Available online at www.sciencedirect.com

jmr&t Journal of Materials Research and Technology

www.jmrt.com.br

Original Article

Wear behaviour analysis on aluminium alloy 7050 with reinforced SiC through taguchi approach

T. Sathish[a,*], S. Karthick[b]

[a] Saveetha School of Engineering, SIMATS, Chennai 602 105, Tamil Nadu, India
[b] Satyam College of Engineering & Technology, Kanyakumari, Tamil Nadu, India

ARTICLE INFO

Article history:
Received 10 December 2019
Accepted 23 January 2020
Available online 31 January 2020

Keywords:
Wear
ANOVA
Reinforcement
Sliding distance
SiC

ABSTRACT

Aluminium alloy is the popular material in the world to produce lot of light weight parts with high strength, in additionally reinforcement is consider to these alloy is improve its strength. In this investigation consider the AA7050 aluminium alloy as a base material with reinforcement of Silicon Carbide (SiC) at various percentage level like as 0%, 4 % and 6 %. The wear of this composites are analysed through the design of experiments (Taguchi approach) for optimize the process parameters. This wear study is considered the parameters are Sliding velocity in m/s (1, 2 and 3), Sliding distance in m (1000, 1400 and 1800) and percentage of composition (0%, 43% and 6%). For this experimental investigation the sliding distance as most significant factor among three. The microstructure analysis demonstrated that there is a SiC particles which reduces wear of the samples.

1. Introduction

Metal Matrix Composition (MMC) is widely used in industry to make appropriates changes in the properties of the base metal. These composites can help to enhance the tribolgical as well as mechanical properties of metal. In MMC a base metal is reinforced by a material to provide additional strength to the metal [1]. In general, for the preparation of light weight metal the aluminium or titanium matrix are reinforced by any of the carbide or oxide materials. Among aluminium or aluminium alloy are the most used matrix metal which are also called as Aluminium Matrix Composition (AMC) for the preparation of light weight commercial products [2].

Kiran Kumar Ekka et al. [3] invstigated the sliding wear behaviour of aluminium matrix nano-composites. The factors are consider for their study is applied normal load, sliding velocity and sliding distance are considered. Taguchi approach was employed for finding sliding wear of this study, the author concluded SiC reinforcement is better wear resistance than Al_2O_3-reinforcement. Sakip Koksal et al. [4] studied the wear rate prediction model of aluminium alloy based composites with reinforced with aluminium diboride (AlB_2) flakes for 10 and 30 wt.%. Test specimens were prepared through squeeze

* Corresponding author.
E-mails: sathish.sailer@gmail.com (T. Sathish), karthicksuyam@gmail.com (S. Karthick).

https://doi.org/10.1016/j.jmrt.2020.01.085

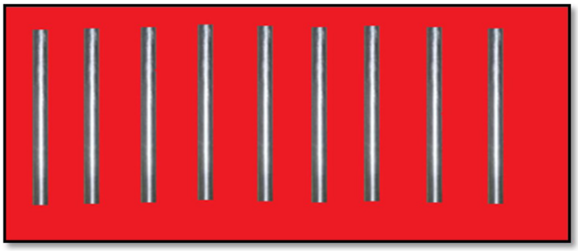


Fig. 1 – Wear specimens (9 specimens).

cast method. The pin-on-disk equipment was used for this wear study. The Aluminium Alloy AA6063 with reinforcement of Silicon carbide (SiC) and coconut shell ash were studied and reported. Surinder Paul et al. [5] investigated the AA6063 with reinforcement of Silicon carbide through stir casting method. The process of stir casting was carried out for 15 min. at stirring rate of 250 rpm. They concluded the result of impact test, tensile strength and hardness of reinforced aluminium alloy was increased as compared to unreinforced alloy. Venkatesan et al. [6] investigated the Graphene reinforced aluminium alloy 7050 and they were used Taguchi's L_{27} orthogonal array with factors as load sliding velocity and sliding distance.

The rest of the paper is organized as follows; the Taguchi approach for the evaluation of proposed work is given in section 2. Then the section 3 describes the experimental work. The subsequent section gives the results and discussion. Finally in the last section the conclusion of the paper is given.

1.1. *Taguchi approach*

The Taguchi approach is a controlling tool for designing a process based on the OA- Orthogonal Array. ANOVA used to minimize the number of experiments and also efficiently improve the processes. In this investigation consider the response value of wear rate and the parameters are % reinforcement, sliding velocity, sliding distance. This study considers the design of experiments of L_9 orthogonal array [7]. The step by step procedure performed in the Taguchi approach is given below;

Step 1: Parameter Selection and identification of control factors

Step 2: Identification of each factors level

Step 3: Selection of an Orthogonal Array (OA) experiment

Step 4: Execution of matrix experiment by assigning control factor to columns of OA

Step 5: Data analysis to predict the optimal value and evaluate the performance

Step 6: Verification and confirmation of analysed data.

1.2. *Experimental work*

The base material of aluminium alloy 7050 and reinforcement of Silicon carbide (SiC) used for this investigation. The 9 samples of 10 mm diameter and 35 mm length work pieces are consider this study is shown in Fig. 1. All the samples are cleaned well in the kerosene before conducting the wear test.

Table 1 – Chemical composition of AA 7050.

Material	% of Composition
Al	89
Cu	2.3
Mg	2.3
Zn	6.2
Zr	0.12

Table 2 – Properties of SiC.

Parameter	Range
Molar mass	40.096 g·mol^{-1}
Density	3.16 g·cm^{-3}
Melting point	2,830 °C
Electron mobility	~900 cm^2/V·s
Magnetic susceptibility	−12.8·10^{-6} cm^3/mol
Refractive index	2.55

Table 3 – Process parameters and their levels.

S. No	Factors	Level 1	Level 2	Level 3
1.	% of Reinforcement	0	4	6
2.	Sliding velocity (m/s)	1	2	3
3.	Sliding distance (m)	1000	1400	1800

The various constitution of the materials are presented in the Aluminium alloy AA 7050 was illustrated in the Table1. The properties of SiC is given in Table 2.

The wear analysis of AA7050 and reinforcement of SiC metal matrix composites are examined by design of experiments Taguchi's L_9 Orthogonal array. The process parameters are to be considered for this wear study experiment are the % of reinforcement, Sliding velocity (m/s) and Sliding distance (m) which are allotted with three different levels is presented in Table 3 [8–12].

The model of the wear test equipment as DUCOM TR 20-LE, the parameters of different sliding velocity likes as 1, 2 and 3 m/s, sliding distance as 1000, 1400 and 1800 m and constant applied load as 20 N. The specimens were cleaned well with fine emery sheet and further it is immersed in kerosene. Weights of the specimens were noted before and after wear, it is calculate the wear loss or weight loss.

2. Result and discussion

In this experiment nine trials are carried out the wear rate and S/N ratio values were determined and were presented in Table 4.

The Table 4 and Table 5 showed the difference between the largest to smallest mean and S/N ratio value in the acceptable levels [13]. It is a information which parameter has the highest delta value is measured as a greater influence on the response of wear rate (Fig. 2).

The Figs. 3 and 4 illustrated the main effect plot for mean and S/N ratio of the wear respectively [14–16]. The Figs. 3 and 4 showed that the increase in sliding distance value the wear rate would be moderately changed since the sliding distance was a major influencing factor to others.

Table 4 – Summary of the wear test with S/N ratio.

S.No	% of reinforcement	Sliding Velocity (m/s)	Sliding distance (m)	Wear rate (mm3/m)	S/N ratio
1	0	1	1000	0.00496	46.0904
2	0	2	1400	0.00387	48.2458
3	0	3	1800	0.00312	50.1169
4	4	1	1400	0.00358	48.9223
5	4	2	1800	0.00239	52.4320
6	4	3	1000	0.00412	47.7021
7	6	1	1800	0.00198	54.0667
8	6	2	1000	0.00273	51.2767
9	6	3	1400	0.00306	50.2856

Table 5 – Response Table for Means.

Level	% of reinforcement	Sliding Velocity (m/s)	Sliding distance (m)
1	0.003923	0.003507	0.003937
2	0.003363	0.002997	0.003503
3	0.002590	0.003433	0.002497
Delta	0.001393	0.000510	0.001440
Rank	2	3	1

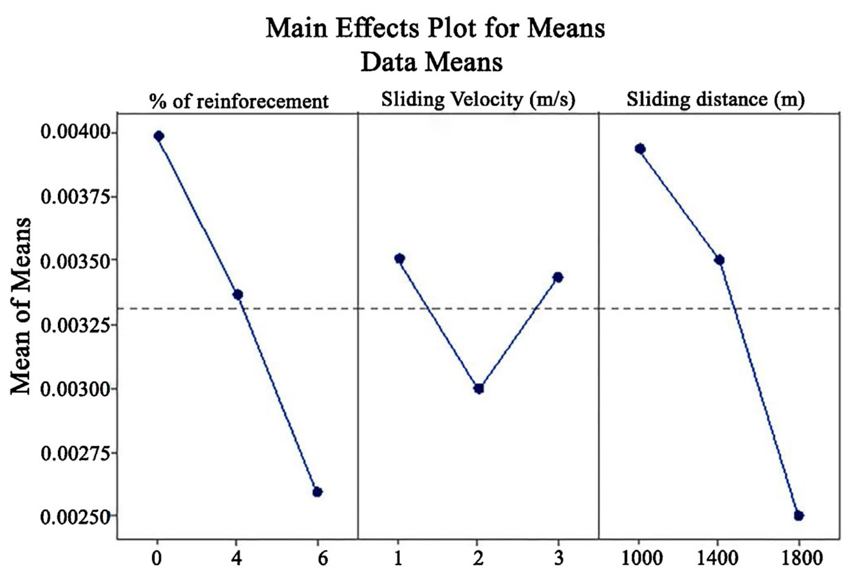


Fig. 2 – Wear rate of AA7050- SiC.

The propability plot shows (See Fig. 4) that all the points were lied on the mean value since the selected parameters of this expriments were good one.

ANOVA is mainly used to evaluate the factors among their significances in their percentage contribution to the response like as wear rate as in Table 7. It is mainly conducted by significance level of 5% and 95% confidence level with high accurate result [17]. Table 6 illustrates the result of Analysis of Variance for aluminium alloyAA7050 - SiC composite. From Table 6 denotes that, the sliding distance influence of 45.64%, percentage of reinforcement is 40.20% and sliding velocity is 0.12% correspondingly on the wear rate of the composites.

Fig. 5 (a), (b) and (c) shows the contour plot of the wear rate, Fig. 5(a) shows the wear rate increases by influence for minimum rate of sliding distance and sliding velocity [18]. Fig. 5(b) shows the wear rate reduces, it proved from the figure by the increasing trend of reinforcement with average sliding velocity. Fig. 5 (c) proves the wear rate was reduced by higher percentage of reinforcement with high sliding distance.

2.1. *Microstructure analysis*

Microscopic images of AA7050 and AA7050-Silicon carbide (SiC) after wear test are illustrated in Fig. 6 (a) & (b) correspondingly. The images are taken out from the conditions of 100 x and 100 μm. Figs. 6 (b) clearly exposes that the silicon carbide particles are uniformly distributed and stick to the base materials as the AA7050 alloy material. These microscopic image 6 (b) was taken for the consideration of the optimum value of factors with output response of wear rate.

The reinforced silicon carbide particles are clearly visible in the Fig. 7. This image was answerable for as higher wear of the specimen, the SEM image of higher wear specimen was considering this study [19,20]. The silicon particles were spread

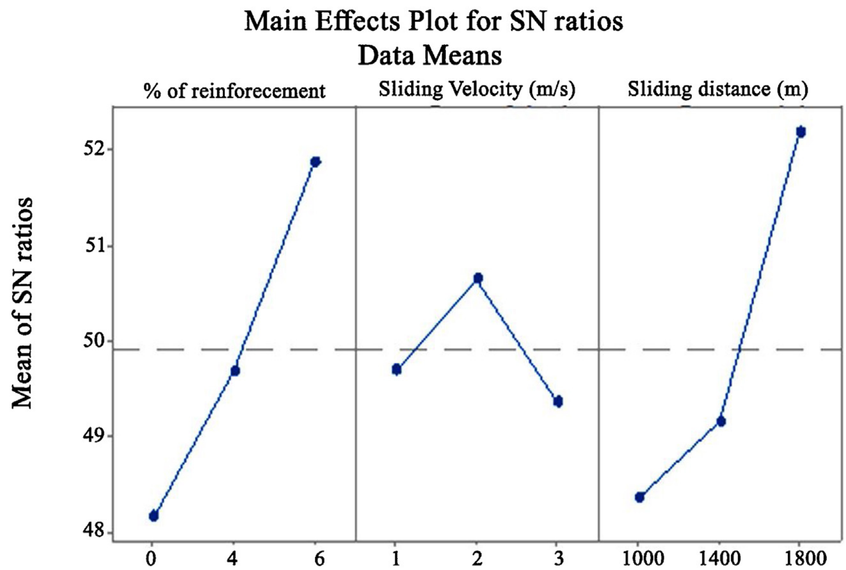


Fig. 3 – S/N ratio-wear rate of AA7050- SiC.

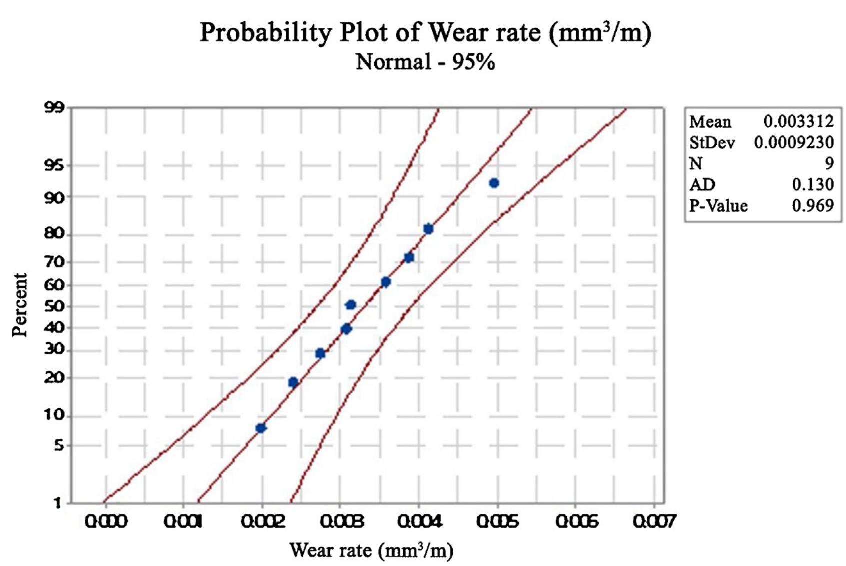


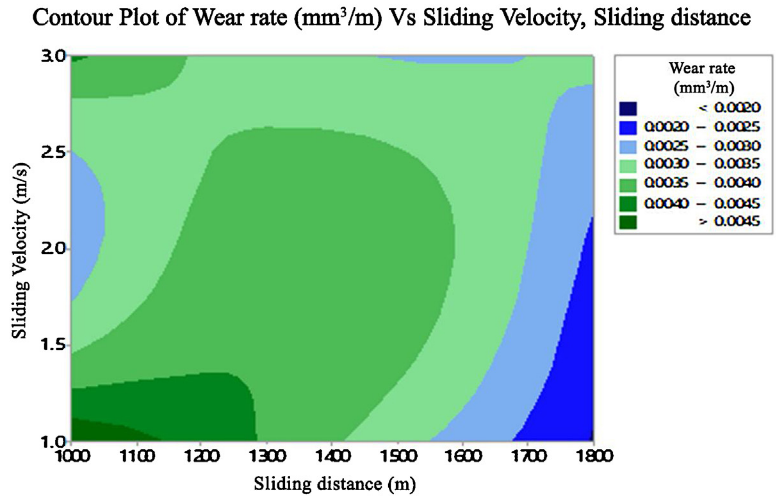
Fig. 4 – Probability plot of wear rate.

Table 6 – Response Table for Signal to Noise Ratios.

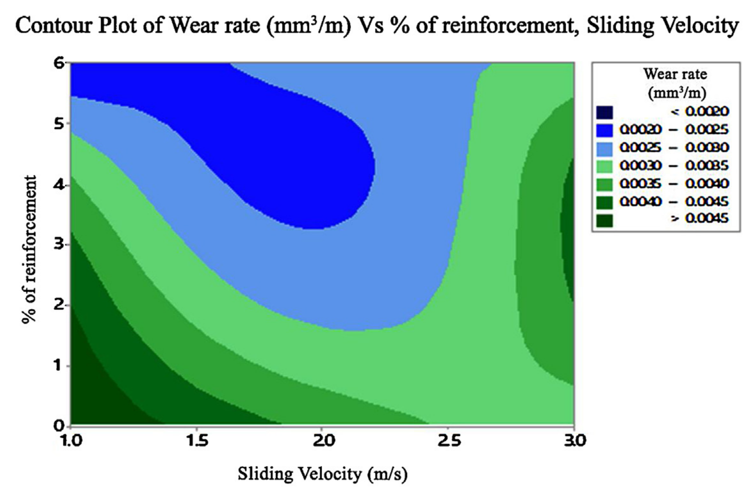
Level	% of reinforcement	Sliding Velocity (m/s)	Sliding distance (m)
1	48.15	49.69	48.36
2	49.69	50.65	49.15
3	51.88	49.37	52.21
Delta	3.73	1.28	3.85
Rank	2	3	1

Table 7 – Analysis of Variance (ANOVA) for wear rate.

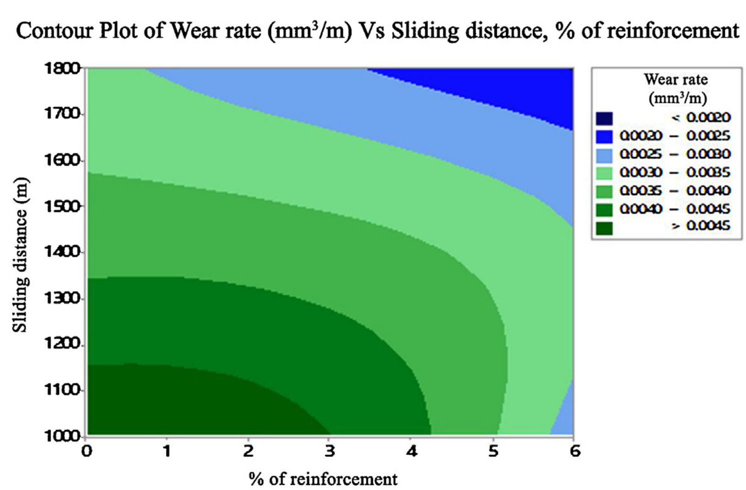
Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	0.000006	85.96%	0.000006	0.000002	10.20	0.014
% of reinforcement	1	0.000003	40.20%	0.000003	0.000003	14.31	0.013
Sliding Velocity (m/s)	1	0.000000	0.12%	0.000000	0.000000	0.04	0.845
Sliding distance (m)	1	0.000003	45.64%	0.000003	0.000003	16.25	0.010
Error	5	0.000001	14.04%	0.000001	0.000000		
Total	8	0.000007	100.00%				



(a). Contour plot for wear rate vs sliding distance, sliding velocity

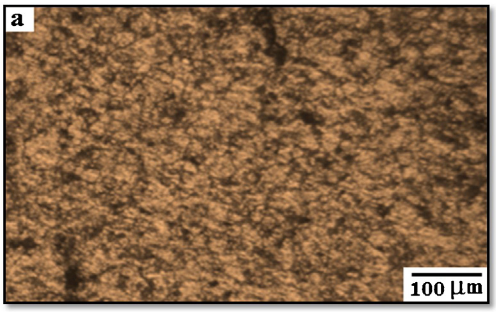


(b). Contour plot for wear rate vs sliding velocity, % of reinforcement

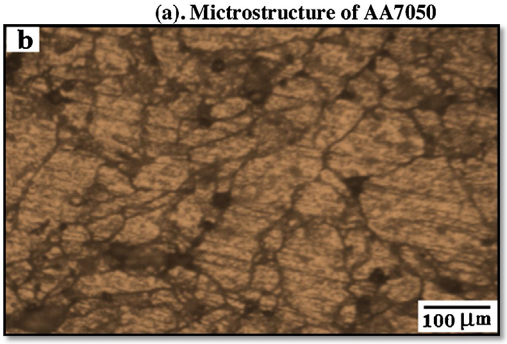


(c). Contour plot for wear rate vs % of reinforcement, sliding distance

Fig. 5 – (a). Contour plot for wear rate vs sliding distance, sliding velocity. (b). Contour plot for wear rate vs sliding velocity, % of reinforcement. (c). Contour plot for wear rate vs % of reinforcement, sliding distance.



(a). Mictrostructure of AA7050



(b). Mictrostructure of AA7050/ SiC Composite after wear test

Fig. 6 – (a). Mictrostructure of AA7050. (b). Mictrostructure of AA7050/ SiC Composite after wear test.

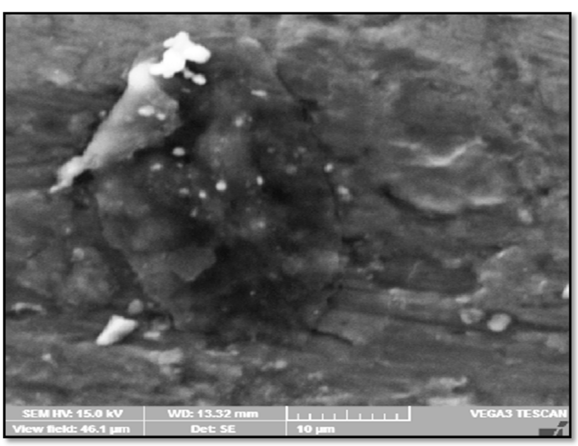


Fig. 7 – SEM image of AA7050 with reinforcement of SiC after wear test.

over the aluminium alloy in unevenly, the illuminated particles in white were observed as SiC and aluminium alloy were showed in the images as darker one.

The SiC particles from the AA 7050 aluminium alloy composite were mostly to be found in the centre of the image. The reinforcements were erratically dispersed in the stir casting sample owing to inefficient stirring variables like as rotational speed and duration of stir sustained during the processing of the specimens. In this image showed the cracks and pores evidently with higher wear rate.

3. Conclusion

In this investigation the experiments were successfully completed the following manner. The optimum values of wear rate were obtained as sliding distance is 1800 m, percentage of reinforcement is 6% and sliding velocity is 2 m/s. Among three factors sliding distance was most influence on wear rate. Sliding distance has an influence of 45.64%, percentage of reinforcement is 40.20% and sliding velocity is 0.12% respectively. The microscopic images were evidently shows the SiC particles are uniformly distributed and it provides resistance to wear. The SEM image explicit the poor stirring process for the specimen fabrication, it caused higher wear even increasing percentage of reinforcements. Finally concluded this study as stirring process also accountable for preparation of composites.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

[1] Praveen Kumar R, Periyasamy P, Rangarajan S, Sathish T. League championship optimization for the parameter selection for Mg/WC metal matrix composition. Mater Today Proc 2019.

[2] Adithiyaa T, Chandramohan D, Sathish T. Flower Pollination Algorithm for the optimization of stair casting parameter for the preparation of AMC. Mater Today Proc 2019.

[3] Ekka KK, Chauhan SR, Varun. Dry sliding wear characteristics of SiC and Al_2O_3 nanoparticulate aluminium matrix composite using taguchi technique'. Arab J Sci Eng 2014, http://dx.doi.org/10.1007/s13369-014-1528-2.

[4] Koksal S, Ficici F, Kayikci R, Savas O. Experimental optimization of dry sliding wear behavior of in situ AlB_2/Al composite based on Taguchi's method. Mater Des 2012;42:124–30, http://dx.doi.org/10.1016/j.matdes.2012.05.048.

[5] Paul S, Sharma GR. Evaluation of mechanical properties of Al6063 alloy MMC reinforced with SiC and coconut shell ash. International Advanced Research Journal in Science, Engineering and Technology 2017;4:79–83. DOI10.17148/IARJSET.2017.4811.

[6] Venkatesan S, Anthony Xavior M. Wear characteristics studies on graphene reinforced AA7050 based composite. Mater Res Express 2019;6:1–16, http://dx.doi.org/10.1088/2053-1591/ab0125.

[7] Sahin Y. Abrasive wear behavior of SiC /2014 aluminium composite. Tribol Int 2010;43:939–43, http://dx.doi.org/10.1016/j.triboint.2009.12.056.

[8] Stojanovic B, Babic M, Sandra V, Blagojevic J. Optimization of wear behaviour in aluminium hybrid composites using taguchi method. Serbian Tribology Society 2015:81–6 https://www.researchgate.net/publication/321654420.

[9] Dhanalakshmi S, Mohanasundararaju N, Venkatakrishnan PG, Karthik V. Optimization of friction and wear behaviour of Al7075-Al_2O_3- B_4C metal matrix composites using Taguchi method. International Conference on Advances in

Metallurgy, Materials and Manufacturing 2018;314, http://dx.doi.org/10.1088/1757-899X/314/1/012025.

[10] Ghosh S, Sahoo P, Sutradhar G. Wear behaviour of Al-SiCp metal matrix composites and optimization using taguchi method and grey relational analysis. J Miner Mater Charact Eng 2012;11:1085–94.

[11] Kiran TS, Prasanna Kumar M, Basavarajappa S, Viswanatha BM. Dry sliding wear behavior of heat treated hybrid metal matrix composite using Taguchi techniques. Mater Des 2014;63:294–304, http://dx.doi.org/10.1016/j.matdes.2014.06.007.

[12] Ramanujam R, Muthukrishnan N, Raju R. Optimization of cutting parameters for turning Al-SiC(10p) MMC using ANOVA and grey relational analysis. Int J Precis Eng Manuf 2011;12(4):651–6, http://dx.doi.org/10.1007/s12541-011-0084-x.

[13] Rana RS, Purohit R, Sharma A, Rana S. Optimization of wear performance of aa 5083/10 wt. % sic_p composites using taguchi method. Procedia Mater Sci 2014;6:503–11, http://dx.doi.org/10.1016/j.mspro.2014.07.064.

[14] Sagar KG, Suresh PM, Suresh R. Wear behavior of aluminum alloy reinforced with beryl metal matrix composites using taguchi method. Mater Today Proc 2018;5:24497–504.

[15] Siriyala R, Alluru GK, Penmetsa RMR, Duraiselvam M. Application of grey-taguchi method for optimization of dry sliding wear properties of aluminum MMCs. Front Mech Eng China 2012;7:279–87, http://dx.doi.org/10.1007/s11465-012-0329-0.

[16] Stojanovic B, Blagojevic J, Babic M, Velickovic S, Miladinovic S. Optimization of hybrid aluminum composites wear using Taguchi method and artificial neural network. Ind Lubr Tribol 2017;69(6):1005–15, http://dx.doi.org/10.1108/ILT-02-2017-0043.

[17] Souissi N, Souissi S, Le Niniven C, Amar MB, Bradai C, Elhalouani F. Optimization of squeeze cast parameters for 2017 a wrought Al alloy using taguchi method. Metals 2014;4:141–54, http://dx.doi.org/10.3390/met4020141.

[18] Velickovic S, Stojanovic B, Babic M, Bobic I. Optimization of tribological properties of aluminum hybrid composites using Taguchi design. J Compos Mater 2016;51:1–11, http://dx.doi.org/10.1177/0021998316672294.

[19] Baradeswaran A, Elayaperumal A, Franklin Issac R. A statistical analysis of optimization of wear behaviour of Al-Al_2O_3 composites using taguchi technique. Procedia Eng 2013;64:973–82, http://dx.doi.org/10.1016/j.proeng.2013.09.174.

[20] Rajesh S, Rajakarunakaran S, Sudhakara Pandian R. Modeling and optimization of sliding specific wear and coefficient of friction of aluminum based red mud metal matrix composite using Taguchi method and response surface methodology. Materials Physics and Mechanics 2012;15:150–66.