International Conference on Systems, Science, Control, Communication, Engineering and Technology 2016 [ICSSCCET 2016]

ISBN	978-81-929866-6-1		**VOL**	02
Website	icssccet.org		**eMail**	icssccet@asdf.res.in
Received	25 – February – 2016		**Accepted**	10 - March – 2016
Article ID	ICSSCCET187		**eAID**	ICSSCCET.2016.187

An Overview of Tribological Characteristics of Aluminium based Composites

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Abstract- *Aluminum matrix composites have been emerged as advanced materials that are well suited in automotive, space, aircraft, defense, and in other engineering sectors. Aluminum and its alloys occupy third place among the commercially used engineering materials. Use of aluminum in transport sector has increased from just 6% in 1950 to 28% in year 2010. Consumption of Aluminum casting has increased from 85,000 ton in 1995 to 180,000 ton in year 2010. The enormous amount of research and development (R&D) that has gone into Al-based MMCs of every possible alloy with different dispersoids establishing beyond doubt the usefulness of making composites but a choice has to be made with both the base alloy selection and dispersoid size and volume percentage for making engineering components. The wear resistant characteristics of the comppsites are most important during the service of the engineering components. This paper reviews the tribological characteristics of the aluminium based metal matrix composites.*

Keywords: *Composite, Aluminium, MMC, Tribology, Wear*

I. INTRODUCTION

Metal matrix composites have potential advantages over monolithic alloys and this has activated considerable attention in the past years. These composites have provided solution to the problem of increasing service requirements for various structural applications through the reinforcement of metal matrix by metallic or non metallic materials. Metal matrix composites (MMCs) are commonly reinforced with high strength and high modulus ceramic phases, which may be in the form of fibre, whiskers, or particulates. The addition of ceramic reinforcement to metal matrix improves strength and stiffness while ductility is compromised. Commonly used metals as matrix in producing structural materials include titanium, aluminum, and exotic metals such as silver, magnesium, beryllium, copper, cobalt, and nickel [1].

Aluminium is the most attractive material in automotive, airplane, space and precise devices industry. Improvement of mechanical and tribological properties of aluminium can be achieved through aluminium reinforcement with the proper material and through creating composite material. The most effective improvement of these properties is achieved through creating hybrid composites with two or more types of reinforcements. By adding the ceramic reinforcement, mechanical properties of the matrix are changed, but in that case problem of machinability occurs. To improve machinability, the graphite is added to composite materials that are already reinforced with ceramic material. Presence of graphite reduces mechanical properties (hardness decreases), but tribological properties are improved [2].

The sliding wear of the composite is a complex process involving not only mechanical but also thermal and chemical interactions between two surfaces in contact. The wear resistance of composite materials is of our present interest because of their potential tribological characteristics that are very well applicable in automobile such as IC engines components, brake disc. [3]. this paper presents the review of tribological characteristics of aluminium based metal matrix compsites.

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II. Types of Aluminium Alloys

Pure Aluminum is relatively soft. To overcome this, the metal can be alloyed with other metals (alloying elements). Most of the Aluminum reaching the market place has been alloyed with at least one other element. There is a long-established international system for identifying Aluminum alloys. The first digit in the four-digit alloy code identifies the major alloying element. Based on the type of alloying element, the Aluminum alloys are divided into 8 groups.

- **1xxx Series:** Contains no alloying elements. The proportion of Aluminum is 99.3 – 99.9% and the rest is formed by tiny impurities. The combination of material properties, especially superior conductivity makes these alloys suitable for applications mainly in electrical and heat-power industry. Materials of this series are considered non-hardenable alloys and have tensile strengths of 40 – 60 MPa.
- **2xxx Series:** the alloying element is copper. Alloys of this series are high strength alloys. The strength is achieved by the heat treatment process. The tensile strength is about 400 MPa on completion of hardening. Alloys of this series are considered not suitable for surface treatments and poor for welding.
- **3xxx Series:** The alloying element is manganese. Alloys of this series are moderate in strength, they have good formability and they are suitable for anodizing and welding.
- **4xxx Series:** The alloying element is silicon.
- 5xxx Series: The alloying element is magnesium. Alloys of this series are moderate in strength (200– 350 MPa). Alloys of this series have excellent resistance to corrosion in aggressive atmosphere and seawater.
- **6xxx Series:** The alloying elements are magnesium and silicon. Alloys of this series are moderate in strength (200 – 350 MPa). The strength is achieved by the heat treatment processing or forming. Alloys of 6xxx series can be easily anodized and high corrosion resistance.
- **7xxx Series:** The alloying element is zinc. Alloys of this series have the highest strength among all series. The tensile strengths ranging between 450– 500 MPa may exceed 600 MPa in some cases. These alloys are prone to stress corrosion, especially when welded.
- **8xxx Series:** The alloying element is other than for the other series (including lithium). [4]

III. Preparation of Composites

There are several possible methods of producing semi finished material and components in light metal composites, which depend primarily on the component geometry and the material systems (matrix/ reinforcement). The process must be divided into preparation of suitable starting material, production of the semi finished material or component and finishing operations. For economic reasons nearnet shape production should be attempted to minimize mechanical finishing operations. In general the following production techniques are available:

- Casting techniques
  - In filtration of short fibres, particle or hybrid pref orms by squeeze casting, vacuum in filtration or pressure in filtration
  - Reaction in filtration of fibre or particle preforms' ,
  - Production of prematerial by stirring particles into metallic melts with subsequent sand casting,chill casting or pressure casting.
- Powder metallurgy techniques
  - Extrusion or forging of metal powder - particle mixtures
  - Extrusion or forging of spray formed semi finished material.
- Further processing of semi finished cast material by Thixo-casting or forming, extrusion, forging, cold forming or super plastic forming,
- Joining or welding of semi finished products,
- Finishing by machining [5].

III. Results and Discussions

A. Kurzawa etal presents a research on abrasion resistance of aluminium-based composites consisting of EN AC-44200 matrix reinforced with AlB2BOB3B particles. The examinations revealed that wear intensity of the composites decreased with increasing volume fraction of the particles. Much more intensive abrasive wear was observed on the first kilometre in comparison to the wear on the subsequent distances, i.e. from 1 to 3.5 km and from 3.5 to 8.5 km of the wear distance. The following conclusions are made:

- Wear of the examined composite materials decreases with increasing volume fraction of ceramic reinforcing particles.

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- Wear process runs much more intensively and with higher friction coefficient f on the first kilometre of the friction distance than on the other applied friction distances 1 to 3.5 km and 3.5 to 8.5 km. Higher intensity of wear at the initial stage is related to creating in the specimen a structurally different zone (deformation of α phase and disintegration of eutectic silicon particles) at some distance from the friction surface. This process takes place on the distance from 0 to 1 km.
- During wear process of the non reinforced matrix material, dominating is adhesive wear. In turn, abrasive wear is dominating in the composite materials.
- With increasing volume fraction of reinforcement particles, the friction coefficient increases ca. 0.250 per each additional 10 vol.% of the reinforcing particles.
- Higher volume fraction of reinforcement particles in the composite materials results in more intensive groves forming of the counterspecimen material. Depth of groves of the cast-iron disk is ca. 30 µm larger per each additional 10 vol.% of the reinforcing particles.
- Roughness Ra at the bottom of a crater on the counterspecimen increases with larger volume fraction of reinforcing particles in the composite materials from 7.4 µm at 10 vol.% to 9.1 µm at 40 vol.% of the particles [6].

A. Vencl etal presents the tribological tests results of Al-Si alloy A356 (EN-Al Si7Mg0.3), with and without 3 wt. % Al2O3 reinforcement. The reinforcement was in the shape of particles with 12 µm in diameter and the technology for producing of composite was compocasting. The following conclusions are made:

- Friction values for matrix and composite material were in expected range for light metals in dry sliding conditions, with remark that composite material, for the applied load range, showed slightly higher values comparing to the matrix material.
- Improvement of wear resistance for the composite material with 3 wt. % Al2O3 reinforcement was significant for specific load up to 1 MPa.
- Adhesive wear was a predominant mechanism of wear followed by plastic deformation with increase of specific load.

Honnaiah C etal presents tribological tests results of Aluminium A356 with 10% Al2O3 reinforcement. The reinforcement was in the shape of particles with size of 25 µ, 45µ, 75µ and 120 µ and the technology for producing of composite was stir casting. Dry sliding wear tests of the specimens were conducted using pin-on-disc test apparatus conforming to ASTM G99 standards with electronic data acquisition system. EN32 hardened steel disc with a hardness of 65HRC and Ra value of 2.5-3.5 µm was used as the counter surface. The wear displacement with respect to sliding distance of different test specimens at different loads were studied and analysed. The slope of the curves is higher initially, indicating running-in wear, during which, asperity contacts take place resulting in higher wear rates. Later, as the asperities get flattened, contact area increases, with reduction in wear rate, which is indicated by reduced slope of wear curves. With further increase in sliding distance, rate of wear increases, due to abrasive wear of entrapped particles between mating surfaces. Experimental investigations on the evaluation of tribilogical characteristics of A356-Al2O3 p metal matrix composites have provided the following conclusions.

- The wear properties of the A356 alloy were considerably improved by the addition of Al2O3 particulates and the wear resistance of the composites was much higher than that of the unreinforced A356 aluminum alloy.
- The wear resistance of composites increased with decreasing particle size of Al2O3 particulates.
- From the wear test results, it can be observed that the transition from mild to severe type of wear takes place in the load range of 30-40 N.
- Frictional force is relatively higher in case of composites compared to that of matrix alloy. And also composites with larger particulate reinforcement experience marginally higher frictional force compared to those with smaller particulates[8].

Ali MAZAHERY etal investigated the The effect of SiC particles reinforcement with average size of 1, 5, 20 and 50 µm and volume fraction of 5%, 10% and 15% on the microstructure and tribological properties of Al-based composite was investigated. Composites were produced by applying compocasting process. Tribological properties of the unreinforced alloy and composites were studied using pin-on-disc wear tester, under dry sliding conditions at different specific loads. The influence of secondary mechanical processing with different rolling reductions on the dry sliding wear characteristics of Al matrix composites was also assessed. The following conclusions are made:

- The decreased porosity of composites during rolling is due to the flow of matrix alloy under the applied shear and compressive forces which result in filling of the voids. The increased rolling reduction provides easier flow of the matrix alloy and hence results in decreased porosity. In fact, the major reason for rolling the particulate metal matrix composites (PMMCs) is to close the pores and attain improved mechanical properties.
- The microstructural studies revealed the more uniform distribution of the particles in the matrix of the cold rolled samples. Microstructure of the composites revealed that during the compocasting process a transformation from a typical dendritic to a nondendritic structure of the primary α phase occurred as a result of shear forces generated by the mixer rotation.

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- It can be seen that the hardness of tested materials increases with the increase of SiC particles amount. The matrix hardness exerts a strong influence on the dry sliding wear behaviour of the SiC particles reinforced composite, and the composite with the lowest matrix hardness displays the lowest wear rate.
- The applied load has a significant influence on the wear rate of tested materials. In general, with the increase of the applied specific load the wear rate of the matrix and composites also increases.
- Unreinforced Al alloys show very intensive wear rate from the beginning of the test. Wear behaviour is determined by extensive material plastic flow on pin surface indicating severe wear regime as dominant. However, composite does not show plastic deformation on the worn surface [3].

Shivaprakash.Y.M presents studies the tribological characteristics of AA2024+10% fly ash composite in non-heat treated and heat treated conditions. Composite used contains fly ash particles [10% by wt] reinforced with wrought aluminium alloy AA2024. The composite is tested for tribological behaviour in the Non-Heat Treated [NHT] and Heat-Treated [HT] conditions under different working parameters in a pin-on-disc tribometer. The results of the experiment indicate that the dispersion of fly ash particles in the AA2024 alloy matrix would increase the wear resistance of matrix alloy. It's observed that a significant improvement in wear performance is achieved by heat treating the composite. The water quenched specimen showed a better properties as compared to air cooled and NHT counterparts. The following conclusions ar made from the study:

- Heat treated AA2024+10% fly ash composite show superior wear characteristics as compared to non-heat treated category, specifically the wear performance was better for water quenched specimens as compared to air cooled and non-heat treated ones.
- The specimens of NHT and HT category, at 35 N load shows that the wear rate decreasing as the sliding distance is increased and it remained constant for sliding distance more than 9000 m.
- Wear rate as a function of normal load is low for the water quench specimens, but is having an increasing trend as the normal load is increased.
- The specific wear rate is found to be lowest for water quench specimens as compared to NHT and air cooled conditions.
- NHT composite is found to have lowest coefficient of friction for all the loads (10, 25 and 35 N) as compared to other HT category specimens.
- Co-efficient of friction was highest for water quench as compared to air cooled and NHT specimens as the sliding distance in increased [9].

IV. Conclusions

The present study gives the overview of the types of aluminium alloys, methods of manufacturing of aluminium based composites and tribological performance of the composites. The addition of carbon based particles (graphite, molybdenum, etc) content to aluminium alloy increases the wear resistance up to certain wt. % of carbon particles and decreases the hardness of composites. Also the machinability is increased with addition of carbon based particles. The effect of adding ceramic particles such as SiC, Al2O3 and B4C in aluminium matrix to increase the mechanical properties such as tensile strength, compressive strength and flexural strength.

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