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ORIGINAL PAPER

# Study on Mechanical and Tribological Characterization of $Al_2O_3$/SiCp Reinforced Aluminum Metal Matrix Composite

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## Abstract

In this investigation, an attempt has been made to hardness and wear rate of Al7075 hybrid metal matrix composite reinforced with the hard ceramics like alumina (2, 4, and 6 wt.% of Al2O3) and silicon carbide (3, 6, and 9 wt.% of SiC) is fabricated by using stir casting method. The samples were aging at temperature of 140 °C, 160 °C and 180 °C and monitored by hardness test. Taguchi's L27 Orthogonal array was used for optimizing the process parameters. The obtained results indicated that hardness increased with increasing reinforcement. A wear test was performed using pin-on disk apparatus at room temperature for constant load of 30N, at a fixed sliding speed of 1.66 m/s and wear resistance increased as the weight percentage of reinforcement increased. Scanning electron microscope (SEM) studies were carried out to evaluate the worn surface. From the analysis of variance (ANOVA), $Al_2O_3$ is the significant factor that affects the hardness and wear loss of hybrid composites followed by SiCp and heat treatment. Confirmatory test was performed for the optimized parameters and these results were within the acceptable range when compared with the experimental results.

**Keywords** Hybrid composite · Stir casting · Aging temperature · Wear rate · Taguchi techniques

## 1 Introduction

Hybrid MMCs are engineering resources reinforced by a combination of two or more dissimilar material in order to achieve the combined benefits of composites. Alumina ($Al_2O_3$), Silicon Carbide (SiC), Boron Carbide ($B_4C$) particles and so on are commonly used non-metallic reinforcements, combined with aluminum alloys to obtain aluminum matrix composites and $Al_2O_3$/SiC, in the form of particulates, are found to have remarkable compatibility. In a stir casting method, normally the particles reinforced is dispersed into the molten metal by mechanical stirring process. Composites with up to 30 wt. % can be used in this process. The major benefits of this process are applicability to mass production. The stir casting process costs very low (up to $1/10^{th}$) for mass production of MMCs when compared to powder metallurgical process. Due to this causes, stir casting is the most commonly used viable technique of manufacturing of AMMCs [1]. Among other parameters, wt. % of $Al_2O_3$ and SiCp is reported to be the most operative parameters influencing hardness and other mechanical properties of aluminum matrix composites. Addition of $Al_2O_3$ to aluminum will shows the increase in its mechanical and tribological properties in composites [1]. Usually, composites have greater compressibility combined with good hardness strength and making them multiuse in a wide range of applications. Information of hardness is very useful in understanding the performance of composites. However, there is no systematic procedure to evaluate the hardness of these composites. The said drawbacks of conventional metallic structure materials have been induced strong interest to find for new possibilities. SiC particle reinforced Al matrix composites have attracted

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strong interest from inventors. Reinforcement particulates may be in interacting physically or electro-chemically with the matrix important to enhanced oxidization. In addition, the relations between the reinforcement and matrix can also be accelerating oxidization. The oxidization along with the particle and matrix interface can be lead to the high diffusion along the enormous interfacial regions in MMCs. This can results in enhanced corrosion resistance of MMCs. Addition of $Al_2O_3$, SiC, $B_4C$ etc. particles reinforced in aluminum will improves the mechanical and tribological properties while ductility will be decreases. The optimization of wt. % of reinforcements ($Al_2O_3$ & SiC) and heat treatment for improving the mechanical and tribological properties of MMCs was fewer reported.

Several research reports are highlighted the mechanical and tribological properties of MMCs in the past two decades. Arun et al. [2] studied the influence of $Al_2O_3$ and Gr on mechanical and tribological behavior of Al-MMC. Various wt. % of $Al_2O_3$ (5, 10 & 15%) and constant wt. % of graphite (5%) were used to produce a composites by stir casting process. From the results they have concluded that the hardness in the composites increased with increase in wt. % of $Al_2O_3$ particles. From the ANOVA, it is observed that $Al_2O_3$ is the most significant factor that affects the wear rate followed by wt. % of Gr particles and stirring speed. Alhawari et al. [3] studied the wear properties of A356 MMCs containing (1, 2.5 and 5%) weight fractions of $Al_2O_3$ particles as the reinforcement. The MMCs were formed using conventional stir casting process and cooling rate at 620 °C and subjected to wear tests. The wear resistance and hardness of the MMCs produced by cooling of casting were found to be higher than those of the MMCs produced by using conventional stirring process. Adetayo et al. [3] studied the influence of reinforcement particle size like single particle size (SPS) and multiple particle size (MPS) on the mechanical and tribological properties of Al-SiCp composite prepared by stir casting process. They reported that the MPS composite improved the hardness with enhanced wear performance compared to SPS composite. Keneth et al. [4] investigated the effect of reinforcement of $Al_2O_3$ with rice husk ash composites on mechanical and tribological properties. They have concluded that the hardness of composites decreases with increase in RHA content. Similar results were found in SiCp and RHA [5] they reported that the wear rate decreases with the increasing in wt. % of the RHA and SiCp. Devaraju et al. [6] studied the influence of reinforcement particles such as SiCp and Gr on mechanical and wear properties of AMMCs has been prepared by stir casting process. Taguchi technique was used to optimize the factors for improving properties of hybrid composites. From the results they have concluded that hardness has been increased due to presence of hard SiCp and also the wear rate has been decreased. Kanthavel et al. [7] studied the influence of$Al_2O_3$ and $MoS_2$ on wear and coefficient of friction properties of AMMCs. The obtained results indicated that the combination of Al+ 5 wt.% $Al_2O_3$ + 5 wt.% $MoS_2$ has minimum wear rate and coefficient of friction at the sliding speed of 0.5 m/s and sliding distance of 1000 m. Adam et al. [8] studied the influence of 22 vol.% $Al_2O_3$ particles by multiple remelting means of gravity casting process. The study was focused on tribological behavior and micro structural studies. From the results they have concluded that the direct re-melting can be treated as economically well-founded and marginal way associated to other recycling methods.

The advanced composite distributes limitations to the ensuing factors like plastic flow at the time of deformation, during heat treatment the grain growth and dislocation, ensuing in greater mechanical properties. Where the higher heat treatment temperature will tends to reduces in elastic modulus and flexural strength due to volatilization in residual material. Increasing the Silicon content with in the Al matrix the elastic modulus can be improved but the heat treatment process can provide considerable development in hardness strength. Eventual combination of properties of AMMCs is contingent on different factors correlated to matrix, reinforcement and heat treatment processing [9].

## 2 Experimentations

### 2.1 Materials and Method

The main objective of the research is to investigate the mechanical property and wearloss of aluminum matrix composites produced by stir casting. In the present study, hybrid metal matrix composites was developed using Al7075 matrix reinforced with Al2O3 and SiCp by stir casting method. Al7075 alloy is widely used in aircraft structures and Marian applications. The chemical composition of Al7075 in wt.% is as in Table 1.An average particle size of 100 mesh size (Al2O3) with ph value 6.5-7.5 and SiCp of 220 mesh size particles were used as reinforcements. Stir casting technique was employed to produce the metal matrix composites. The preheated reinforcement particles were mixed with base alloy during the stirring process. Degassing tablet was used to remove the inert gasses present in molten aluminum metal matrix. The stirring is done at 100 rpm for 5 min and then the molten slurry is poured to pre heated mold. After the solidification, remove the as cast samples from mold. Samples were pre machined by CNC turning. The test samples are shown in Fig. 1. The samples were heat treated at 490 °C and oil quenched at 60 °C. Further, the samples are aging at temperature of 140 °C, 160 °C and 180 °C for 4 hours and cooled at room temperature. The result reported in the

**Table 1** Chemical Composition of Al7075 alloy with wt. %

| Content | Al | Cu | Mg | Si | Fe | Mn | Ni | Pb | Sn | Ti | Zn | Cr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wt. % | Rem | 1.480 | 2.306 | 0.059 | 0.256 | 0.052 | 0.052 | 0.023 | 0.012 | 0.052 | 5.424 | 0.280 |

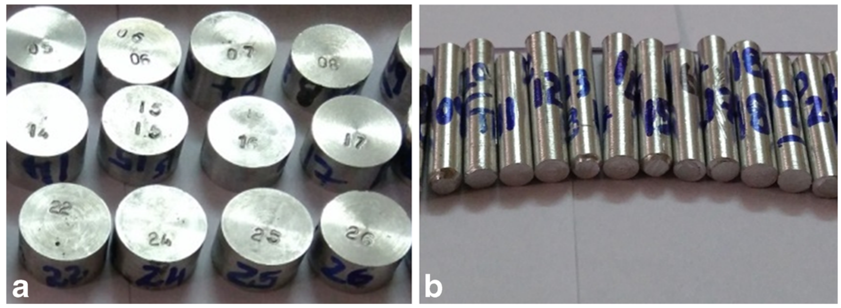


**Fig. 1** **a** Specimens for hardness test and **b** Specimens for Wear test

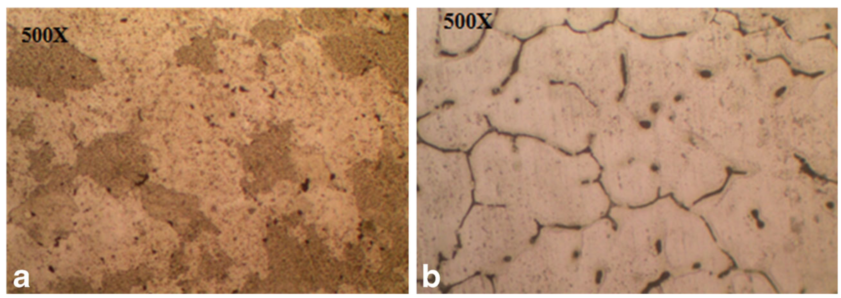



**Fig. 2** Optical Micrographs of **a** Al7075 alloy **b** Al7075 reinforced $Al_2O_3$/SiCp composite

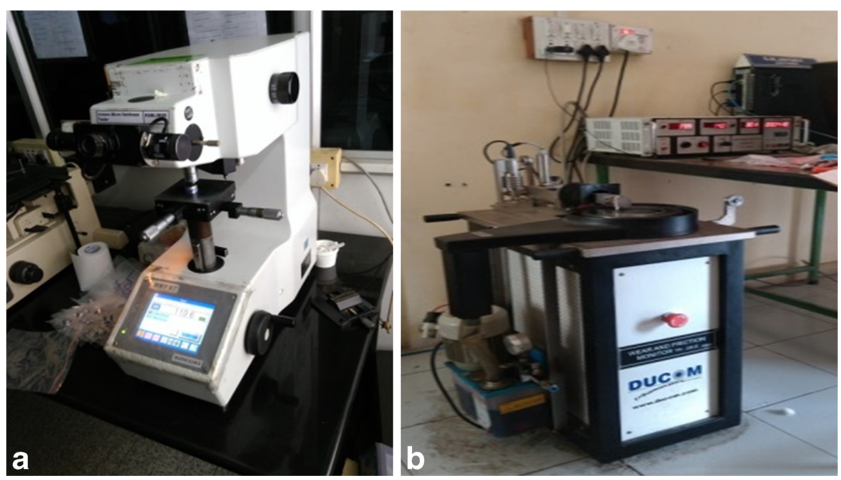


**Fig. 3** **a** Micro hardness tester and **b** Wear Testing machine

**Table 2** Levels of process parameters

| Process parameters | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| $Al_2O_3$ (% weight) | 2 | 4 | 6 |
| SiC (% weight) | 3 | 6 | 9 |
| Heat treatment Temperature (°**C**) | 140 | 160 | 180 |

**Table 3** Experimental results of hardness and wear loss for $L_{27}$ Orthogonal Array

| Trial No. | $Al_2O_3$(% weight) | SiC (% weight) | Heat treatment temperature (° C) | Vickers hardness (VHN) | Wear (gm) |
|---|---|---|---|---|---|
| 01 | 2 | 3 | 140 | 106 | 0.089 |
| 02 | 2 | 3 | 160 | 109 | 0.090 |
| 03 | 2 | 3 | 180 | 113 | 0.081 |
| 04 | 2 | 6 | 140 | 115 | 0.089 |
| 05 | 2 | 6 | 160 | 116 | 0.075 |
| 06 | 2 | 6 | 180 | 116 | 0.074 |
| 07 | 2 | 9 | 140 | 110 | 0.072 |
| 08 | 2 | 9 | 160 | 118 | 0.079 |
| 09 | 2 | 9 | 180 | 120 | 0.068 |
| 10 | 4 | 3 | 140 | 113 | 0.062 |
| 11 | 4 | 3 | 160 | 129 | 0.060 |
| 12 | 4 | 3 | 180 | 128 | 0.055 |
| 13 | 4 | 6 | 140 | 129 | 0.054 |
| 14 | 4 | 6 | 160 | 130 | 0.053 |
| 15 | 4 | 6 | 180 | 134 | 0.051 |
| 16 | 4 | 9 | 140 | 137 | 0.049 |
| 17 | 4 | 9 | 160 | 123 | 0.052 |
| 18 | 4 | 9 | 180 | 124 | 0.044 |
| 19 | 6 | 3 | 140 | 130 | 0.040 |
| 20 | 6 | 3 | 160 | 129 | 0.039 |
| 21 | 6 | 3 | 180 | 135 | 0.047 |
| 22 | 6 | 6 | 140 | 128 | 0.015 |
| 23 | 6 | 6 | 160 | 129 | 0.031 |
| 24 | 6 | 6 | 180 | 135 | 0.029 |
| 25 | 6 | 9 | 140 | 139 | 0.028 |
| 26 | 6 | 9 | 160 | 142 | 0.054 |
| 27 | 6 | 9 | 180 | 130 | 0.021 |

literature survey is consistent with [10, 11]. The reports stated that the aging temperature of 140 to 200 °C at 3-4 hours is the better for improve the mechanical and tribological properties (Fig. 2).

The surfaces of specimens were been polished using emery papers with 400 grit size with diamond paste. Then the specimens are polished using velvet disk polishing machine to get fine finish on the surface is as in Fig. 3. Uniform distribution of reinforcement particles in the matrix alloy was observed through *Nikon* optical metallurgical microscope (Model: Epiphot 200). Microstructure in Fig. 3b shows the uniform distribution of particles in the Al matrix ensued due to the virtuous quality of preform used and the operative perception of the liquid metal even in minute voids

**Table 4** ANOVA results of hardnesstest

| Source | DF | Seq. SS | Adj. SS | Adj. MS | F | P | Cont. (%) | Remarks |
|---|---|---|---|---|---|---|---|---|
| $Al_2O_3$ | 1 | 1682.00 | 71.07 | 71.07 | 2.7371 | 0.0136 | 66.33 | Significant |
| SiC | 1 | 144.50 | 150.37 | 150.369 | 5.7909 | 0.0259 | 5.69 | Significant |
| Heat Treatment | 1 | 43.56 | 154.27 | 154.274 | 5.9413 | 0.0242 | 1.71 | Significant |
| $Al_2O_3$ * SiC | 1 | 0.75 | 0.75 | 0.750 | 0.0289 | 0.8667 | 0.03 | Insignificant |
| SiC * HT | 1 | 126.75 | 126.75 | 126.750 | 4.8813 | 0.03897 | 4.99 | Significant |
| HT * $Al_2O_3$ | 1 | 18.75 | 18.75 | 18.750 | 0.7221 | 0.4055 | 0.73 | Insignificant |
| Error | 20 | 519.32 | 519.32 | 25.966 | | | 20.48 | |
| Total | 26 | 2535.63 | | | | | 100 | |

**Table 5** ANOVA results of Wear Loss

| Source | DF | Seq. SS | Adj. SS | Adj. MS | F | P | Cont. (%) | Remarks |
|---|---|---|---|---|---|---|---|---|
| $Al_2O_3$ | 1 | 0.0094761 | 0.0004961 | 0.000496 | 7.4121 | 0.013115 | 82.09 | Significant |
| SiC | 1 | 0.0005120 | 0.0000016 | 0.000002 | 0.0235 | 0.879697 | 4.43 | Insignificant |
| HT | 1 | 0.0000436 | 0.0000689 | 0.000069 | 1.0299 | 0.322297 | 0.37 | Insignificant |
| $Al_2O_3$ * SiC | 1 | 0.0000270 | 0.0000270 | 0.000027 | 0.4034 | 0.532519 | 0.23 | Insignificant |
| SiC * HT | 1 | 0.0000053 | 0.0000053 | 0.000005 | 0.0797 | 0.780616 | 0.04 | Insignificant |
| HT * $Al_2O_3$ | 1 | 0.0001401 | 0.0001401 | 0.000141 | 2.0932 | 0.163452 | 1.21 | Insignificant |
| Error | 20 | 0.0013385 | 0.0013385 | 0.000067 | | | 11.59 | |
| Total | 26 | 0.0115425 | | | | | 100 | |

in the preform. During heterogeneous bonding, temperature and its holding period have an impact on the micro structure of the MMCs prepared by stir casting technique. The variation in properties is effected through the change in microstructure and/or composition in the required direction [9].

The micro hardness tests are carried out according to ASTM standards using Vickers hardness tester with a 10 mm diamond indenter and the load of 0.5 kg for a period of 10 seconds is applied on specimens. The hardness is measured at three different locations on the sample to get an average hardness value. The micro hardness testing machine is as shown in Fig. 3a. Dry sliding wear tests were conducted by pinondisk wear testing apparatus under the constant load of 3 kg at a fixed sliding speed of 1.66 m/s against EN32 steel disk. The wear test apparatus is as shown in Fig. 3b.

### 2.2 Plan of Experiments

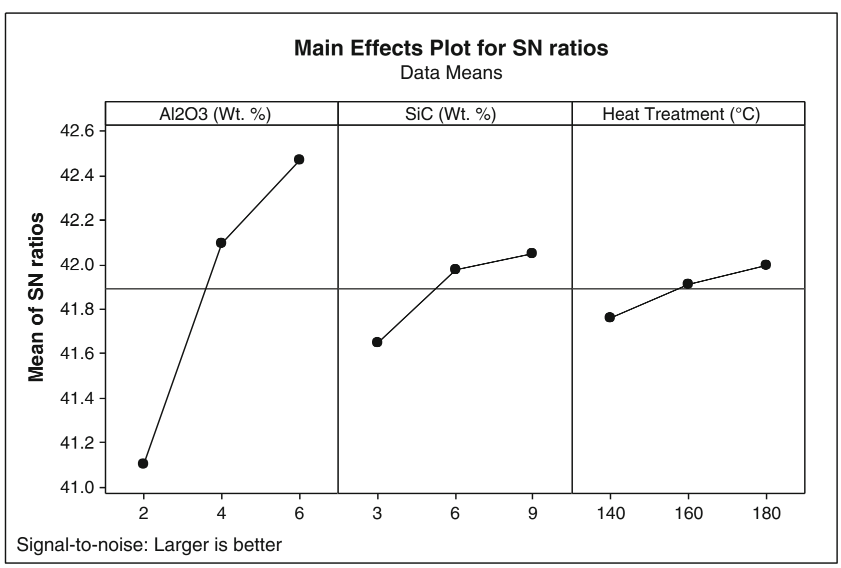
The Design of Experiments (DOE) based approach was used to employ the analysis of hardness and wear properties. According to the Taguchi method, $L_{27}$ orthogonal array are conducted for reducing the number of experiments. The parameters considered for the present study are wt. % of reinforcements and heat treatment were selected as shown in Table 2.The purpose of the optimization is to validate the optimum levels of parameters.

## 3 Results and Discussion

The experimental values of hardness and wear loss for Al7075 composites under different parameters and corresponding response for all experimental runs are given in Table 3.

The mathematical models are used to predict the hardness and wearloss which is formulated by response surface regression analysis. The suitability and significance of developed regression model was tested using predictable regression coefficient technique. The influence of hardness and wear loss are discussed with the help of following ANOVA results.

**Fig. 4** Main Effect Plot for hardness



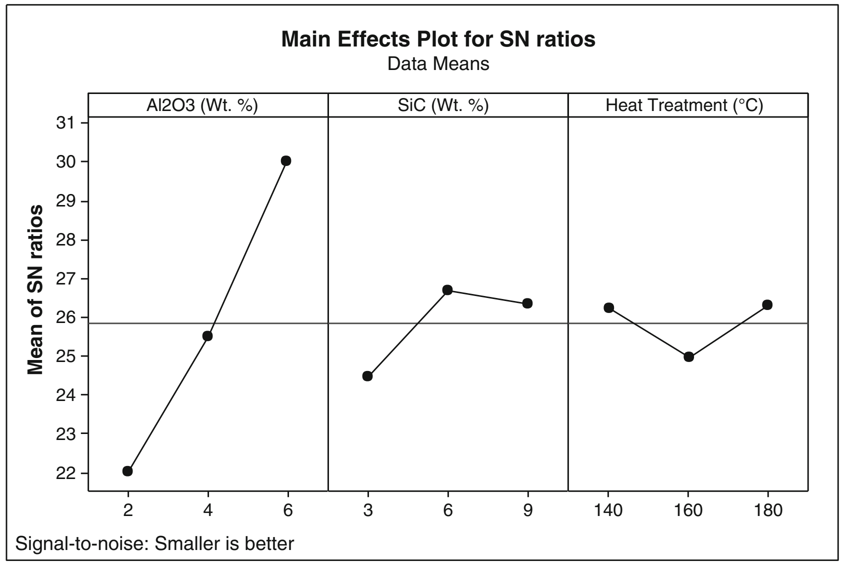



**Fig. 5** Main Effect Plot for wearloss

Table 4 shows the ANOVA results of hardness test for the composites. It can be observed that the $Al_2O_3$ is the maximum significant process parameter due to highest percentage (66.33%) contribution among the overall process parameters. The hardness increases with increase in $Al_2O_3$ content. This is because $Al_2O_3$ acts as a barrier to dislocation flow in aluminum matrix. Therefore, the increase of $Al_2O_3$ will give more barriers and hence low dislocation density, which increases [2]. The hardness of composite depends on the hardness of the reinforcement and the matrix. As the coefficient of thermal expansion (CTE) of ceramic particles is less than that of aluminum alloy, an enormous amount of dislocations are generated at the particle-matrix interface during solidification process, which further increases the matrix hardness [12]. The micro hardness values indicate that addition of reinforcement increases the hardness of the composite. This is due to more amount of alumina particles in the vicinity of the

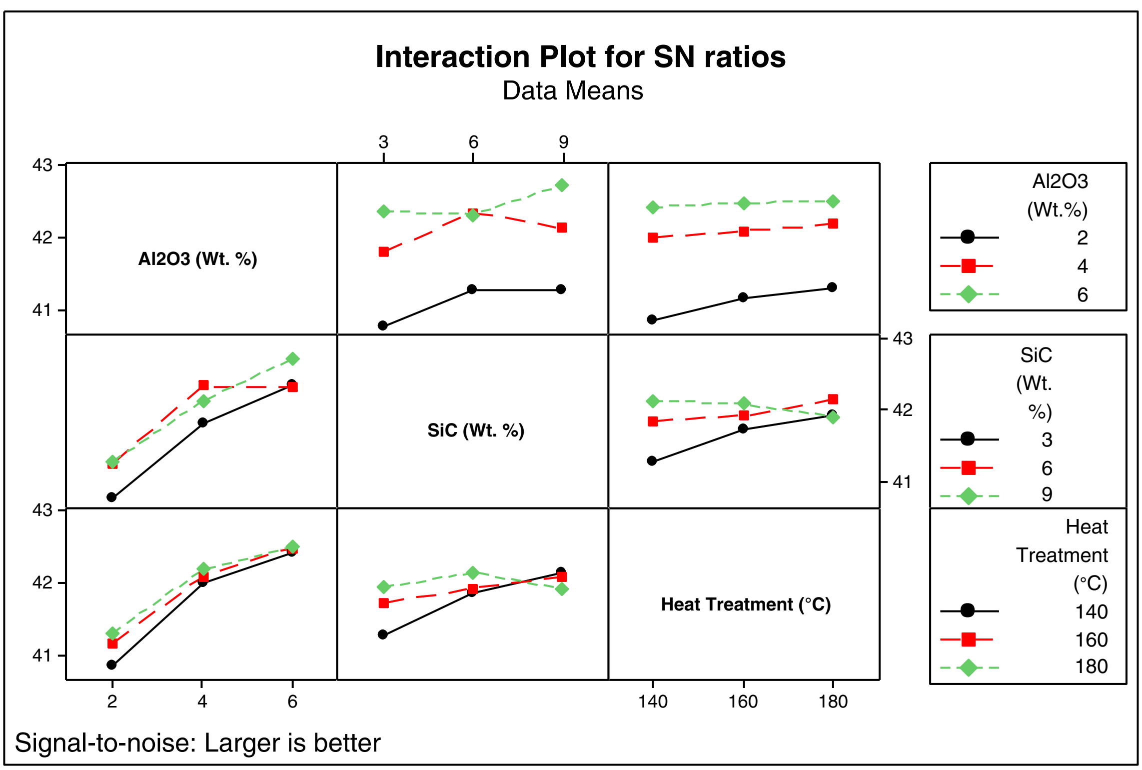



**Fig. 6** Interaction Plot for hardness

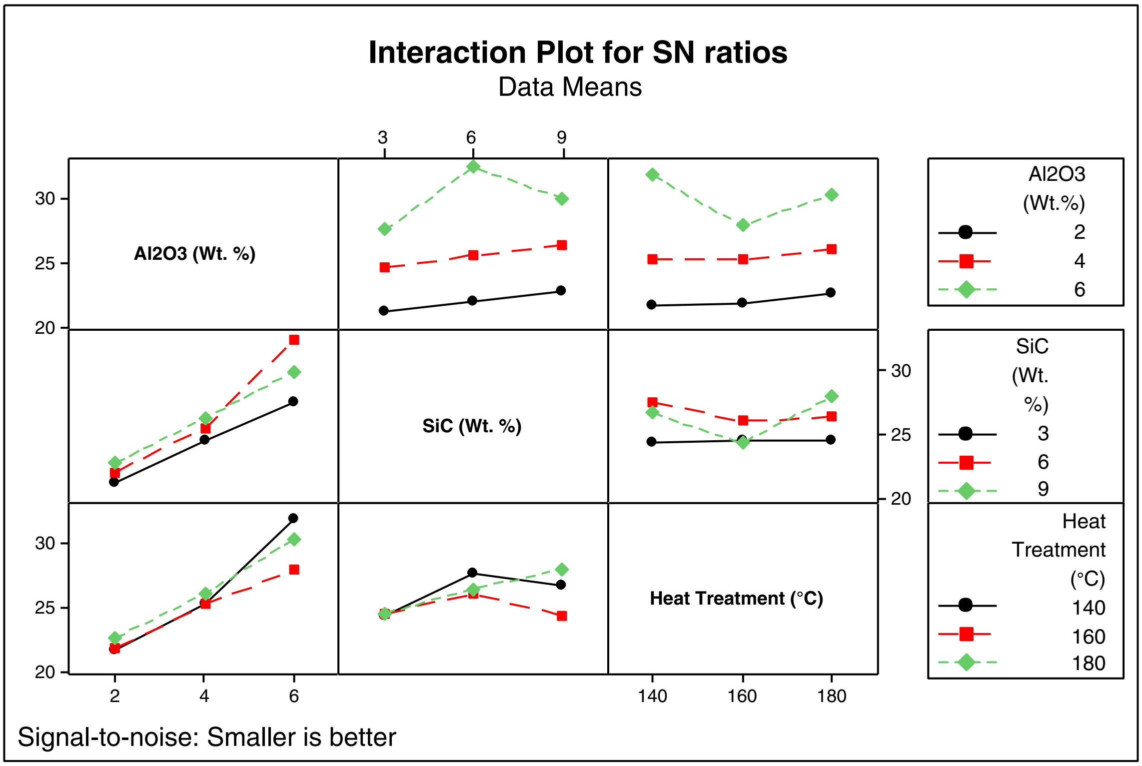



**Fig. 7** Interaction Plot for wear loss

indentation resists the deformation and induces hardness due to strong interface bonding [13]. The SiC (5.69%) and heat treatment was initiate to be least significant individual factor (1.71%). The percentage of contribution of any two factor (SiC * Heat Treatment) interactions was 4.99% and other two combination factors are very less. The collective error accompanying is 20.48%.

Table 5 shows the ANOVA results of wear loss for the composites. It can be observed that the $Al_2O_3$ is the maximum significant process parameter due to highest percentage (82.09%) contribution among the overall process parameters, followed by SiC (4.43%) and Heat treatment was initiate to be least significant individual factor (0.37%). The percentage of contribution of any two factor (Heat Treatment * $Al_2O_3$) interactions was 1.21% and other two combination factors are very less. The collective error accompanying is 11.59%. After carrying out the experiments as per Taguchi's method, the main effects plots for hardness and wear loss of the composite specimens are been plotted. The main effect plots of parameters with respect to hardness and wear loss for composites are shown in Figs. 4 and 5.

The effect of three process parameters i.e. $Al_2O_3$, SiCp & heat treatment and their interactions were evaluated using ANOVA analysis. The Figs. 6 and 7 clearly indicate the interaction plot matrix of various process parameters on hardness and wear loss. This graph shows the interaction effects for three different parameters of wt.% of $Al_2O_3$, SiCp and heat treatment temperatures together for better visualization. From the Fig. 6 the interaction between the

**Fig. 8** Comparison plot of Experiment values Vs. Predicted values for hardness

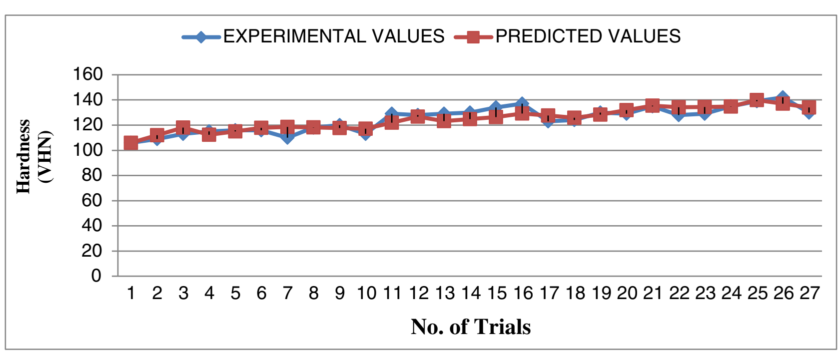


**Fig. 9** Comparison plot of Experiment values Vs. Predicted values for wear loss

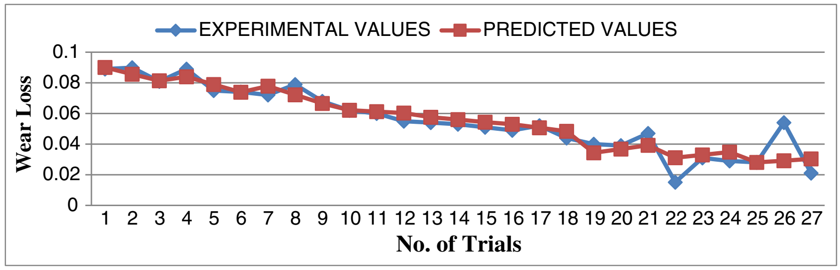



**Table 6** Response table for hardness results

| Response table for Signal to Noise Ratios (Larger is better) | | | |
|---|---|---|---|
| | $Al_2O_3$ | SiC | Heat treatment |
| 1 | 41.11 | 41.65 | 41.76 |
| 2 | 42.09 | 41.98 | 41.91 |
| 3 | 42.47 | 42.05 | 42.00 |
| Delta | 1.37 | 0.40 | 0.24 |
| Rank | 1 | 2 | 3 |
| Response table for Means | | | |
| 1 | 113.7 | 121.3 | 123.0 |
| 2 | 127.4 | 125.8 | 125.0 |
| 3 | 133.0 | 127.0 | 126.1 |
| Delta | 19.3 | 5.7 | 3.1 |
| Rank | 1 | 2 | 3 |

**Table 7** Response table for wear loss

| Response table for Signal to Noise Ratios(Smaller is better) | | | |
|---|---|---|---|
| | $Al_2O_3$ | SiC | Heat treatment |
| 1 | 22.01 | 24.47 | 26.23 |
| 2 | 25.50 | 26.69 | 24.98 |
| 3 | 30.01 | 26.36 | 26.31 |
| Delta | 7.99 | 2.22 | 1.34 |
| Response table for Means | | | |
| 1 | 0.07967 | 0.06256 | 0.05533 |
| 2 | 0.05333 | 0.05233 | 0.05922 |
| 3 | 0.03378 | 0.05189 | 0.05222 |
| Delta | 0.04589 | 0.01067 | 0.00700 |
| Rank | 1 | 2 | 3 |

**Table 8** Optimized parameters combination based on hardness test from Taguchi analysis

| Process Parameters | $Al_2O_3$ (% weight) | SiC (% weight) | Heat treatment Temperature (°C) |
|---|---|---|---|
| Optimized Values | 6 | 9 | 180 |

**Table 9** Optimized parameters combination based on wearloss from Taguchi analysis

| Process Parameters | $Al_2O_3$ (% weight) | SiC (% weight) | Heat treatment Temperature (°C) |
|---|---|---|---|
| Optimized Values | 2 | 3 | 160 |

**Table 10** Confirmatory test results for hardnesstest

| Trial No. | $Al_2O_3$ (% weight) | SiC (% weight) | Heat treatment Temperature (°C) | Vickers hardness (VHN) |
|---|---|---|---|---|
| 01 | 6 | 9 | 180 | 131 |

**Table 11** Confirmatory test results for wearloss

| Trial No. | $Al_2O_3$ (% weight) | SiC (% weight) | Heat treatment Temperature (°C) | Wear (Micron) |
|---|---|---|---|---|
| 01 | 2 | 3 | 160 | 0.088 |

process parameters like wt.% of $Al_2O_3$ and SiCp. There is an interaction effects on parameters for this case is referred to the interaction plot it was noticed that hardness becomes high with higher wt.% of $Al_2O_3$ particularly with higher wt.% of SiCp [14].

Regression analysis is used to calculate the data on the properties of hybrid composite. These regression equations are used to forecasting the hardness and wear loss within the factors used.The regression equation commonly used is represented by Y = f (X,Y and Z). Y denotes the performance characteristics (hardness /wearloss).X, Y and Z are the process parameters ($Al_2O_3$, SiC and Heat Treatment (HT)). The general regression equations for hardness and wearloss are as follows.

i) Hardness = 14.2593 + 10.0833 $Al_2O_3$ + 9.77778 SiC + 0.527778 Heat Treatment - 0.0416667 $Al_2O_3$ * SiC - 0.0541667 SiC * Heat Treatment - 0.03125 Heat Treatment * $Al_2O_3$ (Eq. 1)
ii) Wear Loss = 0.175 - 0.0266 $Al_2O_3$ - 0.00100 SiC - 0.000353 HEAT TREATMENT + 0.000250 $Al_2O_3$ * SiC - 0.000011 SiC * Heat Treatment + 0.000085 Heat Treatment * $Al_2O_3$ (Eq. 2)

To confirm the accuracy of such prediction of trials, the enduring experiments are been conducted and the comparison of experimental values and predicted values are been observed through plots. A plot of experimental values vs. predicted values is plotted for all three levels as shown in Figs. 8 and 9.

Based on hardness and wear loss results, the rank of the factors in response Table indicates the $Al_2O_3$ is the most significant factor as delta of means are designed ranked it 1 of the three factors considered in study a typical response shown in Tables 6 and 7.

The purpose of the confirmatory experiment is to validate the optimum levels of parameters selected. The confirmatory experiment shows that optimum combinations of the factors and levels selected. Samples were casted by selecting the optimized parameters from Taguchi method and were subjected to hardness and wear test. From the Taguchi analysis, optimized parameter settings were obtained and are listed in the Tables 8 and 9. The obtained result of confirmatory experimentation is as tabulated in Tables 10 and 11.

During the experiments of the hybrid composites the mixing will be a major problem. The formation of agglomeration will be more due to the addition of more particles. Due to high surface strain in the melt, the particulates were fed into the Al melt will tended to float on the surface. Finally the capitation effects will be observed and to ensure the incorporation of hybrid reinforcements and their uniform distribution in the melt should be maintained.

SEM image of the Al + 2% of $Al_2O_3$ + 3% SiC + 160°C of HT (Heat treatment) are shown in Fig. 10. It indicates the nearly uniform distribution of reinforcement in the Al matrix. This image also indicates the relatively good dispersion of $Al_2O_3$ and SiC particles in the Al matrix. In

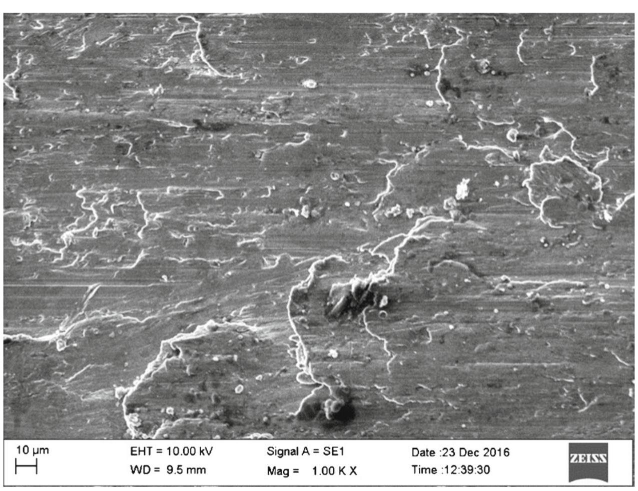



**Fig. 10** SEM image of the Al + 2% of $Al_2O_3$ + 3% SiC + 160 °C of HT

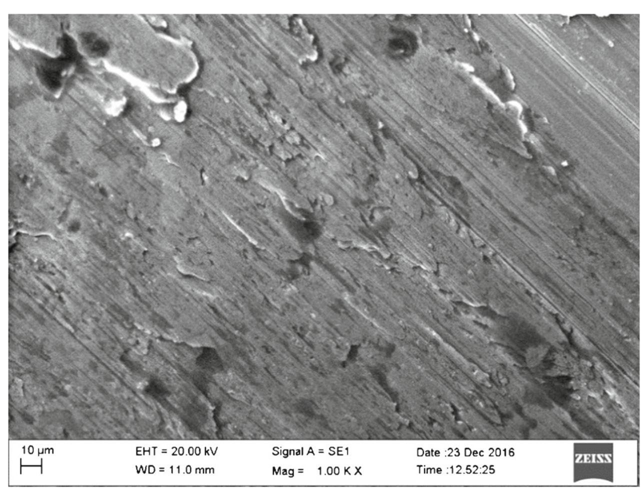



**Fig. 11** SEM image of the Al + 4% of $Al_2O_3$ + 9% SiC + 160 °C of HT

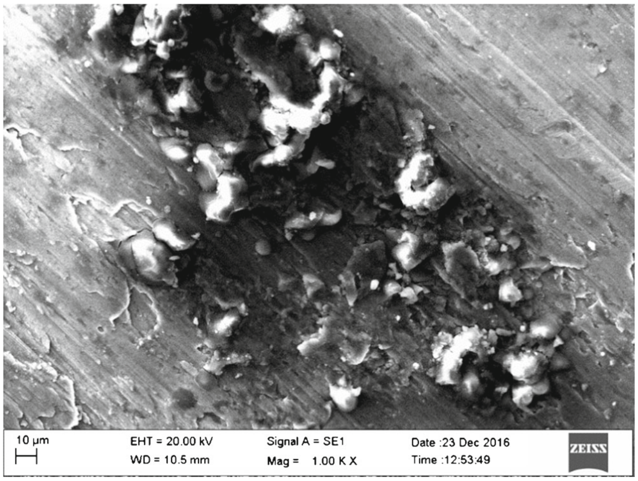



**Fig. 12** SEM image of the Al + 6% of $Al_2O_3$ + 9% SiC + 160 °C of HT

this image $Al_2O_3$ particulates are seen as whitish phases and SiC particulates are seen as dark phases in the Al7075 matrix structure.

The SEM images of the wear test at worn surface of the hybrid composites are shown in Fig. 11 of Al + 4% of $Al_2O_3$ + 9% SiC + 160 °C of HT hybrid. By this image it is observed that shrinkage cavities. These cavities are formed due to the presence of SiC particles in the matrix. The fractured particles can cause voids in the matrix which may result in the reduced strength in the composites. To confirm the nature of fracture in the hybrid structure another fracture surface SEM image for the same specimen (Fig. 12). In this image the granular and shiny appearance indicates on the worn surface of the specimen and also agglomeration was found.

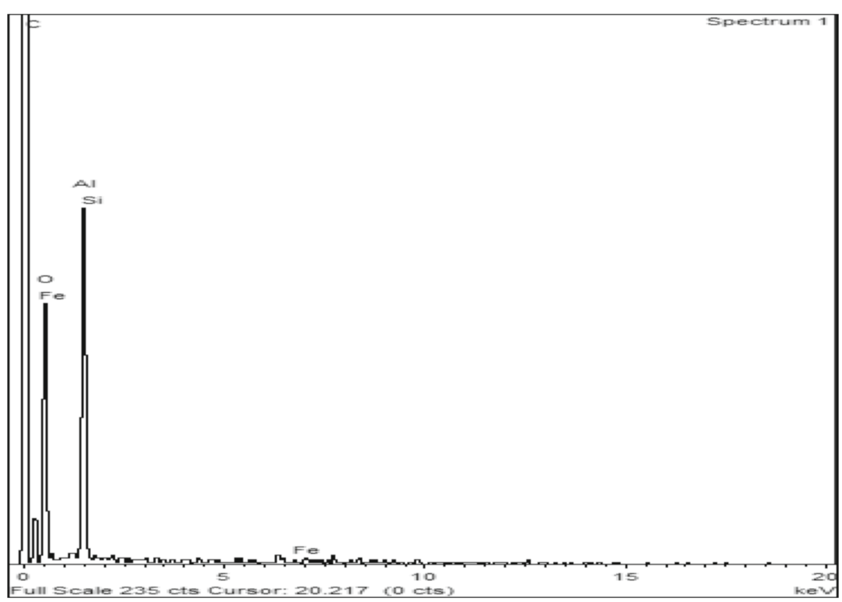
Energy Dispersive Spectroscopy (EDS) study of Al matrix near the $Al_2O_3$ and SiC particles is shown in Fig. 13. The aluminum peak, silicon peak, oxygen peak and carbon peak in the EDS confirms the incorporation of $Al_2O_3$ and SiC particles in matrix. From the observation it is said that the small amount of oxygen detected by EDS is probably coming from an oxide ($Al_2O_3$) presents during sample preparation.

## 4 Conclusion

In the present investigation, the Al7075/Al2O3/SiC hybrid composite is successfully fabricated using stir casting method. The mechanical behavior and tribological behavior are evaluated. The output results can be summarized as follows:

- Mechanical properties of hybrid composites increase with an increase in weight fraction of Al2O3 and SiC particles. Increases in aging temperature increases the hardness and wear resistance properties.
- The optimum parameter for maximization of hardness is obtained at $Al_2O_3$: 6%, SiC: 9% and aging temperature: 180 °C.
- The optimum parameter for maximization of wear loss is obtained at $Al_2O_3$: 2%, SiC: 3% and aging temperature: 160 °C.
- From SEM analysis it is observed that the abrasion wear is the main wear mechanism followed by oxide layer during wear test.

**Fig. 13** EDS of Al matrix (Al + 4% of $Al_2O_3$ + 9% SiC + 160 °C of HT)



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