ANALYSIS OF MECHANICAL PROPERTIES AND MICROSTRUCTURE OF Al 7075-GLASS FIBRE MMC

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Abstract - *Metal Matrix Composites (MMCs) have brought a keen interest in current scenario for potential applications in automotive industries owing to their superior strength to weight ratio. In the present work a modest attempt has been made to develop aluminum (Al) based E-glass fibre composites with an objective to produce high strength MMCs. The present work investigates the variation of properties like Density, hardness, compressive strength and microstructure of an Al-based MMC with different wt. % (2, 3, 4) of E-glass fiber and sintering temperatures(500ºC,550ºC) fabricated by powder metallurgy route.*

The micro sized Al 7075 is selected as matrix material and glass fibre whose length is 1-2 mm is opted as suitable reinforcing material and finally sintered under vacuum conditions. The results showed that the actual densities of the sintered composites gradually increased with increasing sintering temperature and that the highest hardness and compressive strength were achieved in the specimen sintered at 550ºc.The properties including (densities, compressive strength and hardness) of the composites changed with glass fibre content and reached a optimum value when the glass fibre content was 3 wt. %.

Key Words: Al-matrix composites; Metal Matrix Composites (MMCs); E-glass fibre.

1. INTRODUCTION

Mankind has tried to search material which can perform under adverse environmental conditions. Researchers have tried to develop materials that have the desired properties. This is also the main reason behind the creation of composite materials. In composites one of the components is the homogenous matrix and the other is reinforcement which is stronger and stiffer. Composites are used extensively for making prototype parts because different types of shape can be fabricated quickly and inexpensively.

Composites have many advantages for the design of structural devices. It has high stiffness, strength and toughness compared to metal alloys. Many structures experience fatigue loading, i.e., and as a result the internal stress Varies with time. The composite materials are light as well as strong and it is their major advantage compared to metals and alloys. Fatigue stress leads to failure of the component. Composites have excellent fatigue resistance compared to metals and alloys. Composites also have excellent tribological property and its sliding friction could approach those of lubricated steel. Particles or fibers fixed in matrix are the best example of composite materials which are generally useful in structural and automotive applications where the reinforcement material generally uses the load and provide the desirable properties. The property of these composite is determined by the property of reinforcement.

1.1 Composites

A typical composite material consists of two or more materials (bonded and mixed) on macroscopic rules which are not soluble in each other. Normally, a composite materials are composed of reinforcement (fibers, flakes, particles and fillers) implanted in a matrix such as polymers, metals, or ceramics. The function of matrix is to hold the 0reinforcement to form the craved shape while the reinforcement ameliorates the whole mechanical properties of the matrix. The new combined material possesses better strength than the individual components. A composite material is a macroscopic combination of two or more distinct material, having a recognizable interface between them. Composites are not only used for their structural properties, but also for thermal, electrical and environmental applications. [4]

1.2 The History of Composites:

In the centuries before Christ, our ancestors invited composites by mixing straw and clay to make bricks. The straw was the fiber reinforcement and clay was the matrix.

Today, in parts of the world, homes are made with the same material, using straw and vegetable fiber as reinforcement. The ceilings and walls made in the past century with small rows of wooden slats to hold the plaster. Reinforcement of concrete with steel bars for construction has been used for 150 years, in bridge construction and building, in art and statues, etc. [5]

1.3 Metal-Matrix Composites (MMC's):

Metal matrix composite (MMC) consists of two elements one is matrix and the other is reinforcement. Metal matrix composites are unique materials for used in structural application such as automotive and aerospace industries because high strength and thermal stability. Metal matrix composites exist with the combination of both metallic properties with ceramic properties and possess higher strength in shear and compression and provide service at high temperatures.

Nowadays nano composites are gaining popularity in the material industry replacing the monolithic metals. The comparison of micro structural and mechanical attributes of nano composites and micro composites is a hot area of research. There has been an increase in wide use of MMCs in aircraft and automotive industry for structural applications due to the cost effective processing route

Fig 1:Applications of MMC's

1.4 E-Glass Fibre:

E-Glass Fiber is the best industrial material at present. They can be made freely from raw materials, existing in abundance. They show better properties like resistance, transparency, prevention to chemical attack, stability and fibre properties like stiffness, flexibility, and strength. Glass fibers are divided in two classes, low cost all-purpose fibers and premium special-purpose fibers. More than 90% of all glass fibers are used for general purpose products and 10% use for the special purpose.

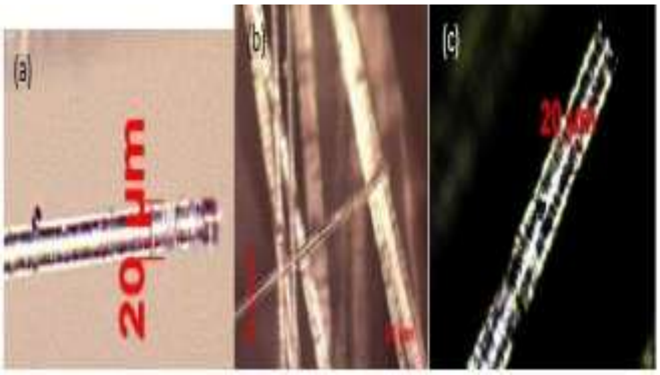


Fig 2: Optical images of E-glass fiber(a,b,c)

1.5 Fabrication Procedure (Powder Metallurgy):

- Selection of Matrix and reinforcement material
- Sample preparation
- Blending &Compaction(cold pressing)
- Sintering
- Characterization

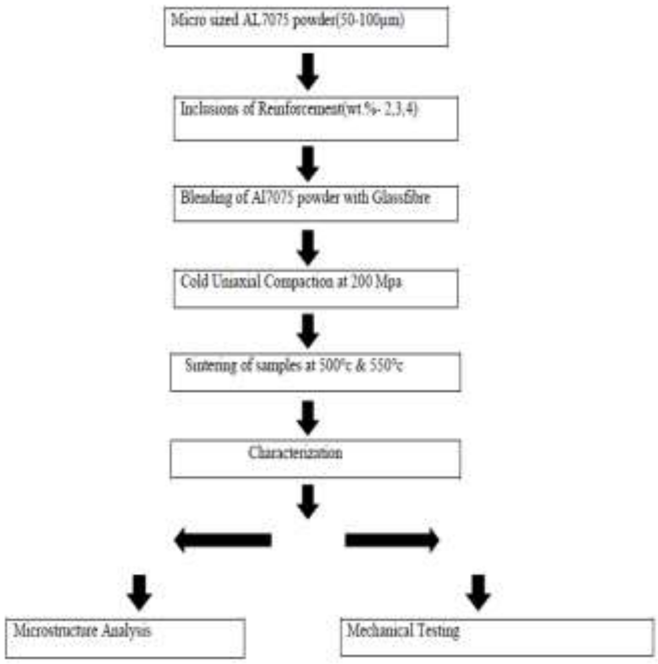


Fig 2: Flow chart of fabrication procedure

1.6 Matrix Material Composition:

Table 1: Composition of AL 7075

Elements	Al	Zn	Mg	Cu
Wt. %	88.5 - 88.9	5.1 - 6.1	2.1 - 2.9	1.2 – 2

Properties:

Young's Modulus: 68-72 GPa, Hardness (ROCKWELL): 60-65HRB, Density:2.86 gm/cc

1.7 Reinforcing Material Composition:

Table 2 : Composition of glass fibre

Elements	SiO_2	Al_2O_3	CaO	MgO	B_2O_3
Wt. %	54.5	14.5	17	4.5	8.5

Fibre Length	Aspect Ratio(l/d)
2	100

Properties:

Young's Modulus: 72-85 GPa, Compressive Strength: 4000-5000MPa, Density: 2.51gm/cc

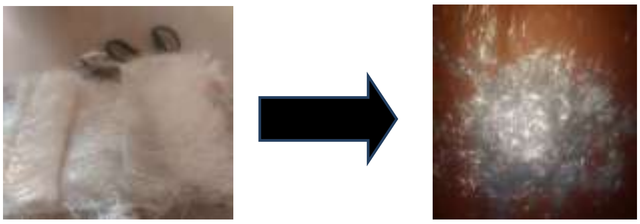


Fig 4: Glass fibre

1.8 Sample Preparation:

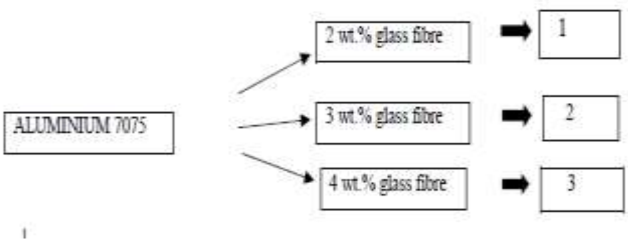


Fig5: Sample preparation

The sample weight is taken as 59Gms, without reinforcement and the corresponding weight fractions shown in above Figure[5](2%, 3%, and 4%) of glass fibre is considered.

1.9 Blending:

Blending is the process of mixing of the powder particles effectively and in homogenize manner. To achieve unbeaten results in compaction and sintering, the metallic powders necessity be thoroughly homogenized beforehand. The blending or mixing can be done by (a) rotation in a drum; (b) rotation in a double-cone container; (c) rotation in a Y-blender; (d) stirring in a blade mixer as shown in figure[6]

Fig 6: Y- Blender

1.10 Compaction:

Powder compaction is the process of compacting metal powder in a die through the application of high pressures. Typically the tools are held in the vertical orientation with the punch tool forming the bottom of the cavity. The powder is then compacted into a shape and then ejected from the die cavity as shown in figure[7]. Pressure of 10 tons/in^2 to 50 tons/in^2 (150 MPa to 700 MPa) is commonly used for metal powder compaction. The compaction pressure selected for AL 7075 is around 600 Mpa and the load is applied in uniaxial direction.

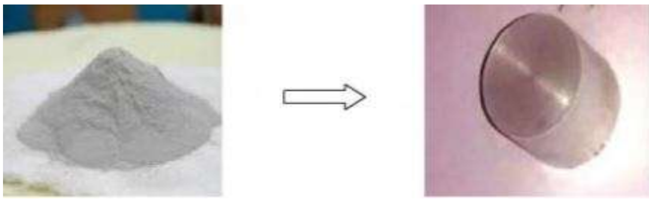


Fig 7:Schematic representation of compaction

Fig 8: Hydraulic press for compaction

1.11 Sintering:

Once compacted into the mold the material is placed under a high heat for a long period of time. Under heat, bonding takes place between the porous aggregate particles and once cooled the powder has bonded to form a solid piece.

1)Sintering can be considered to proceed in three stages. They are:

2)During the first, neck growth proceeds rapidly but powder particles remain discrete.

3)During the second, most densification occurs, the structure recrystallizes and particles diffuse into each other.

4)During the third, isolated pores tend to become spheroidal and densification continues at a much lower rate.

The words "solid state" in solid state sintering simply refer to the state the material is in when it bonds, solid meaning the material was not turned molten to bond together as alloys are formed

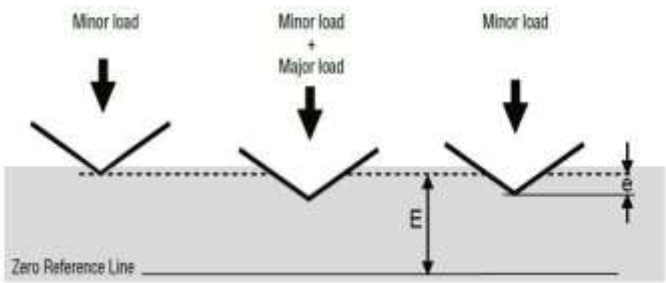
Fig9: Sintering machine and oven

2.0 Characterization:

It is the process of evaluating various mechanical properties on different samples. Characterization reveals the original behavior or properties of the fabricated samples. The properties to be characterized are

1. Hardness
2. Density
3. Compressive strength
4. Microstructure

2.1 Hardness (Rockwellhardness):



Rockwell HR = E – e. “E” is a constant of 100 (diamond) or 130 (ball) units. “e” is the penetration depth in units of 0.002mm.

2.2Microstructure Analysis:

It is necessary to check quality of fabricated specimen by investigating distribution of reinforcement in matrix. Surface morphology study of specimen helps in revealing quality of fabricated specimen. Microstructure analysis gives us a clear information regarding type of distribution of reinforcing material in the matrix and its orientation, which defines the quality and strength of the Metal matrix composite. All the 6 Samples were investigated under optical microscope as shown in Figure[10]

Fig 10: Optical microscope & belt grinder

3.0Results & Discussions:

HARDNESS (HRB):

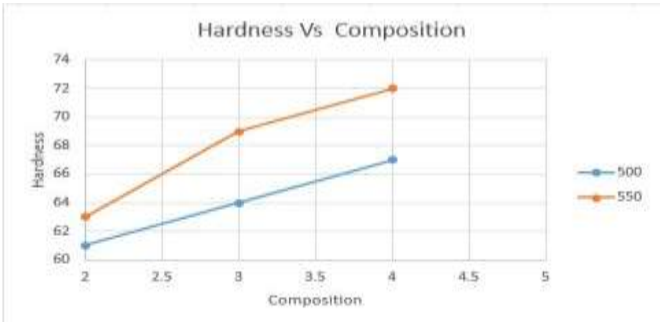
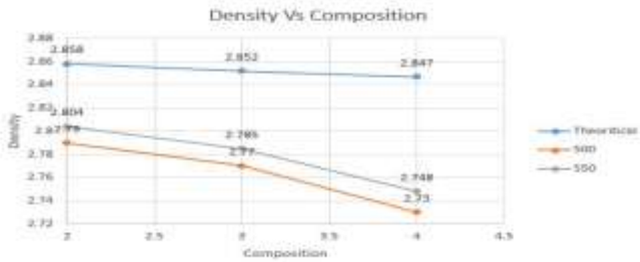


Chart1: Plot between hardness and composition

As it is observed that due to increase in glass fibre composition, the hardness of the composite is increasing. And it is clear that the sintering temperature also plays a significant role in imposing hardness to the composite. At high temperatures, due to diffusion phenomena, the air gaps or voids reduces and the hardness will be uniform and improved as compared to lower temperatures.

RELATIVE DENSITY (d_r): THEORTICAL DENSITY (d_t):



The density of the samples goes on decreasing as the glass fibre content increases. Therefore the sample becomes light in weight as compared to base matrix material. The density of the sample at 500°c is very less because of presence of voids & gaps between the matrix and reinforcing material. But at 550°c, due to diffusion process at high temperature, voids and air gaps are replaced and more bonding takes place between matrix and reinforcing material. Therefore the density decrease as the sintering temperature increases.

4.0 CONCLUSION:

1.The Hardness of the AL 7075 Glass fibre goes on increasing with the addition of glass fibre wt. %.The Sintering Temperature plays an important role in affecting the hardness.
2.The composites sintered at 500°c has less hardness as compared to composites sintered at 550°c.This is due to escape of voids and effective bonding between powder and glass fibre particles at higher temperature.
3.The Density goes on decreasing as the glass fibre content (2%, 3%, and 4%) goes on increasing .The relative density increases with the increase in sintering temperature, because of elimination of pores and voids at higher temperatures.
4.The volumetric strain goes on decreasing with increase in glass fibre content (2%, 3%, 4%).This due to the load during compression test is transmitted to the glass fibre material through the matrix material. The composites sintered at 550°c will have effective distribution of glass fibre, so that it carries more load and experiences less strain.

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