Preparation of Cu-Al-Ni SMA Particulates Embedded Al (2024) Matrix Adaptive Composite by using Stir Casting Method

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***Abstract*: The composite material is composed of a discrete reinforcement & distributed in a continuous phase of matrix, in aluminium matrix composite one constituent is aluminium which forms network i.e. matrix phase and another constituent as reinforcement which is generally shape memory soft material. The basic reason of metals reinforced with soft shape memory particles or fibers are improved properties than its original material like strength, stiffness etc. Stir casting process is mainly used for manufacturing of particulate reinforced metal matrix composite (PMMC). Manufacturing of aluminum alloy based casting composite by stir casting is one of the most economical methods of processing MMC. The properties of these materials depend upon many processing parameters and selection of matrix and reinforcements. This paper presents an overview of stir casting process, process parameter, & preparation of Al (2024) matrix composite material by using Cu-Al-Ni Shape memory particles as reinforcement by varying proportions.**

Keywords: Stir casting process, Aluminum matrix composite, Shape memory materials and reinforcement

I.INTRODUCTION

Now days the recent industry needs development of advanced engineering materials for several engineering applications. Composite material is one of the reliable solutions for such requirement. In composites, materials are combined to empower us to make better use of their parent materials while minimizing to some extent the effects of their deficiencies. The simple term ‘composites’ gives indication of the combinations of two or more materials in order to advance their properties. In the past few years, materials growth has shifted from monolithic to composite materials for amending to the global needs for reduced weight, low cost, quality, and high performance in structural materials. To meet such demands metal matrix composite is one of the reliable sources. Driving force for the utilization of MMCs in areas of aerospace and automotive industries include performance, economic and environmental benefits [1]. In MMC one of the constituent is aluminum 2024 (Al (2024)) alloy, which forms percolating network and is termed as matrix phase. The other constituent is embedded in this aluminum and serves as reinforcement, which is Cu-Al-Ni (CAN) shape memory(SM) particles. The advantages can be used to achieve better properties namely elastic modulus, coefficient of expansion and wear resistance. In the light of the above it is possible to alter properties of Al (2024) alloy by adding CAN SM particles reinforcement in suitable volume fraction. Reinforcing the matrix with particulates of CAN SM particles could give a composite improved properties compared to monolithic base alloy. Further, the attractive feature is the isotropic nature of the properties. Even though the property improvements are not as high as those achievable with continuous fiber ones, they are sufficiently attractive enough for most of the intended engineering applications [2].The cost of the component production by solid state processing route was still high and hence large scale commercialization of wide spectrum of engineering component did not take place. The commonly used reinforcement is silicon carbide particulates (SiCp) in cast alloy matrix (6061/2024). Even though the possibilities of using different kinds of reinforcement in Al alloys as reinforcements, except SiCp and $A1_20_3$ others have not shown any commercial potential [2] Jokhio, Panhwar & Mukhtiar Ali investigate the effect of elemental metal such as Cu-Zn-Mg in aluminum matrix on mechanical properties of stir casting of aluminum composite materials reinforced with alpha "Al_2O_3" particles using stir casting they found increase in tensile strength. Also they found that Mg has pronounced effect on aluminum cast composites up to 2.77% Mg contents which increases wettability, reduces porosity and develops very good bonding with Al_2O_3 [3]. Preparation and characterization of aluminum metal matrix composites reinforced with aluminum nitride was carried out by M.N. Wahab, A.R. Daud and M. J. Ghazali they found considerable significant increase in hardness of the alloy matrix [4].Cast 356/SiCp composites were produced using a conventional stir casting technique by S. Tzamtzis, N. S. Barekar, N. Hari Babu, J.Patel, B.K. Dhindaw they found a good combination of improved ultimate tensile strength (UTS) and tensile elongation is obtained [5].

II. PROCESSING OF AMC

A key challenge in the processing of composites is to homogeneously distribute the reinforcement phases to achieve a defect-free microstructure. Based on the shape, the reinforcing phases in the composite can be either particles or fibers. The relatively low material cost and suitability for automatic processing has made the particulate-reinforced composite preferable for automotive applications. Primary processes for manufacturing of MMCs at industrial scale can be classified into two main groups.

A. Liquid state processes:

Liquid state processes include stir casting, compo casting and squeeze casting spray casting and in situ (reactive) processing, ultrasonic assisted casting [4].

B. Solid state processes:

Solid state process include Powder blending followed by consolidation (PM processing), high energy ball milling, friction Stir Process, diffusion bonding and vapors deposition techniques. The selection of the processing route depends on many factors including type and level of reinforcement loading and the degree of micro structural integrity desired [4]. Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practiced commercially. Its advantages lie in its simplicity, flexibility and applicability to large quantity production. It is also attractive because, in principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production and allows very large sized components to be fabricated.

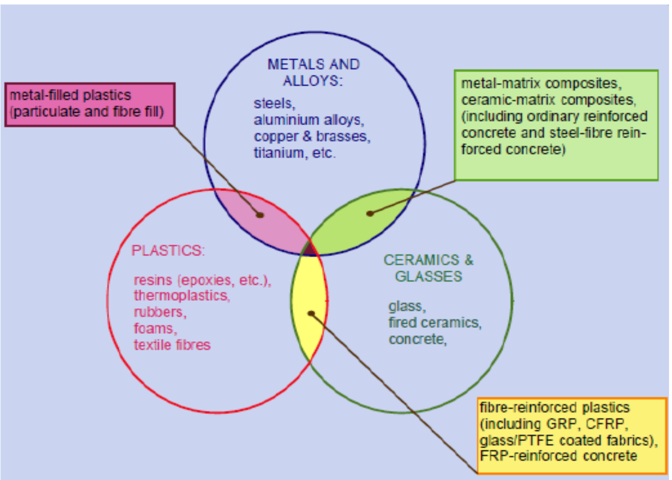

Table.1: A comparative analysis of different technique Used for fabrication [4]

C. Stir casting:

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into an aluminum melt by stirring molten aluminum alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting. Stir casting is suitable for manufacturing composites with up to 30% volume fractions of reinforcement [7].The cast composites are sometimes further extruded to reduce porosity, refine the microstructure, and homogenize the distribution of the reinforcement. A major concern associated with the stir casting process is the segregation of reinforcing particles which is caused by the surfacing or settling of the reinforcement particles during the melting and casting processes. The final distribution of the particles in the solid depends on material properties and process parameters such as the wetting condition of the particles with the melt, strength of mixing, relative density, and rate of solidification .The distribution of the particles in the molten matrix depends on the geometry of the mechanical stirrer, stirring parameters, placement of the mechanical stirrer in the melt, melting temperature, and the characteristics of the particles added [7]. An interesting recent development in stir casting is a two-step mixing process. In this process, the matrix material is heated to above its liquids temperature so that the metal is totally melted. The melt is then cooled down to a temperature between the liquids and solidus points and kept in a semi-solid state. At this stage, the preheated particles are added and mixed. The slurry is again heated to a fully liquid state and mixed thoroughly. This two-step mixing process has been used in the fabrication of aluminium. Among all the well-established metal matrix composite fabrication methods, stir casting is the most economical. For that reason, stir casting is currently the most popular commercial method of producing aluminium based composites.

III. OBJECTIVE OF THE PAPER

The main objective of this paper is to study the operating parameter of the composite as its control the properties of the composite material. Second objective is manufacturing the particulate aluminum metal matrix composite (PAMC) with varying compositions of reinforcement particles of Cu-Al-Ni SM alloy by using stir casting method.

A. Composite Material:-

For composite material selection of Matrix and reinforcement are of prime importance. For this research work we had selected material as follows.

B. Matrix:-

Aluminium alloy 2000, 6000 and 7000 series are used for fabrication of the automotive parts. PAMC under study consist of matrix material of Aluminium alloy Al (2024) whose chemical composition is shown in the Table. An advantage of using Aluminium as matrix material is casting technology is well established, and most important it is light weight material. Aluminium alloy is associated with some disadvantages such as bonding is more challenging than steel, low strength than steel and price is 200% of that of steel. But with proper reinforcement and treatment the strength can be increased to required level.

Comp	Wt. %	Comp	Wt. %	Comp	Wt. %
Al	90.7 - 94.7	Mg	1.2 - 1.8	Si	Max 0.5
Cr	Max 0.1	Mn	0.3 - 0.9	Ti	Max 0.15
Cu	3.8 - 4.9	Other, each	Max 0.05	Zn	Max 0.25
Fe	Max 0.5	Other, total	Max 0.15		

Table:2 Chemical composition of Al(2024)

C. Reinforcement-

Particles of Cu-Al-Ni Shape memory of mesh size 320 are used as reinforcement.

D. Cu-Al-Ni Shape memory particles:-

Cu-Al-Ni shape memory particles are introduced due to the fact that Cu-Al-Ni SM alloy to the Al(2024) matrix substantially enhances the strength, the modulus, the abrasive wear resistance and thermal stability. Furthermore, Cu-Al-Ni shape memory alloy is easily processed by liquid manufacturing and has good wettability with aluminum alloys. Addition of Cu-Al-Ni SM particle results in good wear properties and compatibility. Addition of Cu-Al-Ni particle results in excellent mechanical properties this produces a very hard and strong material.

E. Reinforcement preheats temperature:-

Reinforcement was preheated at a specified 400 ºC temperature 30 min in order to remove moisture or any other gases present within reinforcement. The preheating also promotes the wettability of reinforcement with matrix [7].

F. Addition of Mg:-

Addition of Magnesium enhances the wettability. However increase the content above 1wt. % increases viscosity of slurry and hence uniform particle distribution will be difficult [6].

G. Stirring time:-

Stirring promotes uniform distribution of the particles in the liquid and to create perfect interface bond between reinforcement and matrix. The stirring time between matrix and reinforcement is considered as important factor in the processing of composite. For uniform distribution of reinforcement in matrix in metal flow pattern should from outward to inward.

H. Blade Angle:-

The blade angle and number of blades are prominent factor which decides the flow pattern of the liquid metal at the time of stirring. The blade with angle 45° & 60° will give the uniform distribution. The number of blade should be 3. Blade should be 20mm above the bottom of the crucible [8]. Blade pattern drastically affect the flow pattern

I. Inert Gas:-

As Al(2024) melts, it start reacting with environment oxygen and will produce an oxide layer at the top. This oxide layer will avoid further oxidation but along that it will difficult to brake. So such layer will be big trouble for reinforcement mixture with metal. So in order to avoid this we had used inert gas like nitrogen.

J. Preheated temperature of mould:-

In casting porosity is the prime defect. In order to avoid these preheating the permanent mould is good solution. It will help in removing the entrapped gases from the slurry in mould It will also enhance the mechanical properties of the cast Al (2024). While pouring molten metal keep the pouring rate constant to avoid bubble formation.

K. Powder feed rate:-

To have a good quality of casting the feed rate of powder particles must be uniform. If it is non-uniform it promotes clustering of particles at some places which in turn enhances the porosity defect and inclusion defect, so the feed rate of particles must be uniform.

V. EXPERIMENTAL SETUP AND PROCEDURE:-

Fig1: Stir casting apparatus

This is the layout of the stir casting apparatus. It consist of conical shaped crucible is used for fabrication of MMCs, as it withstands high temperature which is much more than required temperature. This crucible is placed in muffle which is made up of high ceramic alumina. Around which heating element of wound. The coil which acts as heating element is Kanthol-A1. This type of furnace is known as resistance heating furnace. It can work up to 900°C reach within 45 min. Al (2024), at liquid stage is very reactive with atmospheric oxygen. Oxide formation occurs when it comes in contact with the open air. Thus all the process of stirring is carried out in closed chamber with nitrogen gas as inert gas in order to avoid oxidation. Closed chamber is formed with help of steel sheet. This reduces heat loss and gas transfer as compare open chamber. A K type Temperature thermocouple whose working range is -200°C to 1250°C is used to record the current temperature of the liquid. One end of shaft is connected to 6 KW PMDC motor with flange coupling. While at the other end blades are welded. 4 blades are welded to the shaft at 45°C. A constant feeding rate of reinforcement particles is required to avoid coagulation and segregation of the particles. This can be achieving by using hopper. Al (2024) alloy matrix will be formed in the crucible by heating Al (2024) alloy ingots in furnace. A stirring action is started at slow rate of 30 rpm and increases slowly in between 300 to 600 rpm with speed controller. Reinforcement Cu-Al-Ni Shape memory particles is to be incorporated in the metal matrix at semisolid level near 646°C. Dispersion time is to be taken as 5 minutes. After that slurry is reheated to a temperature above melting point to make sure slurry is fully liquid and then it is poured in mould.

Procedure:-

Stir casting process starts with placing empty crucible in the muffle. At first heater temperature is set to 500°C and then it is gradually increased up to 900°C. High temperature of the muffle helps to melt Al (2024) alloy quickly, reduces oxidation level, enhance the wettability of the reinforcement particles in the matrix metal. Aluminium alloy Al (2024) is used as matrix material. Required quantity of Al (2024) is cut from the raw material which is in the form of ingots. Aluminium alloy

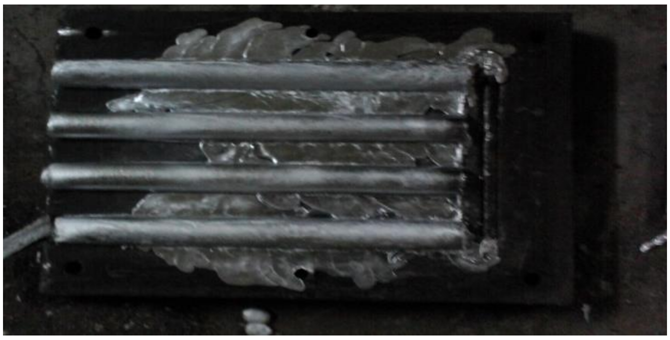

Fig 2: Al(2024)+Cu-Al-Ni Composite

is cleaned to remove dust particles, weighed and then poured in the crucible for melting. During melting nitrogen gas is used as inert gas to create the inert atmosphere around the molten matrix. Powder of Cu-Al-Ni SM particles are used as reinforcement. 1% by weight of pure magnesium powder is used as wetting agent. At a time total 700 gram of molten composite was processed in the crucible. Required quantities of reinforcement powder and magnesium powder are weighed on the weighing machine. Then it is thoroughly mixed with each other with the help of blending machine for 24 hour. This mixture is kept ready 1day before the test has to carry out. Prior to conducting the test this mixture is kept for heating in another heater. Reinforcements are heated for half hour and at temperature of 400°C. When matrix was in the fully molten condition, Stirring is started after 2 minutes. Stirrer rpm is gradually increased from 0 to 300 RPM with the help of speed controller. Temperature of the heater is set to 630°C which is below the melting temperature of the matrix. A uniform semisolid stage of the molten matrix was achieved by stirring it at 630°C. Pouring of preheated reinforcements at the semisolid stage of the matrix enhance the wettability of the reinforcement, reduces the particle settling at the bottom of the crucible. Reinforcements are poured manually with the help of conical hopper. The flow rate of reinforcements measured was 0.5 gram per second. Dispersion time was taken as 5 minutes. After stirring 5 minutes at semisolid stage slurry was reheated and hold at a temperature 900°C to make sure slurry was fully liquid. Stirrer RPM was then gradually lowered to the zero. The stir casting apparatus is manually kept side and then molten composite slurry is poured in the metallic mould. Mould is preheated at temperature 500°C before pouring of the molten slurry in the mould. This makes sure that slurry is in molten condition throughout the pouring. While pouring the slurry in the mould the flow of the slurry is kept uniform to avoid trapping of gas. Then it is quick quenched with the help of air to reduce the settling time of the particles in the matrix.

VI. CONCLUSION

In present study the aim is study the various operating parameter of stir casting process and to prepare MMC with help of stir casting process. For this Al (2024) is selected as matrix phase while Cu-Al-Ni Shape memory particles act as reinforcement. With the help of stir casting process we had successfully manufactured composite at less cost. While manufacturing composite we come to know that process parameters plays a major role for uniform distribution of reinforcement. We had some following conclusion

1) For uniform dispersion of material blade angle should be 45° or 60 ° & no of blade should be 3.

2) For good wettability we need to keep operating temperature at semisolid stage i.e. 630°C for Al (2024). At full liquid condition it is difficult uniform distribution of the reinforcement in the molten metal.

3) Preheating of mold helps in reducing porosity as well as increases mechanical properties.

For further study we are going to check its mechanical properties.

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