A Review Paper of Al 7075 Metal Matrix Composition

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***Abstract*:- In the present study, some selected samples are heat-treated by elevating the temperature to 480°C for 2 hours and then quenched in different mediums in order to investigate the effect on the mechanical properties of the Aluminium 7075 alloy.**

A composite material is a combination of two or more chemically distinct and insoluble phases; its properties and structural performance are superior to those of the constituents acting independently. Metals and ceramics, as well, can be embedded with particles or fibers, to improve their properties; these combinations are known as Metal-Matrix composites. Aluminum 7075 alloy constitutes a very important engineering material widely employed in the aircraft and aerospace industry for the manufacturing of different parts and components. It is due to its high strength to density ratio that it a sought after metal matrix composite. In this paper we present a survey of Al 7075 Metal Matrix Composites. In we focused on the study of behavior of Aluminium alloy (Al 7075) with SiC and TiB_2 composite produced by the stir casting technique. Al7075 alloy is taken as base material and then it is reinforced with silicon carbide (SiC) and titanium di-boride (TiB_2). Different weight % of TiB_2 reinforcement is used by keeping standard weight % of SiC. After preparation of suitable samples, tensile test and hardness test were performed and results were analyzed.

Keywords: Metal Matrix Composites (MMC's), Aluminium Metal Matrix, Silicon carbide, ,Titanium boride,Al7075, Aluminium alloy.

INTRODUCTION

OVERVIEW OF COMPOSITES:

In metal matrix composites, extensive research work has been carried out on Al alloys. 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. Concrete is a mix of aggregate (small stones or gravel), cement and sand. It has good compressive strength (it resists squashing). In more recent times it has been found that adding metal rods or wires to the concrete can increase its tensile (bending) strength. Concrete containing such rods or wires is called reinforced concrete.

The first modern composite material was fibreglass. It is still widely used today for boat hulls, sports equipment, building panels and many car bodies. These materials are lighter and stronger than fibreglass but more expensive to produce.

Carbon nanotubes have also been used successfully to make new composites. These are even lighter and stronger than composites made with ordinary carbon fibres but they are still extremely expensive. They do, however, offer possibilities for making lighter cars and aircraft (which will use less fuel than the heavier vehicles we have now). The new Airbus A380, the world's largest passenger airliner, makes use of modern composites in its design.

This behaviour has been an reason for increasing interest towards the various applications in technological fields.

ALUMINIUM METAL MATRIX COMPOSITES (AMMC):

Aluminum matrix composites (AMMC) are materials in which the ductile metal matrix is reinforced by hard fibers or particulates. In Metal Matrix Composites (MMCs), aluminum and its alloys have attracted most attention as base metal because of its low density, low weight, high strength, superior malleability, easy machining, excellent corrosion resistance and good thermal and electrical conductivity, etc. In AMMC, aluminium acts as the matrix phase and forms percolating network. These AMMCs offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix.

Aluminium alloys, such as the 2000, 5000, 6000 and 7000 alloy series are the most commonly utilised materials in composite fabrication. Addition of various reinforcements such as fly ash, TiC, SiC, Al_2O_3, TiO_2, B_4C etc., to aluminum matrix will enhance the mechanical and tribological properties. In recent years, Al based composite materials have gained significance in aerospace, automotive and structural applications due to their enhanced mechanical properties and good stability at high temperature.

HYBRID METAL MATRIX COMPOSITES:

Hybrid metal matrix composites are current generation composites where more than one reinforcement of different shape and size are used to attain improved properties. Hybrid MMCs are made by dispersing two or more reinforcing materials into a metal matrix. Hybridization is commonly used for improving the properties and for lowering the cost of conventional composites. The applications of hybrid composites are in the field of aerospace industries and automobile engine parts like drive shafts, cylinders, pistons and brake rotors, consequently interests in studying structural components wear behavior.

PROCESSING OF METAL MATRIX COMPOSITES:

Processing of metal matrix composites (MMC) can be classified into three main categories:

1. Solid State Processing
2. Liquid State Processing
3. In-Situ Processing

Powder blending followed by consolidation (PM processing), diffusion bonding and vapour deposition techniques come under solid state processing.The selection of the processing route depends on many factors including type and level of reinforcement loading and the degree of microstructural integrity desired.

STIR CASTING METHODOLOGY FOR AL 7075 ALLOY

Melting the 7075 Al alloy at 900 - 950ºC

↓

Preheating the (SiC + Tib_2) mixture for 500 ºC

↓

Mix the preheated mixture in molten metal

↓

Stirring is done for 3 - 4 min

↓

Molten Metal (MMC's) is poured into the die

↓

Stir casting technique implemented

↓

Varying process parameters done

↓

Cast the solid component

↓

Samples are prepared

↓

Specimen preparation as per the ASTM standards

↓

Metallurgical & Mechanical properties ofMMC (Microstructure, SEM, Hardness, Tensile)

↓

Result and discussion

↓

Conclusion

STIR CASTING ROUTE FOR FABRICATION OF MMC:

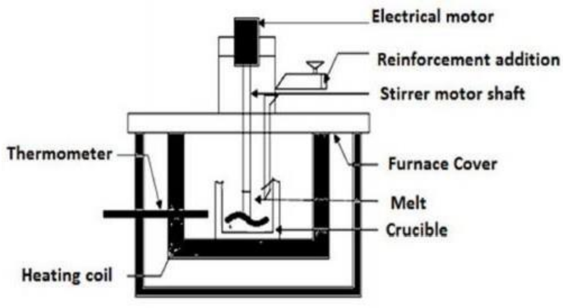

Figure: Stir casting Experimental set up

Preparation of Casting:

The base material used is Al7075 alloy. The required amount of Al 7075 alloy was placed in crucible in an electric heating furnace to a temperature of about 750-800o C maintained. The base metal Al7075 taken as 5.5kg for a casting and 5% of Silicon Carbide and the reinforcement Titanium Boride material with 0 vol.%, 2 vol.%, 4vol.% & 6vol.% of composites was prepared.The molten alloy was degassed (to prevent hydrogen gasses) and after a few minutes the slag formed was removed. The stirrer was carefully placed at a required depth in the crucible and stirred at 650rpm to form a vortox. The reinforcement material added in to vertox and stirred for about 5-10min to obtain a homogenous mixture. The molten mixture carefully poured into the moulds box to obtain the castings, which are later allowed to cool and checked for any defects in the castings.Further samples were prepared as per the ASTM standards for the evaluation of mechanical properties of proposed composites.Stir casting furnace

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 and are stirred thoroughly for a homogeneous mixture with the matrix alloy. In this method, the particles get accumulated often; the accumulated particles can be dissolved at higher temperature by vigorous stirring. The liquid composite materials is then poured into the sand/die casting mould and then allowed to solidify. 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.

Figure: Stir casting Metal Matrix Composition

STIR CASTING PROCESS PARAMETER:

Process parameters plays a vital role on properties of Al based MMC. In case of Stir casting, process parameters like stirring rate, stirring temperature, pouring temperature etc., are to be maintained for achieving better properties of MMC. For manufacturing of composite material by stir casting, knowledge of its operating parameters, different fabrication techniques such as solid state processes including powder metallurgy (PM Route), high energy ball milling, friction stir process, diffusion bonding and vapor deposition techniques are very essential. If the process parameters are properly controlled, it could lead to the improved properties in composite material. The following variable parameters are to be considered, while preparing the MMC by stir casting.

✓ **Speed of rotation:** For successful production of casting, the control of speed is very important. Rotational speed also influences the structure; increase of speed promotes refinement and very low speed results in instability of the liquid mass. It is logical to use the highest speed to avoid tearing.

✓ **Stirring speed:** Stirring speed is one of the most important process parameters as wettability is promoted by stirring i.e. bonding between matrix & reinforcement. The flow pattern of the molten metal is directly controlled by the stirring speed. As solidifying rate is faster it will increase the percentage of wettability.

✓ **Stirring temperature:** The viscosity of Al matrix is influenced by the processing temperature. The particle distribution in the matrix is subjective to the change of viscosity. When processing temperature is increased along with increasing holding time of stirring, there is a decrease in the viscosity of liquid. There is also acceleration in the chemical reaction between matrix and reinforcement.

✓ **Stirring time**: Uniform distribution of the particles in the liquid and perfect interface bond between reinforcement and matrix is promoted by stirring. In the processing of composite, the stirring time between matrix and reinforcement is considered as important factor.

✓ **Pouring temperature:** A major role is played by the pouring temperature on the mode of solidification and determines relation partly to the required structure type. Low temperature is associated with maximum grain refinement and equiaxed structure while higher temperature promotes columnar growth in many alloys. However, the range is limited in practical scenarios. To ensure satisfactory metal flow and freedom from collapse whilst avoiding coarse structures, the pouring temperature must be sufficiently high.

✓ **Mould temperature**: Its principal signification lies in the degree of expansion of the die with preheating. The risk of tearing in casting is diminished by expansion. The mould temperature should neither be too low nor be too high, in non-ferrous casting. The mould should be at least 25 mm thick with the thickness increasing with size and weight of casting.

MECHANICAL PROPERTIES

Hardness Hardness tests were carried out on samples of both unreinforced alloy and its composites, by applying700 grams of load for a period of 15 seconds using Brinell hardness tester as per ASTM E10 standard test method the hardness increase with weight percentage of reinforcement in Al7075 matrix alloy and observed higher hardness in composite compare to matrix material.

Tensile strength Tensile test were carried out on samples of both unreinforced alloy and its composites, the ultimate tensile strength is increases with increase in weight percentage of reinforcement in Al7075 matrix alloy and observed composite has superior UTS by the addition of Titanium Boraide particles in matrix material. It is clears that Al+5%Silicon Boraide+%2Titanium Boride composite has higher strength compared to base alloy.

Compressivestrength

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ADVANTAGES OF ALUMINIUM BASED MMCS

The major advantages of AMCs compared to unreinforced materials are as follows:

- ✓ Greater strength
- ✓ Improved stiffness
- ✓ Reduced density(weight)
- ✓ Improved high temperature properties
- ✓ Controlled thermal expansion coefficient
- ✓ Thermal/heat management
- ✓ Enhanced and tailored electrical performance
- ✓ Improved abrasion and wear resistance
- ✓ Control of mass (especially in reciprocating applications)

LITERATURE SURVEY

This chapter presents a review of the literature data available on the effect of various reinforcement types, their size and volume fraction, ageing behaviour with AL based MMC's.

Zhao et.al. studied the microstructures and mechanical properties of equal-channel angular pressing (ECAP) processed and naturally aged ultrafine grained (UFG) and coarse grained (CG) Al7075 alloys and their evolutions during heat treatment. Their studies established that after the tests, natural aging, tensile yield strength, ultimate strength and micro hardness of UFG samples were higher by 103%, 35% and 48% respectively than those of the CG samples. Their studies show that severe plastic deformation has the potential to significantly improve the mechanical properties of age-hardening Al alloys.

Gopal Krishna U, Sreenivas Rao K V, et al., [1] have reported that, the aluminium matrix can be strengthened by reinforcing with hard ceramic particles like SiC, Al2O3, B4C etc. An effort is made to enhance the mechanical properties like tensile strength and hardness of AMCs by reinforcing 6061Al matrix with B4C particles. The microstructure and mechanical properties of the fabricated AMCs was analyzed. Based on the results obtained from tensile strength test of the metal matrix composites of different particle sizes, 105µ size B4C was chosen.

The optical microstructure images reveal the homogeneous dispersion of B4C particles in the matrix. The reinforcement dispersion has also been identified with X-ray diffraction [XRD]. The tensile strength and hardness was found to increase with the increase in the particle size and also with the increase in wt% of the reinforcement. The tensile strength of AMCs was found to be maximum for the particle size of 105µ and found maximum for 8 wt% in case of varying wt% of the reinforcement of 105µ size.

Karthigeyan et.al. Al7075 alloy composites containing different volume fraction of short basalt fiber are developed using the stir casting process. The experimental strength values of the composites are compared with the theoretical values in this paper. The results suggested that the experimental values best suited the theoretical values owing to the random distribution of basalt fibers in the Al7075 matrix.

Pradeep R et.al observed the study of mechanical properties of Al- Red Mud and Silicon Carbide Metal Matrix Composite (MMC) of Aluminium alloy of grade 7075 with addition of varying weight percentage composition such as SiC8%+Al7075, SiC6%+Red mud2%+ Al7075, SiC4%+Red mud 4%+Al7075, SiC2%+Red mud 6%+Al7075, Red mud 8%+Al7075ed mud and Silicon Carbide particles by stir casting technique. The experimental result reveals that the combination of a matrix material with reinforcement such as SiC and Red mud particles, improves mechanical properties

Ravichandran M et.al carried out the research work by fabricating aluminium metal matrix composites through liquid powder metallurgy route. The aluminium matrix composite containing TiO2 reinforcement particle was produced to study the mechanical properties such as tensile strength and hardness.

Yazdian et.al. have investigated the fabrication and precipitation hardening characterization of nanostructure Al7075 alloy. In their experiment, the Al7075 alloy is milled up to 15 h and then hot pressed. The milled and hot pressed samples are characterized by XRD, TEM, SEM and DTA. Their results indicated that after 15 h of milling, the alloying elements are dissolved in the Al matrix and a supersaturated solid solution with average crystallite size of 30±5 nm is obtained. Hot pressing the powder samples at 500oC under 400 MPa resulted in a fully dense bulk nanostructure Al7075 alloy. The hardness value of the consolidated sample increased from 165 HV to 240 HV after appropriate hardening

Keshavamurthy R et.al studied about Al7075-TiB2 in-situ composite, processed by stir casting technique using commercially available Al-10%Ti and Al- 3%Br master alloys. Both matrix alloy and composite were subjected to microstructure analysis, micro hardness test, grain size studies and tensile test. Microstructure shows fairly uniform distribution of TiB2 particles in matrix alloy. Average grain size of the composite was lower than unreinforced alloy. Micro hardness, yield strength and ultimate tensile strength of Al7075-TiB2 composite, were considerably higher when compared with unreinforced alloy..

Anand Kumar et.al research work carried out by Addition of reinforcement such as TiC, SiC, Al2O3, TiO2, TiN, etc. to Aluminium matrix for enhancing the mechanical properties has been a well– established fact. In-situ method of reinforcement of the Aluminium matrix with ceramic phase like Titanium Carbide (TiC) is well preferred over the Ex–situ method. In the present investigation, Al- Cu alloy (series of 2014 Aluminium alloy) was used as matrix and reinforced with TiC using In-situ process. The Metal Matrix Composite (MMC) material, Al-
.5%Cu/10%TiC developed exhibits higher yield strength, ultimate strength and hardness as compared to Al-4.5%Cu alloy. Percentage increase in yield and ultimate tensile strengths were reported to be about 15% and 24%

respectively whereas Vickers hardness increased by about 35%. The higher values in hardness indicated that the TiC particles contributed to the increase of hardness of matrix.

CHEMICAL COMPOSITION OF AL7075

Among several series of aluminium alloys, Al7075 alloy are highly corrosion resistant, exhibits moderate strength and finds much applications in the fields of construction, automotive and marine applications. In the present work, Aluminium 7075 alloy with the theoretical density 2.81 g/cm^3 was selected as matrix materials. The chemical composition of Al 7075 alloy is given in

Typical chemical composition for Aluminium alloy 7075

Ele men ts	**M n**	**C r**	**F e**	**C u**	**S i**	**M g**	**Z n**	**T i**	**Al**
(wt %)	0. 3	0. 2 8	0 . 5	2 . 0	0 . 4	2 . 9	6 . 1	0 . 2	Bal anc e

Properties for aluminium alloy 7075

Density	2.81 g/cm^3
Hardness, Brinell	150 GPa
Ultimate Tensile Strength	572 MPa
Tensile Yield Strength	503MPa
Elongation at Break	11%
Modulus of Elasticity	71.7 GPa
Poisson's Ratio	0.33
Shear Strength	331 MPa
Shear Modulus	26.9 GPa
Melting Point Temperature	477 – 635^0 C

MACHINABILITY

Alloys of this and similar compositions are rather difficult to machine. This is due firstly to their tendency to drag and secondly to the rapid tool wear caused by the high zinc content. Carbide tipped tools with large rake angles and relatively low cutting speeds give comparatively good results. A cutting lubricant and coolant should be employed.

CORROSION RESISTANCE

7075 exhibits excellent resistance to corrosion under both ordinary atmospheric and marine conditions. For the severest conditions this property can be further enhanced by anodic treatment.

ANODISING

7075 can be anodised by any of the common processes, the resulting protective film ranging in color from grey to dark brown.

APPLICATIONS

Typical applications for aluminium alloy 7075 include: Aircraft and aerospace components, Marine fittings, Transport, Bicycle frames, Camera lenses, Drive shafts, Electrical fittings and connectors, Brake components, Valves, Couplings

The ductility of 7075 enables castings to be rectified easily or even modified in shape, e.g. simple components may be cast straight and later bent to the required contour.

CONCLUSIONS:

The exhaustive literature provided in the previous section highlights the properties of Al7075 MMC's along with various other MMC's. The methodologies suggested by the authors give an insight into the advancements made in the area of composites. It can be observed that Al- Al2O3, Al-SiC-TiB_2 composites can be successfully fabricated by Liquid metallurgy vortex route technique and Powder metallurgy route. In the liquid metallurgy vortex route technique, the percentage of reinforcements used is varied from 2-wt% to 10-wt% of Titanium Boride. The experiments have shown that mechanical and wear properties have increased significantly. The use of ceramic materials, Silicon carbide SiC ,Titanium Boride etc., as a reinforcement for the matrix Al7075 in various proportions can lead to more effective MMC's which exhibit improved mechanical properties.