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Effect of Particulate Reinforced Aluminium Metal Matrix Composite –A Review

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The combined effect of reinforcements on Aluminium Metal Matrix composites with individual and multiple particulate reinforcements like Hybrid Metal matrix composites are finding increased applications in aerospace, automobile, space, underwater, and transportation applications. This is mainly due to improved mechanical and tribological properties like strength, stiffness, abrasion, impact resistance and wear resistance. In the present scenario, a lot of research activities were on pipe line. This paper guides the researchers and engineers towards proper selection of materials by their properties in the relevant field and different techniques involved in manufacturing of metal matrix composites, particularly on the liquid state metal processing technique.

Keywords: Al alloy, Particulate reinforcements, Stir Casting, Process Parameters, MMC, Hybrid Composites.

1. Introduction

Aluminium alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for varieties of applications; owing to their lower weight and excellent thermal conductivity properties. Among several series of aluminium alloys, heat treatable Al6061 and Al7075 are much explored, among them Al6061alloy are highly corrosion resistant, exhibits moderate strength and finds much applications in the fields of construction, automotive and marine applications. Aluminum alloy 7075 possesses very high strength, higher toughness and are preferred in aerospace and automobile sector [1]. Due to their high strength, fracture toughness, wear resistance and stiffness, the composites formed out of aluminium alloys are of wide interest. Further these composites are of superior in nature for elevated temperature application when reinforced with ceramic particle.

2. Reinforcement materials

Several methods are employed in the manufacturing of MMCs. Stir casting is considered as a very popular method due to its unique features. In this method, the reinforcing particles are imparted into the molten material and are stirred thoroughly for a homogeneous mixture with the matrix alloy. The properties of the particle reinforced metal matrix composites produced this way are influenced to a large extent by the type, size and weight fraction of the reinforcing particles and their distribution in the cast matrix.

In Aluminum matrix composites (AMCs), the ceramic reinforcements are generally oxides or carbides or borides such as Al_2O_3, TiB_2, TiO_2,SiC, TiC, B_4C, etc. The processes root of manufacturing, shape, size, and chemical affinity with matrix material of reinforcement materials influence their microstructure, physical properties, tribological properties and other desirable properties of the composite. The formation of strong chemical bonds at the interface is favorable for the wetting of reinforcement by molten metal, which is considered as an important aspect in MMC synthesis. The lower wettability adversely affects the properties of the composite. Non-wetting of the reinforcement with the molten metal is primarily caused by the presence of oxide films on the surface of molten metal and the adsorbed contaminant on the reinforcement. Metallic coatings on the reinforcements, addition of reactive elements, such as magnesium, calcium or titanium, to the molten metal and heat treatment of particles before addition are some of the techniques to improve metal–reinforcement wettability. [2]

3. Stir casting route for fabrication on metal matrix composite

In Stir casting route method of composite materials fabrication, 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. The stir casting methodology is relatively simple and low cost. This can usually be prepared by fairly conventional processing equipment and can be carried out on a continuous and semi continuous basis by the use of stirring mechanism as shown Fig. 1.

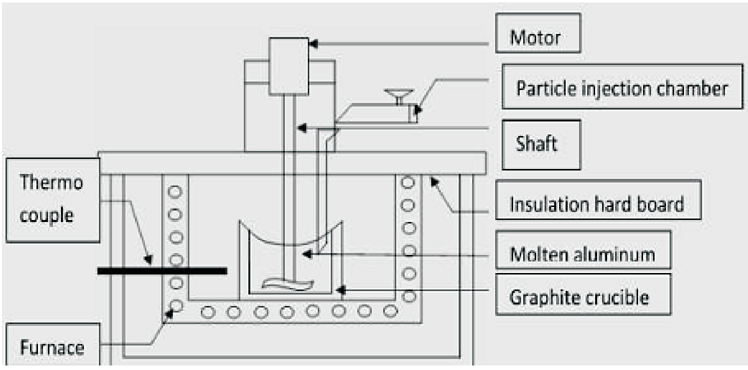

Figure 1 Stir casting Experimental set up

4. Stir casting process parameter

The following variable parameters are to be considered, while preparing the MMC by stir casting. [2–4]

1. **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.

2. **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. Research work carried out by **Rajesh Kumar et.al** suggested that the speed range between 300 and 600 rpm is optimum. As solidifying rate is faster it will increase the percentage of wettability.

3. **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. Once again, the research work carried out by **Rajesh Kumar et.al** observed that operating temperature at 630°C keeps the Al (6061) in semisolid state.

4. **Reinforcement pre-heat temperature:** According to the research work by **Pradeep Sharma et. al.** in order to remove moisture or any other gases present within reinforcement, the reinforcement was preheated at a specified 500^oC temperature for 30 minutes. The wettability of reinforcement with matrix is promoted by preheating.

5. **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.

6. **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.

7. **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.

5. Literature survey

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 like tensile strength, compressive strength, hardness and yield strength. [4]

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 TiO_2 reinforcement particle was produced to study the mechanical properties such as tensile strength and hardness. The characterization studies are also carried out to evident the phase presence in the composite and the results are discussed for the reinforcement addition with the mechanical properties. Results show that, the addition of 5 weight percentage of $TiO_2$to the pure aluminium improves the mechanical properties. [5]

H. Izadi et.al investigated through FSP and has observed improvement in the micro hardness of Al–SiC composites produced by traditional powder metallurgy and sintering methods. The material flow in the stir zone during FSP was successful in uniformly distributing the SiC particles. However, when samples with 16% SiC (by volume) were processed, there were residual pores and lack of consolidation. An increase in hardness of all samples was observed after friction stir processing which was attributed to the improvement in particle distribution and elimination of porosity. [6]

Keshavamurthy R et. al studied about Al7075-TiB_2 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 TiB_2 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-TiB_2 composite, were considerably higher when compared with unreinforced alloy as shown in Fig. 2, 3 and 4 [7].

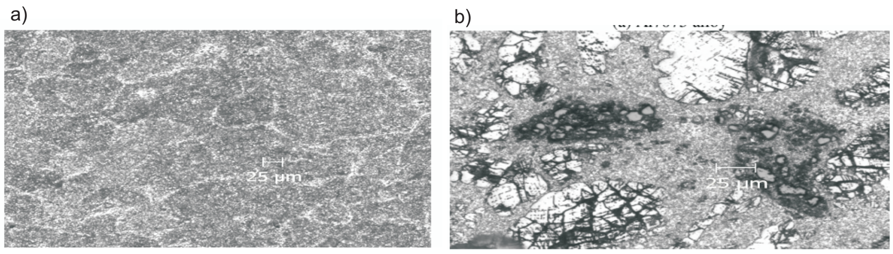

Figure 2 Optical micro photographs of a) Al7075 alloy and b) Al7075 8.5wt% TiB_2 composite

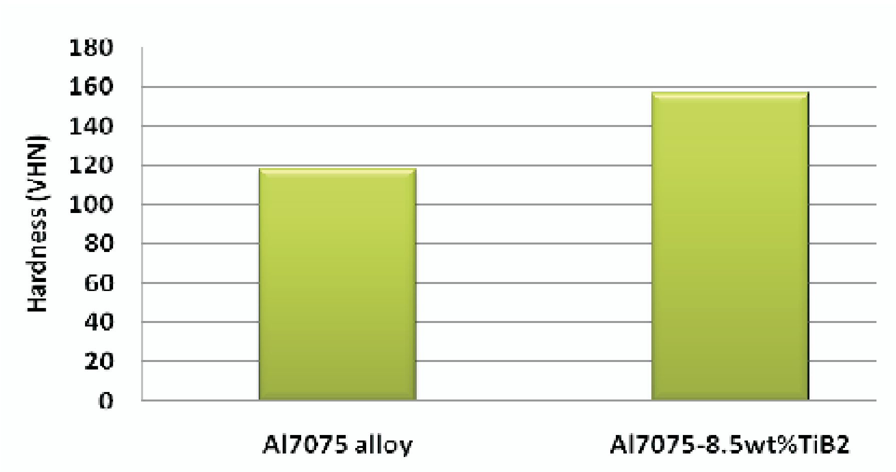

Figure 3 Hardness of Al7075 alloy and Al7075-TiB_2 copmpsite

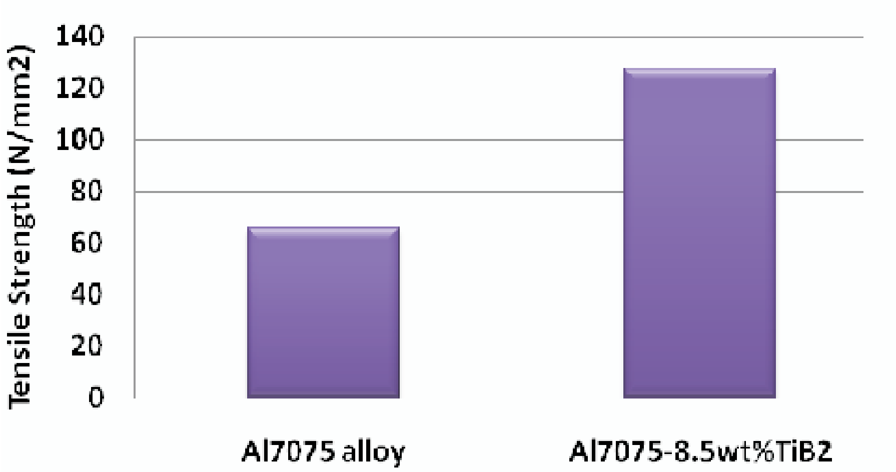

Figure 4 Tensile Strength of Al7075 alloy and Al7075-TiB_2composite

Uvaraja et .al observed that Hybridization is commonly used for improving the properties and for lowering the cost of conventional composites. Hybrid MMCs are made by dispersing two or more reinforcing materials into a metal matrix. They have received considerable research and trials by Toyota Motor Inc., in the early 1980s. Hybrid metal matrix composites are a relatively new class of materials characterized by lighter weight, greater strength, high wear resistance, good fatigue properties and dimensional stability at elevated temperatures than those of conventional composites. Due to such attractive properties coupled with the ability to operate at high temperatures, the Al matrix composite reinforced with SiC and B_4C particulate are a new range of advanced materials. It was found that applications of hybrid composites in aerospace industries and automobile engine parts like drive shafts, cylinders, pistons and brake rotors, consequently interests in studying structural components wear behavior. [8-10]

Anand Kumar et.al research work carried out by Addition of reinforcement such as TiC, SiC, Al_2O_3, TiO_2, 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. [9-10]

6. Conclusion

The current literature review reveals that extensive work has been reported to improve the properties of different aluminium based MMC by forming their composites being reinforced with various materials such as Al_2O_3, TiB_2, TiO_2, SiC, TiC and B_4C etc.,

- It has been observed that one of the least expensive methods to fabricate MMC is STIR CASTING.
- It has been observed that the density of the composite increases with the addition of the hard ceramic reinforcement into the matrix material.
- Behavior of hybrid composites under solid particle erosion is another open end for the meaningful research.
- It has been observed that there is an increase of 30% in hardness and there is an increase in tensile strength that is almost twice the base aluminium alloy.

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.

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