A Project Report on

MATERIAL PROCESSING AND CHACTERIZATION OF AL6061-BERYL COMPOSITES FOR FABRICATION OF FUSELAGE USED IN AIRCRAFT STRUCTURE

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ABSTRACT

Recognizing the fact that the materials play a major role in any industrial applications, while the advancement of material development has an influence on the industrial growth together with economy, there has been a growing search for new materials worldwide from times immemorial. This has led to the development of some advanced materials and their processing methods with continuous efforts being made to enhance the properties of material for their better performance. Besides, considering that monolithic materials cannot meet all the requirements in respect of their properties and performance, many attempts have been made over the years to develop new materials and processes, which has not only resulted in effective and efficient utility of components made from that material, but also have made great impact on the world economy and on the improvement of our quality of life.

One such major development in the field of materials is 'Composite Materials'. Composites are new generation engineering materials, as they offer several unique and outstanding properties compared to conventional monolithic materials. Amongst the various types of composite materials, the development of Metal Matrix Composites (MMCs) is considered as one of the major innovations in materials science in the last three decades. MMCs has metal as matrix and dispersoids of different sizes and shapes with aspect ratios varying from 10-100 with their diameter varying from 0.1–500 μm in the case of particles, from 10-1000 with their diameter varying from 0.1-25 μm for whiskers and >1000 with their diameter varying from 0.1-25 μm for fibre respectively. Literature survey reveals that although a number of light metals such as Al, Mg and Ti have been used as matrices, mostly Al and its alloys, both cast and wrought alloys have been used more extensively as the matrices for MMCs preparation. This is due to their inherent light weight, good corrosion resistance, ease of handling and a wide range of present and future applications. The survey also shows that a variety of materials such as carbides of Silicon (SiC), Titanium (TiC) and Boron (B_4C), oxides of Aluminum (Al_2O_3), nitrides of Silicon (Si_3N_4), Boron (BN) and Titanium dioxide (TiO_2) and even lighter ones such as Graphite, Mica, Glass both in discontinuous and continuous form, have been used as reinforcements. Several techniques like powder metallurgy, spray deposition, liquid metallurgy etc., have been attempted for their primary processing including conventional foundry techniques. Amongst these, the liquid metallurgy methods are

found to be easier to handle during fabrication as well as they being low cost production methods to produce very large size ingots or products particularly with discontinuous reinforcements. This technique will enable to produce large volume of complex shaped components at high production rates; also gain near net shapes, making MMCs to be more cost effective. These MMCs are found to result in isotropic properties, which have been found to be attractive with specific properties comparable to those of ferrous and some non-ferrous monolithic materials. They include 20-50% increase in stiffness, 20-30% in Ultimate Tensile Strength (UTS), about 30% lower co-efficient of thermal expansion, high thermal and electrical conductivities, improved damping properties, friction wear (2-5 times) and seizure resistance, over the matrix material. Judicious selection of matrix-dispersoids combination and processing methods has been found to be the reason for this.

Considering all the above, during the last few decades MMCs have been finding applications in strategic sectors such as aerospace and nuclear areas in addition to automotive and recreation areas.

All the above are presented in more detail in **Chapters 1 & 2 of this project report**.

Further, as mentioned earlier, of all the Aluminum alloys, Al6061 is quite popular choice as a matrix material to prepare metal matrix composites owing to its better formability characteristics and option of modification of the strength of composites by adopting optimal heat treatment.

In addition, this Aluminum alloy is heat treatable, and as a result further enhancement in properties can be expected through reinforcement. Although the synergetic effect of heat treatment and the type of reinforcement plays a dominant role in dictating the final mechanical properties of composites, but only little information is available pertaining to the heat treatment of Aluminum based composites. Furthermore, Aluminum Metal Matrix Composites (AMMCs) offer good mechanical and superior wear resistance properties when compared to the matrix alloy irrespective of applied load and sliding speed. This is primarily due to the fact that the hard particles like SiC, WC and Al_2O_3 etc., when dispersed in matrix makes the matrix alloy plastically constrained and improves the high temperature strength of the base alloy. Hence, in recent years, Aluminum alloy based MMCs are being explored as candidate materials in several interesting tribo related applications such as piston, connecting rod, contactors etc., where sliding is a key component. Excessive wear due to sliding will ultimately result in seizure of the mating parts sometimes leading to catastrophic failure. Tribological characteristics of several MMCs systems involving Glass, Flyash, SiC, Graphite, Mica, Al_2O_3 as discontinuous dispersoids have been reported. 'Beryl' is naturally available in the form of mineral (Silicate of Beryllium and Aluminum). It has a density of 2.6-2.8 g/cc, with a hardness of 7.5 to 8.5 on Mho's scale (700 BHN approximately). Literature survey indicates that only few researchers have made an attempt to use Beryl [$Be_3Al_2(SiO_3)_6$] as reinforcement in Al6061 alloy processed by liquid metallurgy technique to fabricate Aluminum-Beryl particulate composites.

With this back ground, **Chapter 3** presents the Aim, Scope and Objectives of the present work is briefly specified below:

Development of a standardized process of stir casting of composites with Al6061 as matrix and 2-12% wt. Beryl particles as reinforcement; Characterize the composites in 'as-cast' condition for the physical, mechanical and tribological properties; study their morphology and fracture behavior to explain the observed properties;

Chapter 4 gives experimental details. This includes raw materials (Al6061 Alloy and Beryl particles of size 53-75 μm) used, their chemical composition, and preparation of composites by liquid metallurgy of the composites and finally characterization of all these composites for various properties mentioned above, the standards and the equipments used for this purpose, etc.,

Chapter 5 presents the results obtained in this study. First physical properties of the reinforcement particles and their structural characterization through X-ray diffraction (XRD) are presented. Then, density of composites, structural study through XRD, morphology through microscopy, mechanical properties (hardness and tensile strength) of composites as function of Beryl content and wear properties of composites, under different sliding distance and applied load have been presented. The above properties have been studied in 'as-cast', condition for the composite. The worn surfaces of the tested composites have also been presented based on which all the obtained results have been explained. Some of the highlights of the results obtained include the following:

Theoretical density values of Al6061-Beryl particulate composites decreases linearly (2.750 g/cc to 2.748 g/cc) with increasing Beryl content (2% wt. to 12% wt.), while the experimental density values were lower (2.725 g/cc to 2.503 g/cc) than that of the theoretical densities with of course the density of the composite being higher than the base matrix.

XRD analysis of the composites showed the presence of Beryl particles distributed in the matrix of Al6061, which was further confirmed by optical microscopy.

Beryl particles were effective in improving the tensile strength of matrix alloy from 117.2 MPa to 135.1 MPa for an incorporation of 12% wt. Beryl particles. Similarly, the Beryl particles in the matrix alloy significantly improved the hardness of the matrix by about 38.31%.

In the case of wear properties, the composites showed lower specific wear rate for all the applied loads used (4.905-19.62 N) indicating the beneficial effect of addition of Beryl particles with the wear rate decreasing with increase in quantity of Beryl, while the sliding distance increases the wear rate at a decreasing trend.

On the other hand, the wear rate of the unreinforced alloy specimens increases more rapidly with applied load compared with the composite alloy specimens exhibiting two regions which may be called 'running-in' and 'steady state' periods. During the 'running-in' period, the specific wear rate decreased very rapidly with increasing sliding distance while during the steady state period, the wear progressed at a slower rate and linearly with increasing sliding distance indicating that the volume content of the particulate reinforcement has a marked effect on the specific wear rate.

All the above results of wear properties have been explained based on the Scanning Electron Microscope (SEM) studies of worn surfaces, which showed debonding of the particle due to the continuous sliding which makes the particle get loosen from the matrix and get struck between the sliding surfaces acting as 'abrader' leading to abrasive wear for short duration.

Chapter 6 presents the conclusions of this study,

Chapter 7 presents suggestions for future work in this area.