6.881
Rank	2	3	1

percentage of that influence, for each of its values[13,14,15].The results of the ANOVA tests are presented in Table 5 for the surface roughness and for the three analyzed factors that vary over their levels,

Table 5: *Results of Analysis of Variance*

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution
A	2	4.822	2.411	1.55	0.392	2.81%
B	2	5.239	2.620	1.68	0.373	5.26%
C	2	152.459	76.229	48.94	0.020	90.04%
Error	2	3.115	1.558			1.88%
Total	8	165.636				100%

Table 5 demonstrated that feed rate has influence of 90.04%, SiC has 2.81% and speed of spindle has 5.26%. The error percentage was detected to be 1.88%, which is insignificant. Therefore it is measured that the design, analysis and are in the correct way. Henceforth, the optimum factors for turning of AZ91 magnesium alloy are:

SiC(A) % = 3.5%, Spindle speed (C) = 275 rpm, Feed (B) =0.10mm/rev

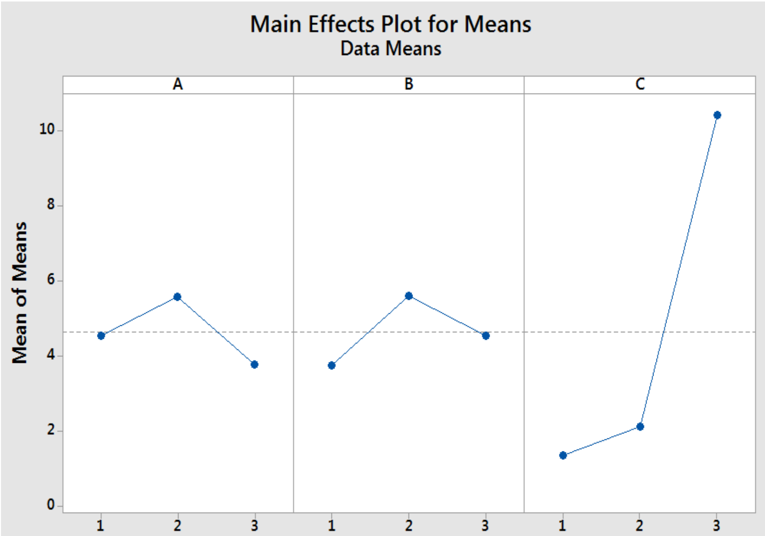

Fig. 2 *Main effect plots for Means*

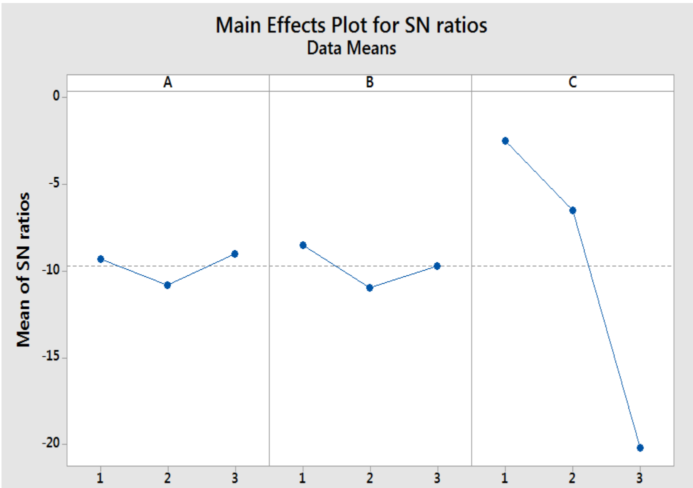

Fig. 3 *Main effect plots for S/N ratio*

CONCLUSIONS

Taguchi's robust design technique was used to analyze sliding wear of the magnesium alloy AZ91 composites as described in this paper. The following conclusions can be drawn from the study:

1. Surface roughness of the magnesium composite AZ91-SiC decreases with increase in composition while it increases with spindle speed and feed rate.
2. The lowest surface roughness in AZ91-SiC composite appears at the feed rate of 0.1mm/rev. and spindle speed of 275rpm and the highest composition 3.5 pct.
3. Taguchi's robust orthogonal array design method is suitable to analyze the wear sliding behavior problem as described in this article. It is found that the parameter design of the Taguchi technique provides a simple,

systematic, and efficient methodology for the optimization of the wear test parameters.

4. The response table and graphs for S-N ratio and means are also symbolized. According to ANOVA, it is discovered that feed rate has a main influence on the surface roughness (90.04%) followed by cutting speed (5.26%) and the SiC % (2.81%).
5. By application of the MINITAB 17 program, linear regression equation was created and developed for the surface roughness in terms of composition, spindle speed, and feed rate.

References

1. M.A. Thein, L. Lu, M.O. Lai, Compos. Struct. 75 (2006) 206–212.
2. K.S. Tun, M. Gupta, Compos. Sci. Technol. 67 (2007) 2657–2664.
3. J. An, R.G. Li, Y. Lu, C.M. Chen, Y. Xu, X. Chen, et al., Wear 265 (2008) 97–104.
4. Y.B. Liu, S.C. Lim, S. Ray, P.K. Rohatgi, Wear 159 (1992) 201–205.
5. W.L.E. Wong, M. Gupta, Solid State Phenom. 111 (2006) 91–94.
6. S.U. Reddy, N. Srikanth, M. Gupta, S.K. Sinha, Adv. Eng. Mater. 6 (12) (2004) 957–964.
7. X.J. Wang, X.S. Hu, K. Wu, M.Y. Zheng, L. Zheng, Q.J. Zhai, J. Mater. Sci. 44 (2009) 2759–2764.
8. E. M. Rubio,J..L.Valenica. A.J.Saá and D. Carou, Inter.J.of Prec. Eng. and Manu. ,14 (2013) 995–1001.
9. N. Wojtowicz, I. Danis, R. Chieragatti, F. Monies, and P. Lamesle, Proc. Eng. 63 (2013) 20-28.
10. S. Basavarajappa and G.C. Chandramohan: J Mater Sci Tech, 2005, vol. 21, pp. 845–50.
11. P. Ravindran, K. Manisekar, and P. Rathika: Mater. Design, 2013, vol. 45, pp. 561–70.
12. B.M. Girish, B.M. Satish, S. Sarapure, D.R. Somashekar, and Basawaraj: Tribol. Trans., 2015, vol. 58, pp. 481–89.
13. J. Sudeepan, K. Kumar, T.K. Barman, and P. Sahoo: Proc. Mater. Sci., 2014, vol. 5, pp. 41–49.
14. S.K. Biswas and A. Satapathy: Mater. Design, 2009, vol. 287,pp. 2841–53.
15. M.H. Cho, S. Bahadur, and A.K. Pogosian: Wear, 2005, vol. 258, pp. 1825–35