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A Review - Effect of AL6061-SiC wt% (Composite) on Ultimate tensile strength by the Stir casting

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Abstract - *Stir casting process of metal matrix is initiated in 1968 in which reinforcement are distributed into molten metal matrix composite (MMC) mechanism by mechanical stirring operation. This study is focused on cast the aluminum composite metal matrix and the production of different aluminum alloy composite with various volume and weight fraction of reinforcement. From the study it has been observed that it is required to work on the AL6061 composite reinforcement and finding the best optimum parameters due to its very large applications and increase the mechanical properties.*

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***Key Words*: Metal matrix composites; Particulates, reinforcement, stir casting process, Microstructure, Optimization.**

1. INTRODUCTION

Composite materials play an important role in the field of engineering as well as advance manufacturing in response to unprecedented demands from technology due to rapidly advancing activities in aircrafts, aerospace and automotive industries. These materials have low specific gravity that makes their properties particularly superior in strength and modulus to many traditional engineering materials such as metals. As a result of intensive studies into the fundamental nature of materials and better understanding of their structure property relationship, it has become possible to develop new composite materials with improved physical and mechanical properties. These new materials include high performance composites such as reinforced composites. Continuous advancements have led to the use of composite materials in more and more diversified applications. [1]

1.1. COMPOSITE

Composites The typical composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure. The constituents retain their identities, that is, they do not dissolve or merge completely into one another although they act in concert. The individual materials that make up composites are called constituents. Most composites have two constituent materials: a binder or matrix (polymers, metals or ceramics) and reinforcement (fibers, particles, flakes and/or fillers). The reinforcement is usually much stronger and stiffer than the matrix, and gives the composite its good properties. The matrix holds the reinforcements in an orderly pattern. Because the reinforcements are usually discontinuous, the matrix also helps to transfer load among the reinforcements. Some authors defined composite as: The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their shortcomings. [2]

There are two major reasons for the current interest in composite materials. The first is simply the need for materials that will outperform the traditional monolithic materials. The second and more important in the long run is that composite offer engineers the opportunity to design totally new materials with the precise combination of properties needed for specific tasks.

1.2. Classification of composites

Composites are classified in various ways by different authors but in simplest and broadest sense this may be classified as

1 Natural, and
2 Man-made or synthetic. [3]

The reinforced composites are classified in two ways:

i. On the basis of matrix used and
ii. On the basis of the geometry of the reinforcement. Based on the matrix phase used, multiphase composites are divided into three categories:

a. Polymer-matrix composites (PMCs),
b. Ceramic-matrix composites (CMCs),
c. Metal-matrix composites (MMCs).

1.3. Classification of composites

In a material composite, when the matrix is a metal or an alloy, it is known as "Metal Matrix Composite (MMC). The matrix is essentially a metal, but seldom a pure one. Except sparing cases, it is generally an alloy. The main unction of the matrix is to transfer and distribute the load to the reinforcement. MMCs are gaining popularity in a variety of industries, including aerospace, automotive and military due to their high specific strength, adequate stiffness, and outstanding wear resistance. However, mechanical properties degrade due to insufficient densification and uneven microstructure, as well as aggregation of the reinforcements and poor interfacial bonding between the reinforcements and the matrix.

As a result, homogeneous dispersion of the reinforcements in the metal matrix is vital in the manufacturing of MMCs; this homogenous distribution is crucial in determining the mechanical and physical properties of the MMCs. A continuous interfacial phase between the matrix and the reinforcement also indicates homogenous distribution and good interfacial bonding strength, resulting in isotropic load transfer between the matrix and the reinforcement. Generally, MMCs are classified according to type of used reinforcement and the geometric characteristics of the same. Normally, the main classification of composites can be made in the form of reinforcement groups into two basic categories:

a. Continuous reinforcement composites, constituted by continuous fibers or filaments,
b. Discontinuous reinforced composites, containing short fibers, whiskers or particles.

1.4. Matrix Material

The matrix material should be carefully chosen depending upon its properties and behaviour with the reinforcement. As it is the primary constituent in MMC, the matrix alloy should be chosen only after giving careful consideration to its chemical compatibility with the reinforcement, to its ability to wet the reinforcement, and to its own characteristic's properties and processing behaviour.

Researchers have proposed a lot of materials as the matrix material depending on their properties. Taya and Arsenault have suggested materials like Al, Ti, Mg, Ni, Cu, Pb, Fe, Ag, Zn, Sn and Si on the basis of oxidation and corrosion resistance properties. Among these Al, Ti, Mg are used widely. [4]

The most common metal alloys in use are based on Aluminium and Titanium. Both of them are low density materials and are commercially available in a wide range of alloy compositions. Magnesium is light, but is highly reactive to Oxygen. Nickel and Cobalt based super alloys have also found some use, but some of the alloying elements present in the matrices have been found to have undesirable effect (promoting oxidation) on the reinforcing fibers at high temperatures.

Aluminium is one of the best materials for matrix because of its unique combination of excellent mechanical and electrical properties of good corrosion resistance, low density and high toughness with high conductivity. [5]

Moreover, Al is cheaper than other light metals like magnesium (Mg). The other advantage of using Al as matrix of MMCs is its corrosion resistance which is very important for using composites in different environments.

Aluminium based metal matrix composites (MMCs) offer potential for advanced structural applications when high specific strength and modulus, as well as good elevated temperature resistance, high service temperature and specific mechanical properties are important.

Generally, 6000 series of aluminium alloys are used as aircraft structural components and in high strength applications. Al6061 alloy-based composites are broadly utilized in automotive, aeronautical and mineral processing sectors due to improved characteristics like stiffness, strength, stiffness, excellent wear & less thermal expansion coefficient.

1.6 Reinforcement

Reinforcement increases the strength, stiffness and the temperature resistance capacity and lowers the density of MMC. In order to achieve these properties, the selection depends on the type of reinforcement, its method of production and chemical compatibility with the matrix and the following aspects must be considered while selecting the reinforcement material. Reinforcements are characterized by their chemical composition, shape, dimensions, and properties as in gradient material and their volume fraction and spatial distribution in the matrix. [6]

Particulate- reinforced MMC show the advantage of nearly isotropic properties and cost-effectiveness. Furthermore, an additional advantage of the particulate-reinforced over fiber reinforced MMC is that most existing processing techniques can be used for fabrication and finishing of the composites, including hot rolling, hot forging, hot extrusion and machining. [7]

It is proven that the ceramic particles are effective reinforcement materials for aluminium and its alloy to enhance the mechanical and other properties. Typically, these ceramics are oxides, carbides and nitrides. These are used because of their combinations of high strength and stiffness at both room and elevated temperatures.

Carbon nanofibers, carbon nanotubes, graphene, silicon carbide (SiC), boron carbide (B4C), titanium diboride (TiB2), and titanium carbide (TiC) are examples of carbon or ceramic reinforcement in metal matrix composites (MMCs). The use of graphite reinforcement in a metal matrix has a potential to create a material with a high thermal conductivity, excellent mechanical properties and attractive damping behaviour at elevated temperatures.

However, lack of wettability between aluminium and the reinforcement, and oxidation of the graphite lead to manufacturing difficulties and cavitation of the material at high temperatures. Silicon carbide particle (SiCp) reinforced aluminium-based MMCs are among the most common MMC and commercially available ones due to their economical production. [8]

2 STIR CASTING

Stir casting is a type of casting process in which a mechanical stirrer is introduced to form vortex to mix reinforcement in the matrix material. It is a suitable process for production of metal matrix composites due to its cost effectiveness, applicability to mass production, simplicity, almost net shaping and easier control of composite structure. [9]

Stir casting setup as shown in Figure 1, consist of a furnace, reinforcement feeder and mechanical stirrer. The furnace is used to heating and melting of the materials. The bottom poring furnace is more suitable for the stir casting as after stirring of the mixed slurry instant poring is required to avoid the settling of the solid particles in the bottom the crucible. The mechanical stirrer is used to form the vortex which leads the mixing of the reinforcement material which are introduced in the melt. Stirrer consist of the stirring rod and the impeller blade.

The impeller blade may be of, various geometry and various number of blades. Flat blade with three number is the preferred as it leads to axial flow pattern in the crucible with less power consumption. This stirrer is connected to the variable speed motors, the rotation speed of the stirrer is controlled by the regulator attached with the motor. Further, the feeder is attached with the furnace and used to feed the reinforcement powder in the melt. A permanent mold, sand mold or a lost-wax mold can be used for pouring the mixed slurry.

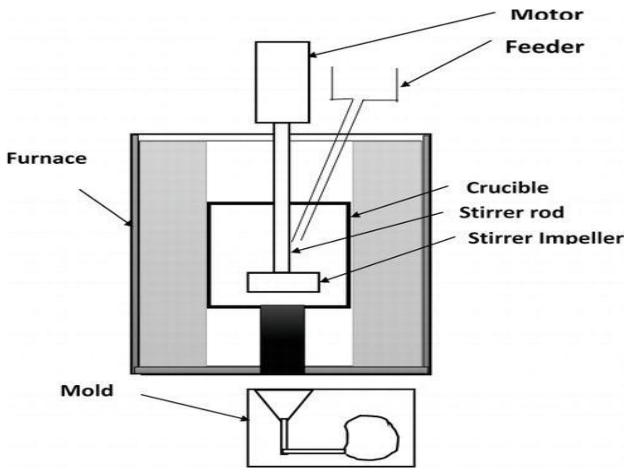

Fig. 1 Basic stir casting process

Various steps involved in stir casting process is shown in Figure 2. In this process, the matrix material is kept in the bottom pouring furnace for melting. Simultaneously, reinforcements are preheated in a different furnace at certain temperature to remove moisture, impurities etc. After melting the matrix material at certain temperature, the mechanical stirring is started to form vortex for certain time period then reinforcement's particles are poured by the feeder provided in the setup at constant feed rate at the centre of the vortex, the stirring process is continued for certain time period after complete feeding of reinforcements particles.

The molten mixture is then poured in preheated mold and kept for natural cooling and solidification. Further, post casting process such as heat treatment, machining, testing, inspection etc. has been done. There is various impeller blade geometry are available. Melting of the matrix material is very first step that has been done during this process. There is various impeller blade geometry are available. Melting of the matrix material is very first step that has been done during this process.

2.1. Mechanical stirring

In stir casting process, the mechanical stirrer is coupled with the varying speed motor to control the speed of the stirrer. There are various stages of impeller stirrer i.e., single stage, double stage and multistage impeller. Double stage and multi stage stirrer are mainly used in chemical industries whereas single stage impeller stirrer is commonly used for fabrication of AMCs and HAMCs due flexibility and to avoid excessive vortex flow. [10, 11]

Process parameters

These parameters are stirring speed, stirring time, blade angle, stirrer size, position of the stirrer and feed rate of reinforcements. The main purpose of introducing stirrer is to form vortex in melt which transfers the reinforcement particles in the matrix melt and maintain them in suspension.

3 LITERATURE REVIEW

Sijo M T, et. al. [2016] investigated on Analysis of stir cast aluminium silicon carbide metal matrix composite: A comprehensive review. They have reviewed Mechanical characterization. They reviewed modelling, simulation and manufacturing methods. They conclude that the improper distribution of SiC in metal metric has been observed during stir cast of AL-SiC and lower wettability of Sic reinforcement particle with aluminium molten metal. [12]

M.Vamsi Krishnaa, et. al. [2014] studied on An Investigation on the Mechanical Properties of Hybrid Metal Matrix Composites. He had compared of AL6061-SiC & AL6061/Graphite hybrid composite Stir casting from 5-15% with 5 wt% increment. They observed fairly uniform distribution of the particles in the composites with few places cluster in micro structural studies. Found less densities in experimental than the theoretical density. [13]

Himanshu Kalaa, et. al. [2014] investigated on A Review on Mechanical and Tribological Behaviours of Stir Cast Aluminium Matrix Composites. In this case, they studied single and multiple reinforcement in the stir casting process. Tribological and mechanical properties Adding of alumina to aluminium is enhancing in its tribological and mechanical properties. They observe Organic reinforcement like fly ash, coconut ash also enhanced the tensile and yield strength. [14]

R. S. Rana, et. al.[2015] investigated on Characterization of Mechanical Properties and Microstructure of Aluminium Alloy-SiC Composites. In this experiment work, AA5083 alloy SiC, Weight percentage of SiC Ultrasonic based Stir casting, Composites Tensile Strength, Compressive Strength, ultrasonic vibration They observe The function of ultrasonic vibration on the composite throughout melting not only refined the grain formation of the matrix, but also enhanced the distribution of nano sized reinforcement.[15]

G. G. Sozhamannan et. al. [2012] investigated on Effect of Processing Parameters on Metal Matrix Composites: Stir Casting Process. In this investigation, experiment on Al-SiCp composite with Stirring speed 450 rpm and Processing Temperatures (700°C, 750°C, 800°C, 850°C, 900°C) with Holding Time (10, 20, and 30 minutes). They observe that tension test revealed that ultimate strength increased gradually up to 800°C and starts to decrease gradually due to the distribution in the Al matrix. The Ultimate strength of metal matrix composite de- creases with increasing holding time. [16]

Figure 7.Optical Image shows particles distribution at 20 minutes holding time

T. Rajmohan, et. al. [2013] investigated Evaluation of mechanical and wear properties of hybrid aluminium matrix composites. In this experiment, select materials Mica and SiC ceramic into Al 356 alloy. They observe in Stir-casting, Microstructures, Chemical symphony the superior strength and hardness are got with Al/10SiC–3Mica composites. The enhancement in mass fraction of mica enhances the wear loss of the composites. [17]

S. Mohan Kumar, et. al. [2017] investigated on Evaluation of Mechanical and Wear Properties of Aluminium AA430 Reinforced with SiC and Mgo. In this experiment use Aluminium AA430 Reinforced with SiC and MgO with weight fraction of SiC + MgO (2.5%, 5% and 7.5%) All other parameters are constant observing the effect on mechanical properties Rising trend of hardness and tensile strength with enhance in weight percentage of SiC + MgO has been observed. The wear rate of the test specimen's is raise with the escalating load and sliding distance. The coefficient of friction slightly reduces with escalating volume content of reinforcement.[18]

Kumar, et. al. [2014] investigated on Comparison of Mechanical Properties and effect of sliding velocity on wear properties of Al 6061, Mg 4%, Fly ash and Al 6061, Mg 4%, Graphite 4%, Fly ash Hybrid Metal matrix composite. They chose 4%MG as a base metal and varying composition of Fly ash i.e., 10%, 15% and20% was taken as reinforcement in second case AL6061, 4%MG, 4% Graphite was taken as base material and varying composition of Fly ash i.e. 10%, 15% and20% as they observed reinforcement Tensile strength increases with addition of fly ash. Similarly when graphite was added then decreases in tensile and hardness. The composite with 4%Mg, 15%Fly ash found to be maximum tensile whereas composite of 4%Mg, 20%Fly ash was found to be of maximum hardness. Specific wear rate decreases with addition of fly ash up to a certain volume whereas with graphite addition it also decreases. [19]

Kandpal B.C. and Singh, et. al. [2017] investigated on Fabrication and characterisation of Al2O3/Aluminium alloy 6061 composites fabricated by Stir casting. In this work take various percentages of Al2O3 particles the microstructures of AMMC were studied using scanning electron microscopy. They observed the Al2O3 particles were distributed homogeneously in the aluminium matrix. Al2O3 particles were properly bonded to the aluminium matrix. The reinforcement of Al203 particles improved the micro hardness and ultimate tensile strength of AMMC. [20]

Anand, et. al. [2020] investigated on Influence of silicon carbide and porcelain on tribological performance of Al6061 based hybrid composites. They studied on Silicon carbide (5 wt %) and porcelain (1.5 – 6.0 wt %) reinforcements. They observed that the hardness of the hybrid composites enhanced approximately by 57% with an increment in porcelain particulates from 1.5 to 6 wt%. However, the wear loss and average coefficient of friction decrease when the porcelain content was added and was found to be minimum at 4.5 wt% porcelain. Hence, the presence of 4.5wt%porcelainin the Al6061/5SiC hybrid composites produces the best wears properties. A composite produces the best wear properties. [21]

D. L. Belging Paul, et. al. [2021] investigated on Mechanical properties analysis of hybrid composites prepared by stir casting approach. In this experiment work use Hybrid composite composed of 50% of Aluminium alloy, 40% Zinc and 10% of copper stirring speed 700 rpm They observed that, aluminium alloys (AA7079) Zinc - Copper hybrid composites are improve the mechanical strength reduce the wear rate effectively Hybrid composites offered good wear resistance as 212 mm under the action of 2 kg load 2 m/s sliding velocity and the time period of 30 min [22]

Dwivedi, et. al.[2020] investigated on Microstructure and mechanical behaviour of Al/B4C metal matrix composite. AA2014 aluminium alloy was taken as matrix material. Reinforcement material was taken as B4C. Uniform distribution of boron carbide was observed inside the AA2014 matrix material. Maximum hardness and tensile strength were found for 10 wt% reinforced boron carbide composites. Toughness, ductility and density reduced by increasing the boron carbide percentage in the matrix material. [23]

Moses J.J., et. al. [2016] investigated on Prediction of influence of process parameters on tensile strength of AA6061/TiC aluminium matrix composites produced using stir casting. In this studied use Input parameter: stirring speed, stirring time, blade angle and casting temperature They observed that the UTS was high when the porosity was low and the distribution was homogenous. An intermediate range of parameters yielded castings with homogeneous distribution of TiC particles and minimum porosity. [24]

Kumar, et. al. [2020] investigated on Recent progress in production of metal matrix composites by stir casting process: An overview. This review article contains substantial aspects of stir casting route like; mechanical properties, effect of various reinforcement, various challenges and future research potential in the development of composites. Stir casting method is prominent technique for developing metal matrix composites (MMCs) due to its easiness and production at reasonable price with bulk manufacturing competency. They concluded that Fabrication of Al alloy-based composite through stir casting route is one of the economical and noticeable techniques as compared to the other process. [25]

Chinna mahammad Bhasha, et. al. [2021] studied on mechanical properties of Al6061/RHC/TiC hybrid composite. In his experiment work, PNAHC (Particulate Nano Aluminium Hybrid Composites) is prepared by reinforcing 3% by weight of rice husk char (RHC) and with varying weight percentages of TiC such as: 3%, 6%, 9% and 12%.The effect of the reinforcements on the PNAHC is studied by tensile, compressive, bending, impact, micro hardness and density The reinforcement greater than 9 wt% of TiC in the matrix leads non-uniform dispersion and group of clustering. The ultimate strength, compression strength, and flexural strength of sample S2 increased 46.71%, 36.72%, 48.85% respectively, compared to the nascent sample. Analysis of the fracture on the impact test surfaces showed a mixed failure mode, with dimples and ridges and de-boning of particles. [26]

Chitharthan, et. al. [2021] investigated on Experimental study on mechanical properties of hybrid metal matrix composites using stir casting process. They studied on Aluminium Oxide (Al2O3) and Boron Carbide (B4C) with a varying weight percentage of reinforcement. They observed that strength of hybrid MMC has increased up to 21.3% by increasing the percentage of Alumina by addition of boron carbide (B4C) the hardness increases by 15.65% and the wear rate decreases by 28.63% the stir casting process parameters were varied and the optimal stir casting process parameters was obtained by Taguchi quality design concept.[27]

Maurya, et. al. [2020] studied on Investigation of mechanical properties of Al 6061/SiC composite prepared through stir casting technique. In this experiment work, weight percent of SiC vary and check hardness and tensile tests from SEM. They observed that the density of Al 6061/SiC composite was improved with the reinforcement of SiC content. The hardness and tensile strength was significantly improved up to 5 wt% of SiC particles. [28]

[18] Moses, et. al. [2014] investigated on Characterization of silicon carbide particulate reinforced AA6061 aluminium alloy composites produced via stir casting. Weight percent of SiC The microstructures of the AMCs were studied using optical and scanning electron microscopy. The reinforcement of Sic particles improved the micro hardness and ultimate tensile strength (UTS) of the AMCs. Sic particles were properly bonded to the aluminium matrix. [29]

4 CONCLUSION

Stir casting is the most inexpensive metal matrix composite fabrication methods.

Stir casting process suffers from poor distribution of the reinforcement particles in the matrix and wettability of particles by Al-alloy for that more work is needed.

It is necessary to stir properly because the distribution of the particles in the molten matrix depends on the stirring parameters, position of the mechanical stirrer in melt.

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