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STUDY OF MECHANICAL AND WEAR PROPERTIES of Al 7075/Al_20_{3p}/Gr_p METAL MATRIX COMPOSITES

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Abstract: Aluminium based Metal Matrix Composites (MMCs) have been a very valuable addition to the field of newer materials for high performance tribological applications. Aluminium based composites are being increasingly used in automobile, The aerospace, marine and mineral processing industries owing to their improved specific strength, good wear resistance , higher thermal conductivity and lower coefficient of thermal expansion. The mechanical properties of commonly used aluminum alloys can be enhanced significantly by incorporating ceramic reinforcements such as Al_2o_3, SiC, TiC, B_4 C, TiN and TiB_2 etc.

In the present project work, the Al/Al_2O_3/Gr_p MMC will be prepared by stir casting process. Then the study & analysis of mechanical and wear properties of Al/Al_2O_{3p}/Gr_p MMC will be done based on the full factorial design of experiment or Taguchi method. The composites will be wear tested on a pin-on-disk apparatus in which 600 grit SiC abrasive paper will be fixed on the disk. The control factors selected are the applied load, sliding distance and weight % of Al_2O_{3p} and Gr_p reinforcement in the metal matrix. Performance characteristics like hardness, tensile strength, coefficient of friction, weight loss etc. will be studied and analyzed in detail.

I. Introduction

New developments in the field of material science have led to new engineering metallic materials, composite materials and ceramics having superior desired mechanical properties and thermal characteristics. Among these, production and use of Metal matrix composites are of great interest as they are finding wide applications in many industries. Aluminum-based particulate reinforced MMCs have emerged as an important class of high performance material for use in aerospace, automobile, chemical and transportation industries.

Aluminium matrix composites (AMCs) are becoming better substitutes for the conventional aluminium alloys because of characteristics like improved strength to weight ratio, energy saving, better wear resistance etc. to mention a few. AMCs reinforced with particles of Gr_P have been reported to be possessing better wear characteristics owing to the reduced wear because of formation of a thin layer of Gr_P particles, which prevents metal to metal contact of the sliding surfaces.

II. Literature Survey

A.Baradeswaran, A.Elaya perumal [1] investigated the influence of graphite on the wear behavior of Al 7075/Al2O3/5 wt. % graphite hybrid composite. The investigation reveals the effectiveness of incorporation of graphite in the composite for gaining wear reduction. The Al 7075 (aluminium alloy 7075) reinforced with Al_2O_3–graphite were investigated. The Al 7075/Al_2O_3/graphite hybrid composite was prepared with 5 wt. % graphite particles addition and 2, 4, 6 and 8 wt. % of Al_2O_3. The hardness, tensile strength, flexural strength and compression strength of the Al 7075–Al_2O_3–graphite hybrid composites are found to be increased by increased weight percentage of ceramic phase. The wear properties of the hybrid composites containing graphite exhibited the superior wear-resistance properties.

Ravinder Kumar,Suresh Dhiman [2] an attempt has been made to investigate the specific wear rate of the unreinforced Al 7075 and hybrid aluminum metal matrix composite reinforced with the hard ceramic (7 wt.% of SiC) and soft solid lubricant (3 wt.% of graphite) fabricated by using stir casting method. The unlubricated pin-on-disc wear tests were conducted to examine the wear behavior of the aluminum alloy and its composites. The sliding wear tests were carried out at various loads (20–60 N), speeds (2–6 m/s), and sliding distances (2000–4000 m). It is inferred that specific wear rate of the hybrid composite is lower than that of the unreinforced Al 7075 in all combination of loads, sliding speeds, and sliding distances.

P.Ravindhran, K.Manisekar [3] reported that The influence of the percentages of reinforcement, load, sliding speed and sliding distance on both the wear and friction coefficient were studied using the pin-on-disk method with tests based on the design of experiments. The hardness of the composites decreases as the % of graphite (Gr) increases. The wear and friction coefficient were mainly influenced by both the sliding distance and the load applied and also this study reveals that the addition of both hard reinforcement likes SiC and soft reinforcement like graphite improves the wear resistance of aluminium composites significantly.

S.Suresh, N.Shenbaga, VinayagaMoorthi [4] investigated the mechanical behaviors such as hardness, tensile strength and tribological behavior. Wear

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experiments were conducted by using a pin-on-disc wear tester at varying load. The wear mechanism of the specimen was studied through SEM. Response Surface Methodology was used to minimize the number of experimental conditions and develop the mathematical models between the key process parameters namely weight percentage of TiB2, load and sliding distance.

K.PalaniKumar, K.Umanath, S.T Selvamani [5] presents the wear behaviour of Al6061-T6 discontinuously reinforced with silicon carbide (SiC) and aluminium oxide (Al_2O_3) composite. The test specimens are prepared and tested as per ASTM standard. The experiments are conducted by using a pin on disc wear tester. Empirical relation is established to estimate the wear using statistical regression analysis and analysis of variance (ANOVA).The results indicated that the wear resistance of the 15% hybrid composite is better than that of the 5% composite.

III. Objectives & Methodology

The main objective of the project work is to prepare the obtained cast composites of Al7075-Al_2O_{3p}-Gr_p and the castings of the base alloys were carefully machined to prepare the 6 cylindrical shape test specimens for mechanical and wear tests as per American society for testing methods (ASTM) standards.

The study & analysis of mechanical and wear properties of Al/Al_2O_{3p}/Gr_p MMC will be done based on the full factorial design of experiment or Taguchi method. Cylindrical specimens will be wear tested on a pin-on-disk apparatus. The control factors selected are the applied load, sliding distance and weight % of Al_2O_{3p} and Gr_p reinforcement in the metal matrix. Performance characteristics like hardness, coefficient of friction, weight loss etc. will be studied and analyzed in detail.

IV. Procedure

The aim of this work is to investigate and study the wear properties of Al7075/ Graphite/Alumina metal matrix composites. MMC will be prepared by the stir casting method. The composites will be wear tested on a pin-on-disk apparatus in which 600 grit SiC abrasive paper will be fixed on the disk to identify the variations in performance characteristics such as wear rate, weight loss, coefficient of friction, and frictional force values for a Al7075/Graphite/Alumina metal matrix composite with varying compositions of Graphite and Alumina particles. The experiments are designed based on Taguchi's orthogonal array and analysis has been carried out using analysis of variance and response table of each characteristics. To determine the mechanical property like hardness values for the Al7075/Al_20_{3p}/Gr_p metal matrix composites.

V .Experimental Apparatus and Methods

In the present work, the plan order for performing the abrasive wear experiments was generated by DOE method and analysis of parameters was done using analysis of variance (ANOVA) technique. The control factors were selected as applied load, sliding distance, and weight percentage of Al_2O_3 and graphite reinforcement. Each control factor was having three levels such a slow, medium and high. Thus, the number of experiments conducted was eighteen as per the P^n relation, where 'P' corresponds to the number of levels and 'n' stands for the number of factors.

The obtained cast composites of Al-Al_2O_3 and the castings of the base alloys were carefully machined to prepare the test specimens for mechanical and wear tests and as well as for micro structural studies as per American society for testing methods (ASTM) standards. The typical pin specimen is cylindrical or spherical in shape.

Fig.1 - 6Samples of cylindrical pins

A. Taguchi Methodology

It is a simple, efficient and systematic approach to determine the optimal process parameters. Conventional design of experiments/full factorial designs requires very large number of experiments as the number of process parameters increases. Further as the number of levels and trials increases, it becomes very difficult and tedious to perform all experiments one can overcome these limitations by using Taguchi's method which provides an alternate to full factorial designs. The OA method considers a part of the complete factorial design which is called Fractional Factorial Design. The OA technique helps to test the main effects and critical interaction effects on the response variable.

Fig 2 - wear testing machine

Fig.3 - Schematic of pin-on-disk apparatus

6. Results and Discussions

The wear, wear rate, coefficient of friction and frictional force are increasing with increase of the alumina. All these characteristics are increasing and then decreasing with the increase of graphite content and applied load. Also these characteristics are decreasing and then increasing with the increase of the sliding distance.

By using Brinell hardness testing, the hardness is determined for the composites. The values are average of 3 readings taken at different locations on the 6 specimens. It is found that the hardness of the composites is more than the base Al7075 (60BHN). This shows that the reinforcements increase the hardness.

Orthogonal Arrays (often referred to Taguchi Methods) represent a versatile class of combinational arrangements useful for conducting experiments to determine the optimum mix of a number of factors in a product to maximize the yield, and in the construction of a variety of designs for agricultural, medical and other experiments. They are often employed in industrial experiments to study the effect of several control factors.

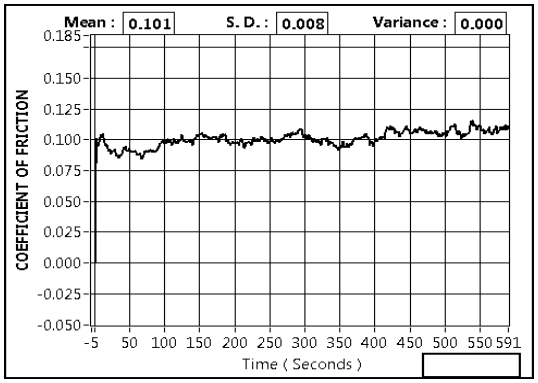

Fig 4 - Wear

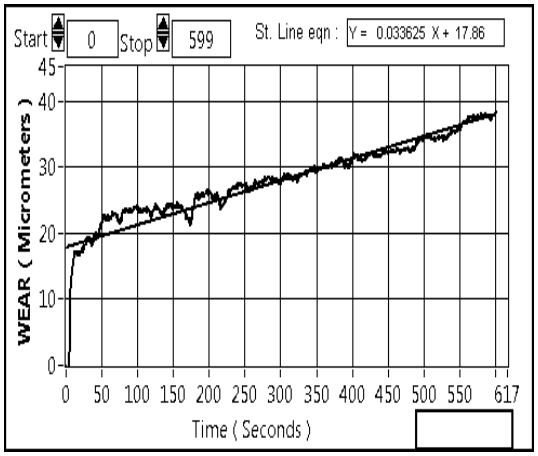

Fig. 5 - Coefficient of Friction

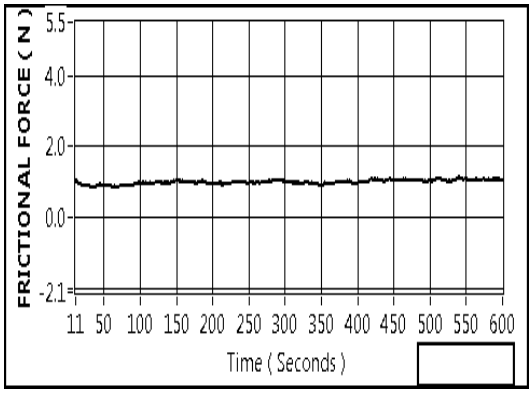

Fig.6 - Force friction

VI. Conclusion

The conclusions of the wear study on Al7075/Al_2O_{3p}/Gr_p hybrid metal matrix composites are as follows-

1. Aluminum 7075 matrix is reinforced with 0-3 wt% Alumina and 2-6 wt% Graphite particles. The hybrid composites are prepared by stir casting route. It is observed from the SEM analysis that the reinforcements are distributed uniformly in the

matrix. Addition of Al_2O_3 particle on the surface of matrix, the plastic deformation of matrix can be resisted with the presence of Al_2O_3 which act as a barrier to the moment of dislocation which causes the more wear resistance than base alloy. Graphite act as a protective layer, this film prevents the breaking of hard Al_2O_3 particles from the pin surface, which results in less surface damage.

2. Taguchi methodology is adopted for the experimentation purpose. L18 orthogonal array is selected to conduct the experiments.

3. Using pin-on-disk tribometer, experiments are conducted on 6 samples of machined cylindrical pins and wear properties like weight loss, friction force, coefficient of friction, wear are analyzed. It has been observed that the rise in the applied load graphite increases the wear rate. It also has been observed that the addition of Alumina increases the frictional force.

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