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Stress Analysis of Cryogenically Treated Magnesium Metal Matrix Composite Reinforced With Alumina And Cenosphere

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Abstract—**This paper, deals with Magnesium alloys are considered as good candidates for many structural components of automobile, aerospace and military industries to satisfy the demand for weight reduction, improving fuel efficiency and reducing greenhouse gas emission. In this project magnesium metal is added with the hybrid powder alumina of 1%, 2%, 3% and cenosphere of 1%, 2%, 3% in different specimen by stircasting method. By stircasting method weight reduction, dimensional stability wear and corrosion resistance can be obtained. A model will be generated using Solid works and stress analysis was carried out using ansys software. The obtained magnesium composite dispersed with alumina and cenosphere powder were given cryogenic treatment and the mechanical properties, hardness, and the microstructure can be done and is analysed by using ansys software. The stress values of composites before and after cryogenic treatment was compared.**

Index Terms— **Scanning electron microscope, Energy-dispersive X-ray spectroscopy, stircasting**

I.INTRODUCTION

A composite material is a material composed of two or more constituents. The constituents are combined at a microscopic level and are not soluble in each other. Generally, a composite material is composed of reinforcement embedded in a matrix. Metal matrix composites (MMCs), like all composites; consist of at least two chemically and physically distinct phases, suitably distributed to provide properties not obtainable with either of the individual phases. Generally, there are two phases either a fibrous or particulate phase in a metallic matrix. For e.g. Mg fiber reinforced in a copper matrix for superconducting magnets and Alumina and Cenosphere particle reinforced with in the Mg matrix composites used in aerospace, automotive and thermal management applications. 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. In traffic engineering,

especially in the automotive industry, MMCs have been used commercially in fiber reinforced pistons and Magnesium 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. We know that one third of our global energy consumption is consumed wastefully in friction. Wear causes an enormous annual expenditure by industry and consumers. Most of this is replacing or repairing equipment that has worn to the extent that it no longer performs a useful function. There are generally five types of wear namely abrasive, adhesive, erosive, Surface fatigue and Corrosive.

Metal Matrix Composites (MMCs), as the name implies, have a metal matrix. Examples of matrices in such composites include magnesium, aluminium and titanium. Typical fibers include silicon and silicon carbide. Metals are mainly reinforced to increase or decrease their properties to suit the needs of design. For example, elastic stiffness and strength of metals can be increased, while large coefficients of thermal expansion and thermal and electrical conductivity of metals can be reduced by the addition of fibers such as Alumina, Cenosphere.

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as magnesium, aluminium titanium, and provides a compliant support for the reinforcement. In high temperature applications, cobalt and cobalt-nickel alloy matrices are common.

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Magnesium metal matrix composite (MMC) products have been the subject of significant development activities. A range of alloy compositions have been used with particulate alumina and cenosphere as reinforcing phase. Major benefits of these materials are increased modulus, typically 40% higher than unreinforced magnesium alloys and specific gravity of only 2.0. The MMC also has good wear characteristics and a lower coefficient of thermal expansion than magnesium alloys. These properties have led to considerable interest from aerospace, automotive, bicycle and engineering industries. The magnesium matrix wrought MMC product, Cenosphere has been developed in tube form and was launched around 1996. There is strong interest for cycle frame applications as thin wall tubes can be made lighter. The high stiffness/ strength of these product should ensure they are attractive for a number of application. A future development is to produce a cast magnesium MMC product and casting have already been made successfully using various techniques.

The remainder of the paper is organized as follows. In Section II, presents the system model. Here the specimen is obtained by stir casting method. Section III, illustrates the testing of specimen to obtain tensile strength, hardness and impact test values by cryogenic test. Section IV illustrates ModeLling and analysis. Section V draw conclusions and an outlook on future work.

II. SYSTEM MODEL

A. Stir Casting

Stir casting set-up mainly consists a furnace and a stirring assembly as shown in Figure 1. In general, the solidification synthesis of metal matrix composites involves a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. The next step is the solidification of the melt containing suspended dispelsoids under selected conditions to obtain the desired distribution of the dispersed phase in the cast matrix. In preparing metal matrix composites by the stir casting method, there are several factors that need considerable attention, including ,the difficulty in achieving a uniform distribution of the reinforcement material, wettability between the two main substances, porosity in the cast metal matrix composites, chemical reactions between the reinforcement material and the matrix alloy.

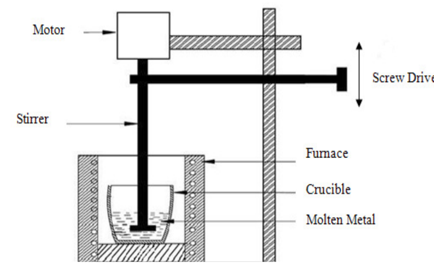

Figure 1 : Stir Casting

In order to achieve the optimum properties of the metal matrix composite, the distribution of the reinforcement material in the matrix alloy must be uniform, and the wettability or bonding between these substances should be optimized. The porosity levels need to be minimized Interface between any two phases can be explained as bounding surface where a discontinuity of some kind occurs .The discontinuity may be sharp or gradual. In general the interface is essentially bi-dimensional region through which material parameters, such as concentration of an element, crystal structure elastic modulus, density and coefficient of thermal expansion, change from one side to another. In general, the solidification synthesis of metal matrix composites involves a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. Thus bonding between two phases at interface is termed as interfacial bonding. In case of composites, bonding at particle - matrix interface is called interfacial bonding.

Composite materials (also called composition materials or shortened to composites) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. The new material may be preferred for many reasons: common examples include materials which are stronger, lighter or less expensive when compared to traditional materials.

In this experimental setup magnesium acts as metal matrix. This metal matrix is first heated by keeping it in a casting container as in Figure 2. Once the magnesium alloy reaches the melting point powdered alumina and cenosphere is added with this liquid.

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Figure 2: Mg rods being heated in furnace

In this Figure 3 this mixture is mixed well by stirrer until all the three components are mixed properly and reaches liquid form.

Figure 3: stirring is done

In this Figure 4 the liquid mixture of magnesium alumina and cenosphere is poured in a cylindrical dye and is allowed to cool in room temperature.

Figure 4: Casting MMC is poured in Die

In this Figure 5 the specimen in the dye is machined to obtain a machining piece.

Figure 5: Machining Piece

III. TESTING

After preparing the composite specimen by stir casting method, the following testing will be conducted. The mechanical properties of a material describe how it will react to physical forces. Mechanical properties occur as a result of the physical properties inherent to each material, and are determined through a series of standardized mechanical tests.

i) Tensile: A tensile test, also known as tension test, is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate.

Figure 6: Tensile specimen

a) Tensile testing machine: The most common testing machine used in tensile testing is the universal testing machine. This type of machine has two crossheads; one is adjusted for the length of the specimen and the other is driven to apply tension to the test specimen. The machine must

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have the proper capabilities for the test specimen being tested. There are four main parameters: force capacity, speed, and precision and accuracy. Force capacity refers to the fact that the machine must be able to generate enough force to fracture the specimen. The machine must be able to apply the force quickly or slowly enough to properly mimic the actual application.

Figure 7: Tensile Specimen after testing

ii) Hardness: Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a compressive force is applied. Some materials, such as metal, are harder than others. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behaviour of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness.

a) Vickers hardness test method: The Vickers hardness test method, also referred to as a micro hardness test method, is mostly used for small parts, thin sections, or case depth work. The Vickers method is based on an optical measurement system. The Micro hardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials as long as test samples are carefully prepared. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from a few grams to one or several kilograms, although "Macro" Vickers loads can range up to 30 kg or more. The Micro hardness methods are used to test on metals, ceramics, and composites - almost any type of material. Since the test indentation is very small in a Vickers test, it is useful for a variety of applications: testing very thin materials like foils or measuring the surface of a part, small parts or small areas, measuring individual microstructures, or measuring the depth of case hardening by sectioning a part and making a series of indentations to describe a profile of the change in hardness. Sample preparation is usually necessary with a micro hardness test in order to provide a small enough specimen that can fit into the tester.

Figure 8: Hardness Specimen after Testing

iv) Impact Test: The Charpy impact test, also known impact test as the Charpy V-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. It works on pendulum principle. Highly stressed and wearing parts such as support blocks and stickers made of alloy steels duly heat treated. Direct indication of impact energy absorbed by specimen on large dial for models: AIT-300-N, AIT-300-EN. Digital panel display for model : AIT-300-D. Initial potential energy for Charpy in 300 joules and for Izod is 170 joules. Least count of 2 joules (for analogue models) and resolution of 0.5 joules (for digital model). Pendulum drop angle for Charpy is 140^0 and for Izod is 90^0. It also offer ASTM Impact testing machine manufactured in tandem with ASTM: E-23 standard.

Figure 9: Impact Specimen after Testing

B. Cryogenic Treatment

The liquid nitrogen as generated from the nitrogen plant is stored in storage vessels. With

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help of transfer lines, it is directed to a closed vacuum evacuated chamber called cryogenic freezer through a nozzle. The supply of liquid nitrogen in to the cryo-freezer is operated with the help of solenoid valves. Inside the chamber gradual cooling occurs at a rate of 2 degree C/min from the room temperature of -80 degree C. Once the sub zero temperature is reached, specimens are transferred to nitrogen chamber or soaking chamber where in they are stored for 24 hours with continuous supply of liquid nitrogen. The specimen obtained is tested in cryogenic testing machine for measuring tensile strength, Hardness and Impact test values.

Sl. No	Sample ID	Tensile Strength N/Mm^2	Impact Test Joules	Hardness Test HBW Values
1	AZ91D+ 1% Al_2O_3 + 1% Cenosphere	163	2.4	50
2	AZ91D+ 2% Al_2O_3 + 2% Cenosphere	198.1	2.65	51
3	AZ91D+ 3% Al_2O_3 + 3% Cenosphere	211	2.7	49

Table 1: Cryogenic Test Results

From these values the results are plotted in graph as

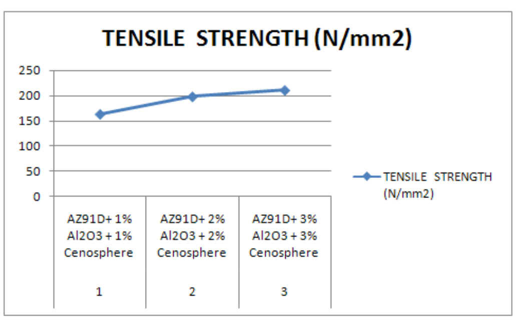

Figure 10: Specimens Vs % Tensile Strength graph

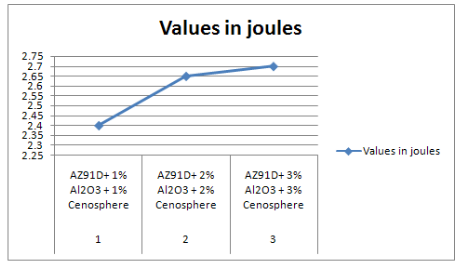

Figure 10: Specimens Vs impact strength graph

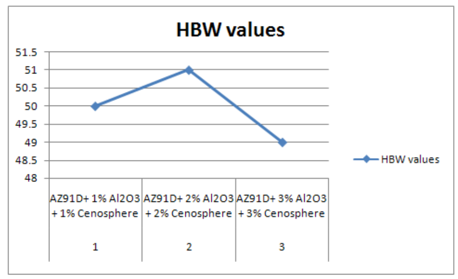

Figure 11: Specimens Vs HBW values

C. Microstructure

Microstructure is the small scale structure of a material defined as the structure of a prepared surface of material as revealed by a microscope above 25x magnification. The microstructure of a material (such as metals, polymers, ceramics or composites) can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior or wear resistance. These properties in turn govern the application of these materials in industrial practice. Microstructure at scales smaller than can be viewed with optical microscopes is often called nanostructure, while the structure in which individual atoms are arranged is known as crystal structure. The nanostructure of biological specimen is referred to as ultrastructure. The concept of microstructure is observable in macrostructural features in common place objects.

IV MODELLING AND ANALYSIS

A. Modelling

3D modeling is the process of developing a mathematical representation of any three-dimensional surface of an object (either inanimate or living) via specialized software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process called 3D

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rendering or used in a computer simulation of physical phenomena. Here CREO is used to create a 3d model of an aircraft nose cone.

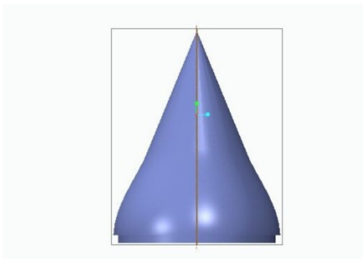

Figure 11: 3D Model of an Aircraft nose cone

B Finite Element Analysis

Finite element analysis (FEA)is the modelling of products and systems in a virtual environment, for the purpose of finding and solving potential (or existing) structural or performance issues. FEA is the practical application of the finite element method (FEM), which is used by engineers and scientist to mathematically model and numerically solve very complex structural, fluid, and multi physics problems. FEA software can be utilized in a wide range of industries, but is most commonly used in the aeronautical, biomechanical and automotive industries. Here ANSYS software is used to evaluate the result.

i) ANSYS Mechanical**:** ANSYS Mechanical software is a comprehensive FEA analysis (finite element) tool for structural analysis, including linear, nonlinear and dynamic studies. The engineering simulation product provides a complete set of elements behavior, material models and equation solvers for a wide range of mechanical design problems. In addition, ANSYS Mechanical offers thermal analysis and coupled-physics capabilities involving acoustic, piezoelectric, thermal–structural and thermo-electric analysis.

ii) ANSYS Workbench Platform: The ANSYS Workbench platform is the framework unifying our industry-leading suite of advanced engineering simulation technology. With bidirectional parametric CAD connectivity, powerful highly automated meshing, an automated project-level update mechanism, pervasive parameter management and integrated optimization tools, the ANSYS Workbench platform delivers unprecedented productivity, enabling process capture and Simulation-Driven Product Development.

C. Results

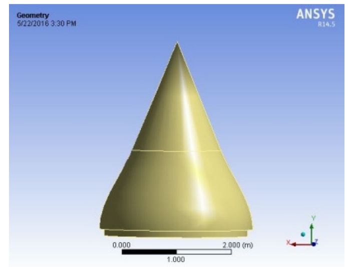

Figure 6.2 Ansys model of an aircraft Nose cone

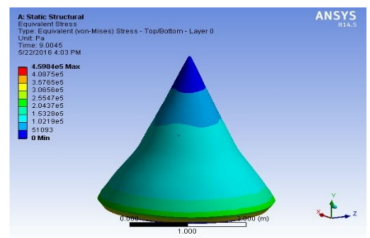

Figure 6.3 Deformation of Magnesium+ 1%Alumina+ 1% Cenosphere composite before treated at 15KN

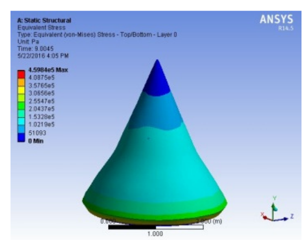

Figure 6.4 Deformation of Magnesium+ 1%Alumina+ 1% Cenosphere composite After treated at 15KN

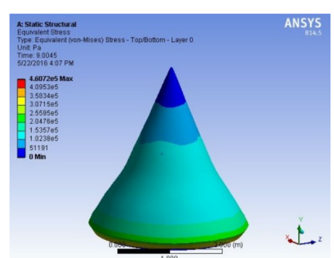

Figure 6.5 Deformation of Magnesium+ 2%Alumina+ 2% Cenosphere composite before treated at 15KN

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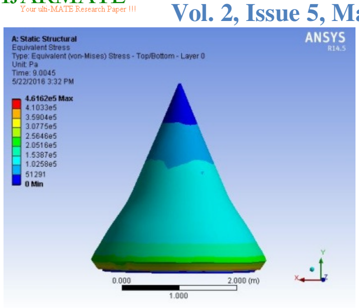

Figure 6.6 Deformation of Magnesium+ 2%Alumina+ 2% Cenosphere composite After treated at 15KN

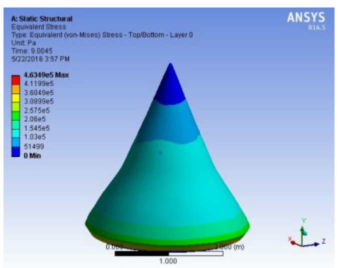

Figure 6.7 Deformation of Magnesium+ 3%Alumina+ 3% Cenosphere composite Before treated at 15K

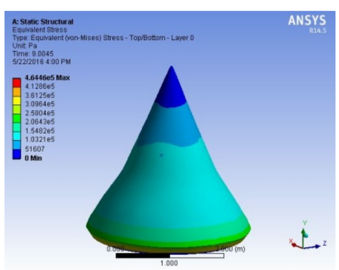

Figure 6.8 Deformation of Magnesium+ 3%Alumina+ 3% Cenosphere composite After treated at 15KN

Von-Misses Stress analysis before cryogenic treatment and after cryogenic Treatment is calculated and is compared by using the ANSYS software

V CONCLUSION

This paper provides good candidates for many structural components of automobile, aerospace and military industries to satisfy the demand for weight reduction, improving fuel efficiency and reducing greenhouse gas emission. By stir casting method weight reduction, dimensional stability wear and corrosion resistance can be obtained. The obtained magnesium composite dispersed with alumina and cenosphere powder were given cryogenic treatment and the mechanical properties, hardness and the microstructure by Scanning electron microscope (SEM), Energy-dispersive X-ray spectroscopy can be done and stress distribution is analysed by using ansys software. The stress values of composites before cryogenic and after cryogenic treatment will be compared and obtain better performance after cryogenic treatement . .

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