Modelling The Abrasive Wear Characteristics of In-Situ Synthesized Al-ADC -12%Cu/Tic Composites

Dhanashri R. Patil[1], Prachi R. Patil[2], Rutuja S. Patil[3], Pranali R. Pawar[4], Prof.S.Y.Pawar[5]
[1, 2, 3, 4, 5] Dept of Mechanical Engineering
[1, 2, 3, 4, 5] MVP's KBT college of Engineering, Maharashra, India

Abstract- *The reviews of this paper is to evaluate the wear resistant properties of aluminum base composite and check their feasibility for give cam-shaft operating condition by optimizing their performance characteristics and tribological properties.*

I. INTRODUCTION

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. Aluminium matrix composites find a wide range of popularity in transportation sector because of lower noise and lower fuel consumptions overran other material.A composite is a material that consists of constituents produced by a physical combination of pre-existing monolithic com-pounds to obtain a new material with unique properties when compared to the base composition.

II. LITERATUREREVIEW

Many researches have contributed during implementation & study of this project, some of the application are summarized below.

Pradeep Kumar Yadav, Gajendra Dixit [6]. In the present study, an effort has been taken to fabricate and compare the erosion-corrosion of aluminium alloy (ADC12) based composite as ADC12-7%SiC and ADC12-7%TiB2 in Basic, Acidic, Seawater and Aqueous atmosphere. TiB2 reinforced composite revealed better hardness when compared to that of SiC composite. Erosion-corrosion of aluminium alloy composites were performed at different erodent concentrations (40, 60, 80 wt%) and a speed of 1000, 1500 revolution per minute. It is marked by the study that composites show ameliorate wear resistance than alloy at all speeds and all concentrations except in Basic medium. Microstructural analysis elicited Al-Si interfaces to be a preferential site for corrosion attack. Addition of reinforcement reduces the metallic area for erodent attack; hence composites show less material loss than the alloy. Among composites, TiB2 reinforcement composite show ameliorates wear resistance irrespective of speed, slurry concentration, and slurry medium. However, regardless of the material, the material loss at 1000 rpm is more than 1500 rpm in Basic media. Based on the analysis, Material removal has the following order in different mediums as; Basic > Acidic > Marine >Water

The present study uses an Al-Si alloy (ADC-12) and its composites ADC12-7%SiC, ADC12- 7%TiB2 with SiC and TiB2 reinforcement. The chemical compositions of ADC12 alloy are shown in Table 2.1. SiC and TiB2 Particles for reinforcement taken as the particle size of 5 to 40 mm. Herein, SiCand TiB2 particles preheated at 1000℃ for 3 h to raise the bonding by eliminating the absorbed hydroxides, moisture, and gases. The temperature of the furnace was raised to 750℃ to melt base alloy entirely and then the preheated reinforcements were added. 2g of magnesium is added to raise the bonding of reinforced particles. Mechanical stirring is done for 20 min at an average speed of 350 rpm. The liquefied materials were then poured into the sand mould by gravity casting. The dimensions of the mould are 150×80×10 mm in plate shape for sample fabrication. For microstructure analysis, samples were mechanically polished using standard metallographic technique and etched with Keller's regent and observed in HR FESEM (Zeiss, ULTRA Plus).

Table 2.1 Chemical compositions of aluminium alloys ADC (in wt.%)

Element	Si	Mn	Mg	Cu	Fe	Ni	Al
ADC-12	10.29	0.12	0.47	1.98	0.75	0.8	Rest

The erosion-corrosion test was carried out in slurry erosion tester TR-40 (Model-Ducom Bangalore India). For testing purpose, the rectangular bar of size 25.4 × 76.2 × 6.35 mm was taken with a hole at the center of size 8.5 mm for holding a sample in the slot. The experiments were conducted for 60 min.

PulkitGarg, AnbeshJamwalb, Devendra Kumara, Kishor Kumar Sadasivunic, ChaudheryMustansarHussaind,

Pallav Gupta [1]. An overview on synthesis routes, mechanical behavior and applications of aluminium matrix composites. Special focus is given to primary processing techniques for manufacturing of aluminium matrix composites. In the end, commercialization challenges, industrial aspects and future research directions are also briefed.

Manufacturing route adopted in fabricating any composite plays a vital role in determining the final properties of the composite. There are several techniques which are being adopted for the development of quality MMC products. Primary processes for manufacturing of AMCs at industrial scale can be classified into three main groups:1) Solid state processes 2) Liquid state processes 3) Deposition processes.
In the stir casting process of composite manufacturing the reinforcement is introduced into molten metal by stirring. Stir casting process generally involves producing a melt of theselected matrix material, followed by the introduction of a reinforcing material into themelt and obtaining a suitable dispersion through stirring. Fig. 2.3 shows the stir casting of MgO reinforced aluminium (Al) matrix composite. Stir casting is one of the most economical techniques available to produce large near-net shape parts from MMCs which involves conventional stir mixing followed by casting. Vortex technique is the simplest and most commercially used method among all stir casting routes. Vortex technique involves the introduction of pre-treated ceramic particles into the vortex of molten alloy created by the rotating impeller.

First step in the vortex method is the incorporation of ceramic particles into the vortex formed by stirring of the molten metal. Next step is to stir the mixture after the particles are feed to the melt in order to obtain a uniform dispersion of the particles, and the final step is to cast the molten mixture to obtain the composite material.

There are many manufacturing parameters like crucible size, ability and the size of impeller, temperature of the molten metal, stirring time, stirring speed, rate of particle feeding into the mixture, and temperature of the mould which need to be controlled to obtain a homogeneous mixture of reinforcement in the matrix. The two major challenges in this process are, firstly ceramic particles are generally not wetted by liquid metal matrix, and secondly, reinforcing particles tend to sink or float depending on their density relative to the liquid metal and therefore dispersion of ceramic particles can be non-uniform.

Dr. B. Stalin, S. Arivukkarasan, P. Marish Kumar [9]. This project deals with the fabrication of 5, 10, 15% of nano boron carbide reinforcement with aluminium LM4 metal matrix by liquid stir casting and the fabricated composites are tested under ASTM standard for hardness, impact and tensile strength. The results are compared with the base metal. This project deals with the characterisation of Aluminium LM4 reinforced with nano Boron Carbide composites. Composites are fabricated through stir casting technique. The mechanical property, tensile strength is evaluated for all the weight percentage composite samples. The combination of aluminium LM4 with nano boron carbide has increased the tensile strength of the base metal.

The selection of material is based on the properties, cost and the area of application where it is needed. In metal matrix composites, mostly pure aluminiumare being used for its light weight and good corrosive resistance. Aluminium cast alloys have a great scope and application in the current scenario. Aluminium LM4 is selected as the base material which has high static load that are anticipated and creep extinction at elevated high temperature. This cast alloy conforms to BS 1490:1988 standards which contains silicon as the major constituent.

Table 2.5 Chemical composition of Al LM4

Composition	Weight %
Silicon	5.2
Copper	3.0
Zinc	0.5
Iron	0.4
Manganese	0.15
Nickel	0.5
Titanium	0.2
Magnesium	0.3
Lead	0.1
Others	0.05
Aluminium	Remaining

Reinforcement material: Boron Carbide (B4C) is one of the hardest man-made materials available. Above 1300°C it is even harder than diamond and cubic boron nitride. Boron carbide ceramics have mechanical properties similar to those of silicon carbide ceramics, but have even greater wear resistance. Because of its hardness, together with its very low density.

Stir Casting: Based on literature study, availability and cost, stir casting method is preferred than powder metallurgy. The main component of the casting system is the tilting furnace.

The crucible inside the furnace is made of silicon carbide and the capacity is 5Kg. The temperature withstand of the crucible is upto 2500°C. The stirrer is made of Inconel material which has the highest temperature capability. The stirrer is open stirrer. The maximum speed of the stirrer is 1400rpm.

Muffle furnace is used for preheating the matrix material and reinforcement material. Weight percentage for 5,10, 15% of B4C are calculated and cylindrical rods for all weight percentage are to be fabricated. Materials are preheated upto $300^{o}C$ in a graphite crucible inside the muffle furnace. Then the matrix material is melted upto $850^{o}C$. Then the preheated reinforcement material is added with the melted matrix material in the furnace. Flux is added to remove the slag from the materials.

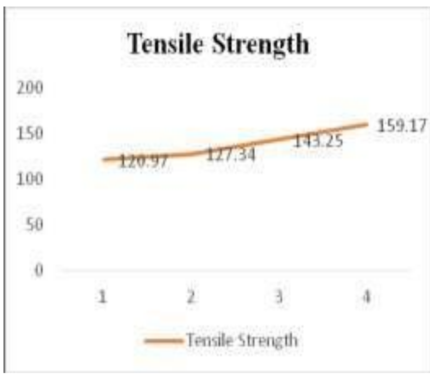


Fig. 2.10 Tensile Strength

From the above graph it is identified that the tensile strength of the sample Al LM4 with 15% reinforcement of nano B4C is higher than other two reinforcement sample of Al LM4 – 5% nano B4C and Al LM4 – 10% nano B4C.

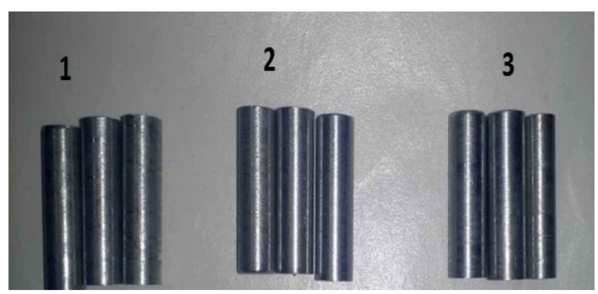
2.3 EXPERIMENTALTECHNIQUE

2.3.1 Proposed solution:-Evaluate the wear resistant properties of aluminum base composite and check their feasibility for give cam-shaft operating condition by optimizing their performance characteristics and tribological properties.Metal Matrix Composites (MMCs) are suitable for applications requiring combined strength, thermal conductivity, damping properties and low coefficient of thermal expansion with lower density.Effect of reinforcing on composite behavior is also being studied. Third objective is to improve wear performance of cam shaft bearing by replacing aluminum alloy lining by ADC-12/TiC composite.

2.3.2Manufacturing:-Then the synthesis of the particulate filled alloy was carried out in the set stir casting technique. In this process metal was melted above super heating temperature. i.e. 700ºc in a graphite crucible under a cover of nitrogen gas by using electrical resistance heating furnace.During this process mechanical stirrer was used to create turbulence motion to well agitated of molten metal. Speed of stirrer 600rpm.During this process immersed impeller depth was approximately 2/3 of the height of the molten metal from the bottom of the crucible.After this process the molten metal was poured into the mild steel die having size of $35mm^3x35mm^3x260mm^3$. After casting the specimen were given a T6 heat treatment in which the solution treatment was done at 490ºc for 2h, then by direct quenching into water and aging treatment was done at 120ºc.After this sample were prepared for pin on disc apparatus by matching in required size of 15mm diameter and 30mm height.

TYPES OF SAMPLE PREPARED

Sample No	Matrix	Reinforcement by weight percentage (Wt %)
1	ADC 12	0%TiC
2	ADC12	10%TiC
3	ADC12	20% TiC



2.4THEROTICAL ANALYSIS

2.4.1Design of Experiment :-The technique of laying out the conditions of experiments involving multiple factors was first proposed by the Englishman, Sir R. A. Fisher. The method is popularly known as the factorial design of experiments. A full factorial design will identify all possible combinations for a given set of factors. Since most industrial experiments usually involve a significant number of factors, a full factorial design results in a large number of experiments. To reduce the number of experiments to a practical level, only a small set from all the possibilities is selected. The method of selecting a limited number of experiments which produces the most information is known as a partial fraction experiment. Although this method is well known, there are no general guidelines for its application or the analysis of the results obtained by performing the experiments. Taguchi constructed a special set of general design guidelines for factorial experiments that cover many applications.

- The design of an experiment involves the following steps: -
- Selection of independent variables
- Selection of number of level settings for each independent variable
- Selection of orthogonal array
- Assigning the independent variables to each column
- Conducting the experiments
- Analyzing the data
- Inference

2.4.2 Taguchi Method :-Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on "ORTHOGONAL ARRAY" experiments which gives much reduced "variance" for the experiment with "optimum settings" of control parameters. Thus, the marriage of Design of Experiments with optimization of control parameters to obtain best results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well 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, help in data analysis and prediction of optimum results.

2.4.3 Selection of the Independent Variables :-Before conducting the experiment, the knowledge of the product/process under investigation is of prime importance for identifying the factors likely to influence the outcome. In order to compile a comprehensive list of factors, the input to the experiment is generally obtained from all the people involved in the project. Deciding the Number of Levels Once the independent variables are decided, the number of levels for each variable is decided. The selection of number of levels depends on how the performance parameter is affected due to different level settings. If the performance parameter is a linear function of the independent variable, then the number of level Setting shall be2.However, if the independent variable is not linearly related, then one could go for 3, 4 or higher levels depending on whether the relationship is quadratic, cubic or higher order. In the absence of exact nature of relationship between the independent variable and the performance parameter, one could choose 2 level settings. After analyzing the experimental data, one can decide whether the assumption of level setting is right or not based on the percent contribution and the error calculations.

2.4.4 Selection of an Orthogonal Array :-Before selecting the orthogonal array, the minimum number of experiments to be conducted shall be fixed based on the total number of degrees of freedom present in the study. The minimum number of experiments that must be run to study the factors shall be more than the total degrees of freedom available. In counting the total degrees of freedom the investigator commits 1 degree of freedom to the overall mean of the response under study. The number of degrees of freedom associated with each factor under study equals one less than the number of levels available for that factor. Hence the total degrees of freedom without interaction effect is 1 + as already given by equation. For example, in case of 11 independent variables, each having 2 levels, the total degrees of freedom is 12. Hence the selected orthogonal array shall have at least 12 experiments. An L12 orthogonal satisfies this requirement. Once the minimum number of experiments is decided, the further selection of orthogonal array is based on the number of independent variables and number of factor levels for each independent variable.

2.4.5 Assigning the Independent Variables to Columns :- The order in which the independent variables are assigned to the vertical column is very essential. In case of mixed level variables and interaction between variables, the variables are to be assigned at right columns as stipulated by the orthogonal array. Finally, before conducting the experiment, the actual level values of each design variable shall be decided. It shall be noted that the significance and the percent contribution of the independent variable’s changes depending on the level values assigned. It is the designer’s responsibility to set proper level values.

2.4.6 Conducting the Experiment :-Once the orthogonal array is selected, the experiments are conducted as per the level combinations. It is necessary that all the experiments be conducted. The interaction columns and dummy variable columns shall not be considered for conducting the experiment, but are needed while analyzing the data to understand the interaction effect. The performance parameter under study is noted down for each experiment to conduct the sensitivity analysis[17].

2.4.7 Analysis of the Data :-Since each experiment is the combination of different factor levels, it is essential tosegregate the individual effect of independent variables. This can be done by summing up the performance parameter values for the corresponding level settings. For example, in order to find out the main effect of level 1 setting of the independent variable 2, sum the performance parameter values of the experiments 1, 4 and 7. Similarly for level 2, sum the experimental results of 2, 5 and 7 and so on. Once the mean value of each level of a particular independent variable is calculated, the sum of square of deviation of each of the mean value from the grand mean value is calculated. This sum of square deviation of a particular variable indicates whether the performance parameter is sensitive to the change in level setting. If the sum of squared aviation is closet zero or in significant, one may conclude that the design variables is not influencing the performance of the process. In other words, by conducting the sensitivity analysis, and performing analysis of variance(ANOVA),one can decide which In dependent fact or dominates over other and the percentage contribution of that particular independent variable.

2.4.8 Inference :-From the above experimental analysis, it is clear that the higher the value of sum of square of an independent variable, the more it has influence on the performance parameter. One can also calculate the ratio of individual sum of square of a particular independent variable to the total sum of squares of all the variables. This ratio gives the percent contribution of the independent variable on the performance parameter. In addition to above, one could find the near optimal solution to the problem. This near optimum value may not be the global optimal solution. However, the solution can be used as an initial /starting value for the standard optimization technique.

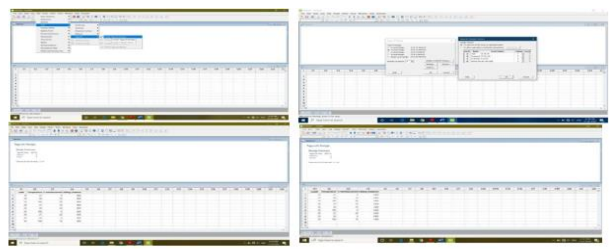
2.4.9 Minimum Number of Experiments to be Conduct :- The design of experiments using the orthogonal array is, in most cases, efficient when compared to many other statistical designs. The minimum number of experiments that are required to conduct the Taguchi method can be calculated based on the degrees of freedom approach[17].

2.4.10 Formulation of L9 Orthogonal Array:- The orthogonal array has the following special properties that reduce the number of experiments to be conducted. The vertical column under each independent variables of the above table has a special combination of level settings. All the level settings appear an equal number of times. For L9 array under variable 4, level 1, level 2 and level 3 appears thrice. This is called the balancing property of orthogonal array All the level values of independent variables are used for conducting the experiments. The sequence of level values for conducting the experiments shall not be changed. This means one cannot conduct experiment 1with variable 1, level 2setup and experiment 4 with variable 1, level 1 setup. There as on for this is that the array of each factor columns is mutually orthogonal to any other column of level values. The inner product of vectors corresponding to weights is zero. If the above 3 levels are normalized between-1 and 1, then the weighing factors for level 1, level 2, level 3 are-1,0,1 respectively.

2.5 Formulation of L9 Orthogonal Array

2.5.1 Fig.4.1 Step 1 to Create Taguchi Design in MINITAB18
2.5.2 Fig.4.2 Step 2 to Select L9 Orthogonal Array in MINITAB18
2.5.3 Fig.4.3 Step 3 to Assign Factors in MINITAB18
2.5.4 Fig.4.4 Step 4 to Obtained L9 Orthogonal Array in MINITAB18

Which is shown in below image :-



III. CONCLUSION

- Camshaft bearings are also hydrodynamic bearings. They suffer from the same operational conditions as do crankshaft bearings like, overloading, oil starvation, too thin minimum oil film, misalignment, and contaminated oil. The possible failures are also similar to the main bearing i.e. material fatigue, excessive wear, seizure, and corrosion.
- Wear of the cam shaft bearing is produced dominating effect on cam shaft life. Wear lead to misalignment, unbalance, unavoidable vibration and all this again promote wear. Thus, these entire factors are correlated. Improper operations of cam shaft effect on valve opening and reduce volumetric efficiency of the engine also loss of air-fuel mixture.
- These works also help in reducing the weight of automobile and ultimately it increases the mileage of vehicle. strength to weight ratio of ADC 12 + TiC composite is higher than the aluminum alloy which is currently use in automobile cam shaft.
- Analysis of composite is done by using the MINITAB 18 software. Taguchi technique is one of the sections of MINITAB 18 which is use for optimization of operating condition of cam shaft bearing.
- Design of experiment (DOE) section of MINITAB 18 software is used to determine the minimum number of

experiments to be carried out for the analysis of wear resistant properties of newly developed composite.

- Analysis of variance (ANOVA) and signal to noise (S / N) ratio is use to determine the dominating variable or factor for the wear of composite. Sliding distance, load, and percentage of reinforcement are taken as the design variable for statistical analysis of wear by using ANOVA.

REFERANCES

[1] PulkitGarg, AnbeshJamwalb, Devendra Kumara, Kishor Kumar Sadasivunic, ChaudheryMustansarHussaind, Pallav Gupta. Advance research progresses in aluminium matrix composites: manufacturing & applications; JMRTEC-2019;746.

[2] M.E. Tuttle, Structural Analysis of Polymeric Composite Materials, Marcel Dekker, Inc., 2004.

[3] Singh N, Banerjee S, Parkash O, Kumar D. Tribological and corrosion behavior of (100-x) (Fe70Ni30) - (x) ZrO2 composites synthesized by powder metallurgy. Mater Chem Phys2018;205:261–8.

[4] Singh N, Parkash O, Kumar D. Phase evolution, mechanical and corrosion behavior of Fe (100-x) Ni (x) alloys synthesized by powder metallurgy. J PhysChem Solids 2018;114:8–20.

[5] Baradeswaran A, ElayaPerumal A. Evaluation of aluminiummetal matrix composites (AA 6061 and AA 7075) fortribological applications. Int J Miner Metall Mater2014;21.

[6] Pradeep Kumar Yadav, Gajendra Dixit. Investigation of erosion-corrosion of aluminium alloy composites:Influence of slurry composition and speed in a different mediums. Journal of King Saud University – Science 2019; 1018-3647.

[7] VeeravalliRamakoteswaraRaoa, NalluRamanaiah, Mohammed MoulanaMohiuddinSarcar. Mechanical and tribological properties of AA7075–TiC metal matrix composites under heat treated (T6) and cast conditions. JMRTEC 2016;5(4):377– 383.

[8] V. C. Uvaraja1, N. Natarajan. Optimization of Friction and Wear Behaviour in Hybrid Metal Matrix Composites Using Taguchi Technique. Journal of Minerals and Materials Characterization and Engineering, 2012;11;757-768.