International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Fabrication and tribological study of AA601 hybrid metal matrix composites reinforced with B4C nanoparticles

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Abstract - *The composite materials having various different properties and behavior based on the various properties. Because of this properties composite materials are replacing the traditional materials because of their remarkable and unachievable properties, the various types of metal matrix addition of nanoparticles producing a new property in material and alloy world. All the composite materials showing good result. The nano addition effect of metal matrix on tribological properties is to be used in automotive, industrial and various applications in industry and other sector. The current situation will investigate the wear and sliding behavior of an Aluminium alloy Al.6061-which is applied on hybrid metal matrix composites(HMMCs) reinforced with B4C ceramic nanoparticles. Present study will be focused on tribological properties of Al.6061–B4C nano composite and also comparison with Al.6061 alone. The proposed of Al.6061-B4C nano composites are to be fabricated by stir casting method with pure, 0.5%, 1% volume fraction of B4C nano particles and pin of 10X30 mm diameter and height are to be cut. The wear tests are to be with varying parameters getting by with the help of Pin on Disc wear testing setup. From the proposed results effect of various test parameters on wear behavior of pure Aluminium 6061 matrix alloy and nano B4C reinforced aluminium metal matrix composites are to be studied. After with the help of Taguchi's technique we were got the results. Results are tabulated with the help in Minitab–16 software. To analyses and getting various results, effect and condition of every input parameter on the wear rate and friction with the help of Minitab-16 Software.*

***Key Words*: Wear, COF, Taguchi Technique, Anova, Friction, L9 Orthogonal Array.**

1.INTRODUCTION

The Study of mechanics of wear and friction of material properties and the relationship between wear and friction back to the sixteenth century, almost immediately after the invention of Newton's law of motion. This study of wear and friction based on the behavior of metals. It was studied by several scientist and researchers that the variation of friction depends on interfacial conditions such as normal load, relative surface motion, stick slip, sliding velocity, surface roughness of the rubbing surfaces, geometry, type of material, system rigidity, temperature, relative humidity, lubrication and vibration. After getting results in between all these factors sliding velocity and normal load are the two major factors which that play a significant and important role for the variation of friction. In the study of composite materials with surface films which are either deliberately applied or produced by reaction with the environment the coefficient of friction may not. The two or more materials or phases are Composite material is a mixture of the same material, insoluble in one another possessing properties which are better and good results on basis of process to each other and the group of any of the component materials. The volume fraction of component materials should be above 5 percentage of total volume and their properties it should be different from each other. Usually, while considering the volume fraction of material is significantly higher than the other materials which are considered in volume fractions of the others and that material is called matrix. The Matrix can be divided in the different types like ceramic, metal and polymer. The Aluminium strength is higher than other metals. This strength of aluminum is preferably determined by its purity and the other properties. Pure Aluminium (99.99 percentage) has a tensile strength of about 49MPa, which can be increased to 700MPa using suitable alloying and heat treatment. More than 300 Aluminium alloy compositions are recognized, and many additional variations have been developed. Because of the properties of aluminium it shows great results. During the past few decades Aluminium alloys become the primary alternative material in many engineering applications owing to their high strength- to-weight ratio. There are also some of the limitation in the aluminium alloys. While during the study of aluminium alloys it can be seen that, there are also certain limitation of these alloys specifically in wear related applications is their relatively low wear resistance. Reinforcing Aluminium alloys with a high strength and high stiffness secondary phases are one of the useful techniques to enhance the wear resistance property of these materials. The Aluminium alloys has properties that it can be reinforced with particles, dispersoids or fibers. However, on account of excellent combination of properties such as high specific stiffness, high specific strength and electrical ,

thermal conductivities, low coefficient of thermal expansion and wear resistance, particulate composite metal matrix reinforced with aluminium alloy based composites find a wide application in various sectors for example in mining and mineral, automobile, aerospace, defense and other related sectors in which aluminium plays important role and gives the better properties while considering other metals properties. There are various methods and the process available for making particulate reinforced metal matrix composites (MMCs) ranging from powder metallurgy to casting methods. While considering the other process One of the most economically attractive method is the cast route which employs near standard foundry practice. In this project we use Taguchi technique for wear analysis, the method of Taguchi technique is very simple while taking the results in the process. A powerful tool for the design of high quality systems. This method provides a simple efficient and systematic approach to optimize designs for performance, quality and cost. The methodology is valuable when design parameters are qualitative and discrete. The process in Taguchi parameter design can optimize the performance characteristics through the setting of design parameters and reduce the sensitivity of the system performance to source of variation. Taguchi process is multi stage process, which follow a certain sequence for the experiments process performance. This design of experiments process made up of three main stages. This three main stages are the conducting stage, the planning stage, and analysis interpretation stage. The planning stage is the most important stage one must give a maximum importance to this stage. The results which are collected from all the experiments in the set are analyzed and processed to determine the effect of various design parameters. This approach is to use a fractional factorial approach and this approach may get with the help of orthogonal arrays. Mathematical technique is get in Analysis of variance, which is based on a least square approach. The treatment of the experimental results is based on the analysis of average and analysis of variance and then the correlation between the factors and response multiple regression equation were generated using MINITAB software.

1.1 Objective

- To find better alternative material for Armor, Military applications.
- Compare the wear loss pure Al.6061 alloy and hybrid nano composite material.
- To find out influence of each control factor on wear of the selected alloy.

2. EXPERIMENTAL PROCEDURE

2.1 Design of Experiment

The design procedure of samples of pin with diameter 10 mm and length 30 mm were used for wear analysis. Roughness of the material was removed before conducting of the experiment. This process is conducted on the available pins which will be use during the process. Before going to wear testing of the material pin with the help of emery paper which have different grade like 400, 1000 and 2000 grade. Before conducting the process Sample were cleaned in acetone before testing. There is different counter surface disc structure. All the disc structure is used according analysis. The grade of EN-32 steel (0.62%Si-0.35Mn-1.02C-1.05Cr-0.3Ni) was used for experimentation. The experiments were conducted as per the standard L9 orthogonal array. L9 orthogonal array method is used for the experiment. The wear and friction parameters all are selected for the experiment on the basis of process. This parameter is sliding speed in m/s, load in N and sliding distance in m. Every parameter was given different levels. All three levels which are shown in Table 1 are as follows.

Table -1: Testing parameters and their Values format

Factors	Level 1	Level 2	Level 3
Sliding velocity (m/s)	1.572	2.094	2.718
Load(N)	28.43	38.24	48.05
Sliding Distance	2827	3771	4712

In the experiment we were used L9 orthogonal array method. The standard L9 orthogonal array consists of nine tests in the experiment process. As mentioned in the Table 3. The first column is given by sliding speed, second column was assigned by load and third column was assigned by sliding distance. The response studied in various methods of weight. For the wear test in terms of grams weighting method is used. With the objective for the experiment of "smaller is the better" type of quality characteristic is specifically used.

2.2. Materials required

In the current study of AA-6061 alloy having great properties. This metal matrix composite showing good results. composition shown as below mentioned in Table 2 is used in the experiment. All alloys were selected as Base Matrix since its properties can be custom fitted through heat treatment process. The Boron Carbide reinforcement, and there are adequate written works clarifying the improvement in wear properties through the expansion of B4C.

Table 2 Composition of AA-6061

Alloy	Al	Mg	Si	Fe	Cu
AA6061	95.85-98.56	0.8-1.2	0.4-0.8	0.0-0.7	0.15-0.4

Alloy	Cr	Zn	Ti	Mn	Remainder
AA380	0.04-0.35	0.0-0.25	0.0-0.25	0.0-0.15	0.0-0.15

2.3. Stir casting fabrication method

Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is commonly acknowledged, and is right now practiced commercially. Its preferences are its simplicity, adaptability and appropriateness to large scale production and, because in principle it allows a conventional metal processing to be utilized, and its low expense. This fluid metallurgy technique is mostly preferable and it is also economical of all the available routes for metal matrix composite production, permits large sized components to be manufacture, continue high efficiency rates. The expense of getting ready composites materials using a casting method it is around one-third to half that to a competitive technique, and the high volume production, it is anticipated that expense will fall to one-tenth. Generally, stir casting of MMCs includes production of melt of the selected matrix material, followed by the technique of introduction of a reinforcing material into the melt, acquiring a suitable dispersion through stirring. The following step is to solidification of the melt containing suspended particles to obtain the desired distribution of the dispersed phase in the cast matrix. In composites produced by this technique, particle distribution will change significantly relying upon process parameters during both the melt and solidification phases of procedure. The increment of particles to the melt drastically change the viscosity of the melt, and this has suggestions of casting processes. It is significant that solidification happen before considerable settling has been permitted to occur.

The most significant requirement when using a stir casting process is consistent stirring of the melt with an electric motor driven agitator to prevent settling of particles. If the particles are denser than the primary alloy, they will normally sink to the base of the melt. This implies that technique of stirring the melt must be acquainted before casting process to guarantee that the particles are evenly distributed throughout the casting process.

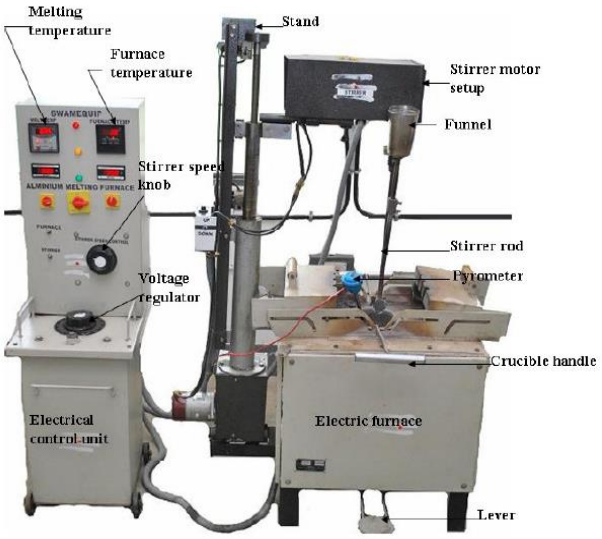

Figure - 1: Experimental setup for fabrication of material (*Stir casting setup*)

2.4. Wear test on Pin-on disc setup

Dry sliding wear test for various numbers of specimen was performed by utilizing a Pin on Disc machine. In this way invesstigation on pin on disc testing process was utilized for tribological portrayal. The test sratergy is as per the following

- At first, pin surface was levelled such a that it will support the load over its entire cross section called first stage. This way accomplished by the surface of pin test ground utilizing emery paper (80 coarseness size) before testing.
- Last step is the genuine testing called constant. This step is the dynamic rivalry between material exchange process. Prior to the test, both the pin plate were cleaned with ethanol doused cotton.

Figure - 2: Pin-on disc sliding wear testing machine with integrated system.

3. RESULT AND ANALYSIS

The main aim of experiment is to plan and to locate the significant factors and the factors of elements impacting the wear and friction procedure to accomplish the minimum wear rate for the materials. The experiment was created depend on orthogonal array. With the aim of relating the sliding velocity, applied load and the sliding distance.

3.1. Taguchi method

Dr. Taguchi of Nippon of the company name as Telephones and Telegraph in Japan has built up a technique depend on "ORTHOGONAL ARRAY" This technique plays important role in experiments which gives reduced "fluctuation" in the parameters in experiment. For the investigation with "optimum settings" of control parameters. Thus the marriage of Design of Experiments with enhancement of control parameters to acquire best results is achieved in the Taguchi Method. The "Orthogonal Arrays" (OA) give a lot of even balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, this help in data analysis and prediction of optimum results in the experiment. The Taguchi procedure includes various techniques. Which are lessening the variation of procedure which help in through the robust Design of Experiments. Multiple linear regression Equation has been gotten in the experiment through the MINITAB-16 software. The general goal of strategy has been delivering great item requiring little to no efforts. The Taguchi technique has been least difficult strategy in various contrasted strategies which are advanced expletory strategies like response surface technique which is mix of statistical experiment design basic, regression modelling method and optimization technique. Significant downside of every one of these strategies has been their inability to include the effect of uncontrollable factors like ecological conditions. Taguchi technique has been viewed as the best technique than recently developed calculation technique various experiments. Which in numerous events require less human impact.

3.2. Formation of L9 orthogonal array

The orthogonal array has the accompanying extraordinary properties that reduce the number of trails to be conducted.

- The vertical section under every independent variable has an extraordinary blend of level settings. All the level settings seem an equivalent number of times. For L9 array under factor 4, level 1, level 2 and level 3 shows up thrice. This is known as the adjusting property of orthogonal arrays.
- All the level estimations of independent variables are utilized for conducting the tests.
- The arrangement of level values for directing the trials will not be changed. This implies one cannot lead experiment 1 with variable 1, level 2 arrangement and experiment 4 with variable 1 , level 1 arrangement. The purpose behind this is the arrays of each factor columns are commonly orthogonal to some other column of level values. The inward result of vectors relating to loads is zero. If the above 3 levels are standardized between - 1 and 1, at that point the weighing factors for level 1, level 2 , level 3 are - 1 , 0 , 1 respectively.

3.2.1. Selection of orthogonal array

The determination of Orthogonal array relies upon three things arranged by priority, viz., the number of factors and their interactions, number of levels for the factors and the desired experimental resolution or cost restrictions. Sums of 9 investigations were performed dependent on the run order generated by the Taguchi model [Table 2]. The response for the model is wear rate .The general format of L9 symmetrical exhibit is appeared in Table 3.Experimental design with a L9 orthogonal array as recommended by Taguchi has been utilized to carry out experiments regarding three input sources parameters and for three levels of individual parameters. The response for the model is wear rate .The general layout of L9 orthogonal array is shown in Table 3.Experimental design with a L9 orthogonal array as suggested by Taguchi has been used to carry out experiments with three inputs parameters and for three levels of individual parameters. The input parameters utilized are Load (L), Sliding speed(S) and Sliding distance (D). According to Taguchi experimental structure theory a set of three levels assigned out to each procedure parameter has two degrees of freedom (DOF). This gives a sum of six DOF for three procedure parameters selected in this work. The closest three level orthogonal array accessible and fulfilling the rule of choosing the Orthogonal Array is L9 having 26 DOF. The details of investigations with parameters and levels are given in Table 4.

Table - 3: L9 Orthogonal array for this experiment

L9 Test	Sliding velocity (S)	Load (L)	Sliding distance (D)	Wear of Al6061+0.5%B4C (Pure)
1.	1.571	29.43	2827	0.0075
2.	1.571	39.24	3771	0.0193
3.	1.571	49.05	4712	0.0323
4.	2.095	29.43	3771	0.0084
5.	2.095	39.24	4712	0.0258
6.	2.095	49.05	2827	0.0208
7.	2.618	29.43	4712	0.0111
8.	2.618	39.24	2827	0.0086
9.	2.618	49.05	3771	0.0201

Table 4: S/N ratio for Al.6061 alloy and Nano Hybrid composites

L9 Tests	S/N ratio forAl.6061 (Pure)	S/N ratio for Al.6061+0.5% B4C(Nano)	S/N ratio for Al.6061+1% B4C(Nano)
1	42.4988	45.3521	47.5350
2.	34.2889	35.5978	39.4123
3.	29.8189	30.9031	32.9950
4.	41.5144	45.0362	46.9357
5.	31.7676	35.2894	36.8328
6.	33.6387	37.2024	38.4891
7.	39.0935	40.3546	41.1103
8.	41.3100	42.8534	44.2934
9.	33.9361	36.4205	39.0935

3.3. Results of Statistical Analysis of experiment

The analysis of variance (ANOVA) is the full form of the ANOVA. This analysis method was used to analyze the influence of wear and friction parameters like sliding speed, load and sliding distance. The ANOVA establishes the relative significances of factors in terms of their percentage contribution to the response. This analysis was carried out for a level of significance of 5% and many more values according to requirement in the process. (i.e., the level of confidence 95%). Tables 5, 6 and 7 show the results of ANOVA analysis of Al.6061 alloy, Al.6061+0.5%B4C(Nano), Al.6061+1%B4C(Nano) respectively. We can observe from the ANOVA analysis (Table 5) that the sliding speed, load and sliding distance have the influence on wear of Al.6061 alloy. The last column of the Tables 6 and 7 indicate the percentage contribution of each factor on the total variation indicating their degree of influence on the result. One can observe from the ANOVA Table 5 that the load (58.29%) and sliding distance (29.03%) have great influence on the wear of the aluminium material. The Table 6 shows ANOVA analysis of Al.6061+0.5%B4C(Nano) alloy. From the results, it is found that load (51.80%) and sliding distance (32.27%) have great influence on the wear of the Al.6061+0.5%B4C(Nano). Similarly, Table 7 shows ANOVA analysis of Al.6061+1%B4C(Nano). From the results, it is found that load (49.75%) and sliding distance (39.79%) have great influence on the wear of the Al.6061+1%B4C(Nano).

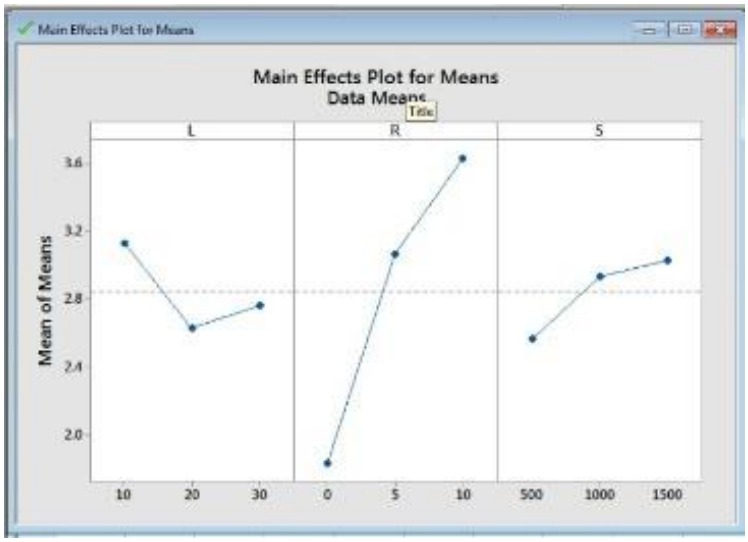

Fig.3: S/N ratio for Al.6061 alloy

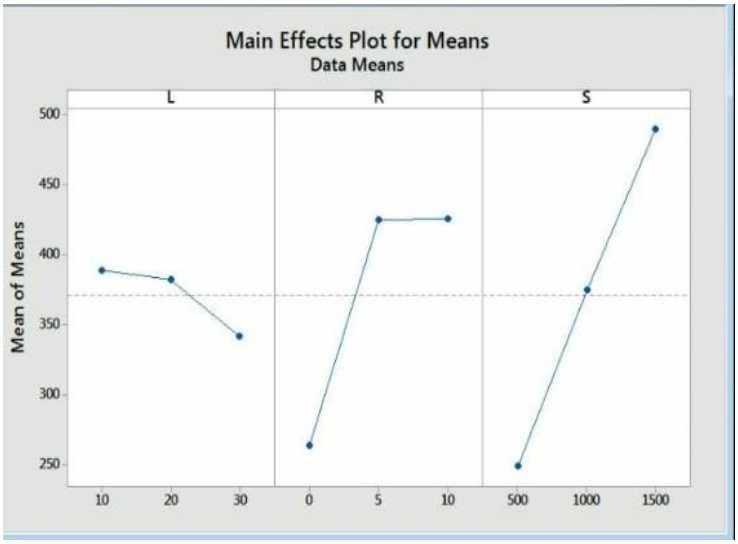

Fig.4: S/N ratio for Al.6061+0.5%B4C(Nano)

4. CONCLUSIONS

The Composite materials and constituents of other metals are replacing the traditional materials in various forms of industry. which are helpful in various ways because of their remarkable and unachievable properties and the addition of nanoparticles obtaining a new trend in material world. The effect of nano addition plays important role in the experiment procedure. While considering the tribological properties of the various metals and metal matrix composite it is essential to be used in automotive and industrial and the various applications because of which it will get better results. Current study will investigate the wear and sliding behavior of an aluminium alloy (AA) 6061-based on hybrid metal matrix composites(HMMCs) reinforced with B4C ceramic nanoparticles which is used during the experiment. Present work will be focused on tribological properties of Hybrid metal matrix (friction and wear behavior) of AA6061–B4C composite and also comparison with AA6061 alone. The proposed AA6061-B4C composites are to be fabricated by stir casting method with suitable amount of temperature which is used during the process while conducting the experiment with 0.5 %, 1 %volume fraction of B4C particles. The friction and wear behavior tests are to be carried at various load parameters at constant sliding speed of 1m/s using pin on disc wear testing equipment setup. From the proposed results effect of test parameters on wear and coefficient of friction for aluminium matrix alloy and silicon carbide-based Aluminium metal matrix composites are to be studied with the help of Taguchi Technique. After by using Taguchi's method the results are to be tabulated in MINITAB – 16 software to analyses results and to study the effect of every input parameter which is used during the experiment procedure on the wear rate and coefficient of friction. After Optical microstructural and SEM study are to be carried out to find out the pattern of distribution of B4C Nano particles in the Metal Matrix of Aluminium and to carry out the analysis of the worn surfaces.

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