Studies on Tribological Properties of Aluminum 356.1 Nano Metal Matrix Composites using Biolubricant: A Review

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Abstract - Aluminum is a metal which have light weight element used in several alloys and composites because of its unusual blend of properties such as low density, high wear resistance and corrosion resistance. Aluminum is used in plenty of applications such as automobile, aerospace, industries and home appliances. Composite materials have both metal matrix and reinforcement. Metal matrix composites are used widely in all purposes. In this review, recent advances in processing, and mechanical characterization of aluminum composites reinforced with different particles are addressed. Aluminum alloy is reinforced with ZrO2 which are fabricated using stir casting technique with different weight percentage ratios will enhance the desired properties. By using these components mechanical and tribological properties are to be finding out for different tests like hardness, tensile test and wear test in the future work.

Keywords: ***Aluminum 356.1, MMC (Metal Matrix Composites), Reinforcement, Properties.***

I. INTRODUCTION

Originating from early agricultural societies and being almost forgotten after centuries, a true revival started of using lightweight composite structures for many technical solutions during the second half of the 20th century. After being solely used for their electromagnetic properties (insulators and radar-domes), using composites to improve the structural performance of space craft and military aircraft became popular in the last two decades of the previous century. First at any costs, with development of improved materials with increasing costs, nowadays cost reduction during manufacturing and operation are the main technology drivers. Latest development is the use of composites to protect man against fire and impact and a tendency to a more environmental friendly design, leading to the reintroduction of natural fibres in the composite technology. Composites are developed by combination of two or more different materials, referred as base matrix and reinforcement; it offers advantages of producing resultant material with superior characteristics as compared to close relative materials. Composite materials, or shortened to composites, are microscopic or macroscopic combinations of two or more distinct engineered materials (those with different physical and/or chemical properties) with a recognizable interface between them in the finished product. Composites were developed because no single, homogeneous structural material could be found that had all of the desired characteristics for a given application.

II. LITERATURE REVIEW

Girija Moona et.al [1] reviewed on Aluminum Metal Matrix Composites. In this article, they have investigated the improvement of Aluminum metal matrix composites with different types of reinforcement to improve hardness, toughness, wear resistance, fatigue properties of aluminum reinforced materials and associated with the different areas using various parameters. Priyaranjan **Samal et.al [2]** reviewed the recent progress in aluminum metal matrix composites: A review on processing, mechanical and wear properties. In this article, aluminum matrix reinforced with kinds of reinforcement such as oxides, carbides, borides etc, aluminum matrix with reinforcement have been showing good processing, microstructure wear and mechanical properties. **Pranav Dev Srivyas et.al [3]** reviewed on Aluminum metal matrix composites a review of reinforcement; mechanical and tribological behavior.AMC has superior properties other than conventional aluminum alloy. Aluminum Matrix composites are reinforced with various kinds of material. In this review, using suitable reinforcement in aluminum matrix results in good mechanical properties like hardness, brittle yield strength, strength to weight ratio and tribological properties like wear resistance, coefficient of friction. **Arun Kumar Sharma et.al [4]** studied the advancement in application opportunities of Aluminum Metal Matrix Composites. Composites had developed continuously for the multipurpose applications. For metal matrix composites, Aluminum is the best metal used in many purposes due to its lightweight with high efficiency

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and low cost. In this paper, they were used an opportunities of Aluminum in various applications to produce composite materials with desired properties for various applications with wide range of reinforced materials which results in good mechanical properties and tribological properties. **Naveen Kumar et.al [5]** reviewed on Tribological behavior and mechanical properties of Al/ZrO_2 metal matrix nano composites. In this review, aluminum alloy is used as base metal matrix and reinforced with zirconium oxide; fabrication was done by stir casting process of aluminum nano composites with various weight percentage of ZrO_2. It improves the mechanical properties like ultimate tensile strength, impact strength, micro hardness, less reduction in ductility and fracture toughness and tribological properties like coefficient of friction and wear resistance of aluminum nano composite with various weight percentage of zirconium oxide. When compared to unreinforcement base matrix reinforced aluminum alloy obtains good properties. **Girish et.al [6]** studied the Synthesis and Mechanical Properties of Zirconium Nano Reinforced with Aluminium Alloy Matrix Composites. I this work, Aluminum 356.1 reinforced with Zirconium nano parctile using combustion synthesis process with different weight percentage ratios like 0.5, 1.0, 1.5 and 2.0 % using stir casting technique with speed of 100rpm and time 30 minutes at constant temperature of 850°C. Scanning electron microscopy was used for structural characterization of aluminum reinforced zirconium nano particles. Mechanical properties like tensile strength and hardness test were carried out. By adding Zirconium nano particles leads to improvement in yield strength and ultimate tensile strength. Results shows that the tensile strength increases with increase in reinforcement and ultimate tensile strength increases at room temperature 540°C. As the weight percentage of reinforcement increases hardness also increases consistently. At 2.0 wt% shows better mechanical properties other than the reinforcement percentage. **Satish Kumar Thandalam et.al [7]** studied the Synthesis; microstructural and mechanical properties of ex situ zircon particles ($ZrSiO_4$) reinforced Metal Matrix Composites (MMCs). In this, review gives the detail development on the synthesis, microstructure and mechanical properties of zircon reinforced Metal matrix composites, with accurate attention on the abrasive wear performance of the composites. It also summarizes the work done by various research on zircon reinforced MMCs in achieving higher hardness and wear resistance in the composites. **Harsha et.al [8]** studied the mechanical properties of aluminium/nano- zirconia metal matrix composites. In the study, aluminum alloy matrix reinforced with ZrO_2 was fabricated by stir casting process with different weight percentage ratios like 2.5 and 5%. Scanning electron microscopy (SEM) was used for structural characterization of aluminum alloy reinforced with ZrO_2. Mechanical properties such as tensile test, compression test, yield strength, ultimate tensile strength, hardness and percentage of elongation were conducted. The constituents present in aluminum matrix alloy and composites were verified using EDX spectrum. Results shows that the tensile strength, yield strength, ultimate tensile strength increases with increase in reinforcement at 5wt% as compared to other reinforced weight percentage and unreinforced particles, hardness increase with increase in reinforcement at 5wt % as compared to unreinforced particles. % of elongation decreases with increase in reinforcement. **Girisha. K.B [9]** conducted an experiment on Wear Performance and Hardness Property of A356.1 Aluminium Alloy Reinforced with Zirconium Oxide Nano Particle. In this study, Aluminum A356.1 were reinforced with ZrO_2 synthesized by combustion process and fabrication was carried out by stir casting process with various weight percentage like 0.5, 1.0, 1.5 and 2.0% respectively. The nano particles were characterized by PXRD (Powder X-ray diffraction) and TEM. Hardness test and wear test were carried out at different weight percentage ratios with various conditions of speed, load and time. The result showed that the hardness and wear properties increases at 2.0 wt% compared to other weight percentage ratios. **Gandharv et.al [10]** studied the dry sliding wear behavior of A356-ZrO_2 Metal Matrix Composites. In this research, dry sliding was carried out on pin on disc apparatus with load of 5n, 20N and sliding speed of 0.628m/s of aluminum 356 and reinforced ZrO_2 with weight percentage of 5wt%. The result showed that the reinforced aluminum has superior wear and friction properties as compared to unreinforced material. Wear and co-efficient of friction increases with increase reinforced ZrO_2 particles when compared to base aluminum alloy. **Mohsen Hajizamani et.al [11]** researched on Fabrication and Studying the Mechanical Properties of A356 Alloy Reinforced with Al_2O_3-10% Vol. ZrO_2 Nanoparticles through Stir Casting. In this study, nanoparticles of Al_2O_3-10% ZrO_2 with an average size of 80 nm were fabricated with 0.5, 1, 1.5 and 2 wt. % of the reinforcement using stir casting technique. The microstructure was done by SEM. Hardness, tensile strength increases with increase in reinforcement. Also density decreases with increase in reinforcement %. **Mariyappan et.al [12]** showed the Improvement in tribological behavior of aluminum 356 hybrid metal matrix composites. Aluminum 356 is fabricated with ZrO_2 and SiC as reinforcement using Liquid state process (stir casting process). Tests were conducted as per the ASTM standard. Mechanical properties enhance good result with increase in reinforcements. **Dyva Isac Premkumar et.al [13]** conducted a Development and Characterization of Aluminum 6061 - Zirconium Dioxide Reinforced Metal

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Matrix Composites by Stir Casting. Aluminum alloy Al6061 reinforced with ZrO_2 which are fabricated by stir casting technique. Al6061-ZrO_2 fabricated materials are used to find the mechanical properties like hardness, tensile test and density with various weight percentage ratios of 0, 1, 2 and 3 wt%. The results showed that the hardness and tensile test percentage increases with increase in reinforced material and density decreases. **Satish Babu Boppana et.al [14]** conducted a study on the Synthesis and characterization of nano graphene and ZrO_2 reinforced Al 6061 metal matrix composites. Aluminum alloy 6061 is reinforced with ZrO_2 and Graphene using stir casting process (Fluid metallurgy) with percentage ratios of 05, 0.75 and 1 wt%. Mechanical properties such as tensile strength, yield strength and % of elongation are conducted as per ASTM standard. Result shows that the mechanical properties increase as the reinforcement increases and % of elongation decreases with increase in reinforcement. **Gunasekaran et.al [15]** studied the Mechanical properties and characterization of Al7075 aluminum alloy based ZrO_2 particle reinforced metal-matrix composites. Aluminum alloy Al7075 was fabricated with ZrO_2 reinforcement particle using compocasting process (Stir casting) with various wt% ratios like 3, 6, 9 and 12 wt%. Microstructural characterization was done by SEM and EDAX images are homogeneous. Hardness, ultimate tensile strength was carried out. Result showed that the mechanical properties increase as the reinforcement was increased and wears resistance and friction coefficient decreases with increase in reinforcement.

A complete study on literature survey shows that the reinforcement have better mechanical and tribological properties such as hardness, tensile strength, yield strength, density, compression test, % of elongation, wear resistance and co efficient of friction compared to unreinforcement composite materials. These are carried out through fabrication process of both alloy and reinforcement using different kind of fabrication technique. As mentioned above stir casting process have implemented more for composite materials. This literature survey also revealed that aluminum 356.1 reinforced with ZrO_2 also might show good mechanical and tribological properties with different weight percentage ratios.

Objectives:

1. To study the conceptual framework on the Aluminum 356.1 nanometal matrix composite.
2. To fabricate the Aluminum 356.1 nanometal matrix composite by stir casting technique

III. An Overview on Tribological Properties of Aluminum 356.1 Nano Metal Matrix Composites using Biolubricant

1. Materials

a. Metal Matrix Composites

Metal composite materials have found application in many areas of daily life for quite some time. Often it is not realized that the application makes use of composite materials. MMCs have been in existence for the past 30 years and a wide range of MMCs has been studied. MMCs are added by reinforcing material into metal matrix. MMC are getting broad these days to replace monolithic materials like steel. Matrix is usually a lighter metal such as aluminum, magnesium or titanium. MMC are widely used in industries, automobiles, aerospace and transportation because of its superior mechanical properties such as wear resistance, ductility, high stiffness, hardness and strength which are better than monolithic materials. These materials are produced in situ from the conventional production and processing of metals. Materials like cast iron with graphite or steel with high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders, also belong to this group of composite materials. For many researchers the term metal matrix composites is often equated with the term light metal matrix composites (MMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. MMCs have been used commercially in fiber reinforced pistons and aluminum crank cases with strengthened cylinder surfaces as well as particle-strengthened brake disks. These innovative materials open up unlimited possibilities for modern material science and development; the characteristics of MMCs can be designed into the material, custom-made, dependent on the application. From this potential, metal matrix composites fulfill all the desired conceptions of the designer. This material group becomes interesting for use as constructional and functional materials, if the property profile of conventional materials either does not reach the increased standards of specific demands, or is the solution of the problem.

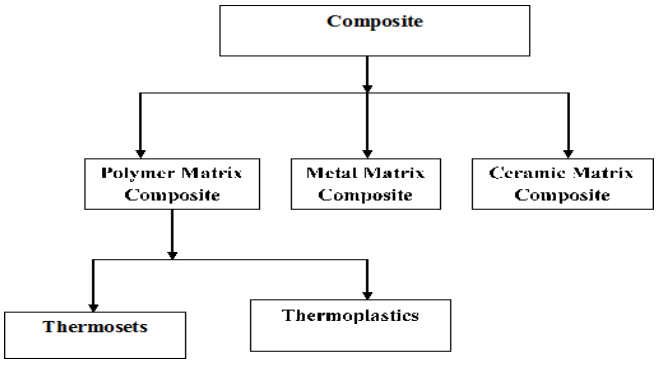

Fig 1: Matrix Phase

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b. Aluminum Nano Metal matrix composites

Aluminum Alloys are predominating metal. Aluminum nano metal matrix composites are used in automobiles, aerospace and food industries due its light weight, ductility and ability to improve its mechanical properties by adding reinforcement. It has high corrosive, wear resistance and specific modulus. Aluminum and its alloys are mainly used for metal matrix. Aluminum nano metal matrix composites have been the subject of interest for many researchers as, the aluminum alloy overcomes the drawbacks of ferrous materials and the composite provides the desired characteristic of specific performance which have been used in industries. Aluminum 356.1metal matrix composite is a cast aluminum alloys which are used for fabrication of the composites. Aluminum alloy A356.1 is used widely in various purposes. The alloying element such as copper,silicon, magnesium, zinc, etc. is added into pure aluminum for obtaining specific properties. Reinforced metal matrix composites have been popular due to its inexpensive and have the advantage of isotropic properties. Mixing of ceramic particles into aluminum matrix is still remained as a problem these days. The reinforcement is added to check a chemical reaction with the matrix. Aluminum matrix composites fabrication is done by reinforcing the materials like Al_2O_3, SiC, B_4C, TiC, ZrO_2, Graphite, CNTs, diamond particles and Graphene etc. These are commonly used reinforcement due to their superior properties, availability and low cost.

Fig 2: Aluminum 356.1 IngotsTable 1: Properties of A356.1

Properties	Unit	Value
Density	lbs/in^3	0.097
Tensile strength	Ksi x 10^3	33
Hardness	BHN	70
Elongation	%	3.5
Melting Point	°F	1035-1135

2.Reinforcement:

a. Zirconium Oxide (ZrO_2): Zirconium dioxide (ZrO_2), sometimes known as zirconia (not to be confused with zircon), is a white crystalline oxide of zirconium. Its most naturally occurring form, with a monoclinic crystalline structure, is the mineral baddeleyite. A dopant stabilized cubic structured zirconia, cubic zirconia, is synthesized in various colours for use as a gemstone and a diamond simulant. Zirconia is produced by calcining zirconium compounds, exploiting its high thermostability. Zirconia is chemically unreactive. It is slowly attacked by concentrated hydrofluoric acid and sulfuric acid. When heated with carbon, it converts to zirconium carbide. When heated with carbon in the presence of chlorine, it converts to zirconium (IV) chloride. This conversion is the basis for the purification of zirconium metal and is analogous to the Kroll process. Zirconium dioxide is one of the most studied ceramic materials. ZrO_2 adopts a monoclinic crystal structure at room temperature and transitions to tetragonal and cubic at higher temperatures. The change of volume caused by the structure transitions from tetragonal to monoclinic to cubic induces large stresses, causing it to crack upon cooling from high temperatures. When the zirconia is blended with some other oxides, the tetragonal and/or cubic phases are stabilized. Effective dopants include magnesium oxide (MgO), yttrium oxide (Y_2O_3, yttria), calcium oxide (CaO), and cerium (III) oxide (Ce_2O_3). Zirconia is often more useful in its phase 'stabilized' state. Upon heating, zirconia undergoes disruptive phase changes. By adding small percentages of yttria, these phase changes are eliminated, and the resulting material has superior thermal, mechanical, and electrical properties. In some cases, the tetragonal phase can be metastable. If sufficient quantities of the metastable tetragonal phase is present, then an applied stress, magnified by the stress concentration at a crack tip, can cause the tetragonal phase to convert to monoclinic, with the associated volume expansion. This phase transformation can then put the crack into compression, retarding its growth, and enhancing the fracture toughness. This mechanism, known as transformation toughening, significantly extends the reliability and lifetime of products made with stabilized zirconia.

b. Fabrication Process

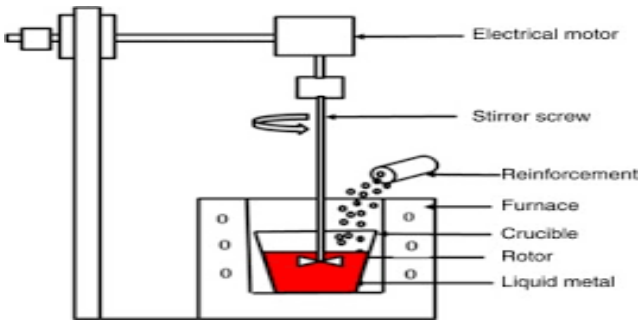

Fig 3: Stir casting process

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Various techniques are developed to manufacture metal matrix composites such as solid state processing (Powder metallurgy) and liquid state processing (Stir casting, squeeze casting) but out of them stir casting process is most widely used because it is simple and cost effective. Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional metal forming technologies. In stir casting we use stirrer to agitate the molten metal matrix. The stirrer is generally made up of a material which can withstand at a higher melting temperature than the matrix temperature. Generally graphite stirrer is used in stir casting. The stirrer is consisting of mainly two components cylindrical rod and impeller. The one end of rod is connected to impeller and other end is connected to shaft of the motor. The stirrer is generally held in vertical position and is rotated by a motor at various speeds. The resultant molten metal is then poured in die for casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement. A major concern in associated with the stir casting is segregation of reinforcement particles due to various process parameters and material properties result in the non-homogeneous metal distribution. The various process parameters are like wetting condition of metal particles, relative density, settling velocity etc. The distribution of particle in the molten metal matrix is also affected by the velocity of stirrer, angle of stirrer, vortices cone etc. In this method first the matrix metal is heated above its liquid temperature so that it is completely in molten state. After it is cooled down to temperature between liquid and solidus state means it is in a semi-solid state. Then preheated reinforcement particles are added to molten matrix and again heated to fully liquid state so that they mixed thoroughly each other.

IV. CONCLUSION

Current development on Metal matrix composites is widely preferred in various applications because of its excellent mechanical properties with better wear resistance. Fabrication and mechanical property evaluation of MMCs with zircon reinforcement has been discussed in the above literature review. With regard to processing of zircon reinforced MMCs carried out through the stir casting process because of its ease, flexibility and low cost for the fabrication of large size components. Though this method offers numerous advantages. Mechanical properties such as hardness, and tensile strength were reported to improve with the dispersions of zircon particles. In conclusion, taking into consideration from technical and economic factors, zircon particles emerge to be promising reinforcement especially for aluminum Metal Matrix Composite.

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