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ANALYSIS OF TENSILE STRENGTH OF 2024 AL MATRIX COMPOSITE REINFORCED WITH B_4C NANO-PARTICLES

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ABSTRACT

Now a days the Nano Metal Matrix Composites (NMMCs) are highly effective and playing a vital role in production area as compared to the unreinforced Metal Matrix Composites (MMCs). The reason of this effectiveness is their improved properties like mechanical, wear strength, stiffness, higher thermal properties, reduced weight, higher surface to volume ratio and good damping behavior etc. The fabrication of metal matrix nano composites (MMNCs) using mechanical stir casting process generally results poor distribution of nano particles having high porosity in the matrix. To overcome the above problems, mechanical stir casting was combined with electromagnetic stir casting process and formed Hybrid Casting Process. Al 2024/1 % wt B4C nano composite was fabricated by injecting B_4C particulates into Al alloy with the assistance of argon gas. The wettability of the reinforcement was enhanced by milling nano-SiC particles with micro Mg powder. The examination of composite was carried out through tensile testing. The tensile strength of Al2024/1 % wt B_4C nano composite has been improved significantly as compare to the Al2024 alloy.

Keywords: Hybrid stir casting, ANMMC, Tensile strength.

I. INTRODUCTION

The primary aim of fabricating metal matrix composite (MMC) is to combine the desirable attributes of metals and ceramics. The incorporation of high strength, high modulus ceramic particles to a ductile metal matrix produce a material whose mechanical properties including specific strength, specific stiffness, wear resistance, excellent corrosion resistance and high elastic modulus are intermediate between the metal matrix alloy and the ceramic reinforcement [2, 5]. Particulate reinforced MMCs are cost-effective alternatives and have the advantage of being machinable and workable using conventional processing methods [3]. Thus, they have remarkable scientific, technological and commercial importance because of their improved properties. Hence, they are being used extensively for high performance applications such as in aircraft and automotive industries [5]. Wrought aluminum alloys have long being used as a matrix alloy to produce metal based composites. The main reason of this is the low density of aluminum. For producing aluminum based composites, 2xxx and 7xxx series alloy are among the best aluminum alloys because of heat treatable [6]. There are various fabrication techniques available to produce MMCs. The fabrication processes may vary considerably as changing the matrix and reinforcement materials. Fabrication methods can be divided into two types: solid state, liquid state processes [7].

The liquid state process has some important advantages such as better matrix–particle bonding, easier control of matrix structure, simplicity, low cost of processing, and nearer net shape as compared to other processing techniques. Normally, micron-sized particles are used to improve the ultimate tensile and the yield strengths of the metal. However, the ductility of the MMCs deteriorates significantly with high ceramic particle concentration. Nano-scale ceramic particles are used as reinforcements in the matrix to maintain good ductility, high temperature creep resistance and better fatigue. A variety of methods such as stir casting, ball milling, and nano-sintering are available for fabricating the metal matrix nano composites (MMNC). However, it is extremely difficult for the mechanical stirring method to distribute and disperse nano-scale particles uniformly in metal melts due to their large surface-to-volume ratio and their low wettability in metal melts, which easily induce agglomeration and clustering [8]. In general, the surface of non-metallic particles is not wetted by the metal melt. As per the literature survey, the composites fabricated by liquid metallurgy exhibit excellent bonding between the ceramic reinforcement and metal when reactive elements, such as Mg, Ca, Ti, or Zr are added to improve wettability [2]. A liquid is said to wet a solid if the contact angle at the interface is less than 90º [1].

Although, few studies have been reported on 2024 aluminum alloy reinforced with nano B4C particulates. In this study, the electromagnetic stirring coupled with mechanical stirring, which is called hybrid stir casting technique, was successfully introduced to distribute and disperse nano B4C particles into aluminum 2024 alloy melts. Planetary ball mill was used for uniform mixing the nano B4C particles with highly reactive Mg Powder to improve the wettability. To characterize the segregation and composition distribution in the as-cast material, scanning electron microscopy (SEM) technique and energy dispersive X-ray spectroscopy (EDS) analysis were used. A mechanical property of casted nano composite was successfully analyzed in terms of tensile strength.

II. EXPERIMENTAL PROCEDURE

The chemical composition of aluminium 2024 alloy is shown in Table 1. Nano B_4C particles of 40 nm size are used as a reinforcement material. The wettability of nano B_4C particles is very less with aluminium 2024 alloy melt. Hence, to improve the wettability, Mg metal powder of size 20 µm is added to nano B_4C particles. Planetary ball mill is used for uniform mixing of both powders. The ball mill was rotated at a speed of 80 rpm for 12 hours and thus uniform composite powder was prepared as a reinforcement material. Fig. 1 shows the schematic of designed set-up that was used in this study. In the mechanical stir casting method, a mechanical stirrer is used to distribute the reinforcement in the matrix melt. In this method, after the matrix material is melted, it is stirred vigorously to form a vortex at the surface of the melt, and the reinforcement material is then introduced at the side of the vortex. The stirring is continued for a few minutes before the slurry is cast [2]. In electromagnetic stir casting technique, the vortex on the surface of the melt is formed by stirring the melt with the help of electromagnetic field. Stirring of the melt is carried out for 2 min in the mushy zone under a temperature range from 620°C to 650°C in a graphite crucible and then the reinforcement material is introduced in the vortex. The current was increased gradually from 0 to 25 A in orders to increase the strength of the electromagnetic field [12]. The melt is solidified under the electromagnetic field. The melting process of aluminum 2024 alloy was performed in graphite crucible placed in a resistance furnace. Initially, 900 gram of Al 2024 alloy was placed in the crucible and heated up to 750 º

C for complete melting of the alloy. Consequently, graphite crucible was placed in the designed set-up of hybrid stir casting. Melt was stirred with the help of mechanical stirrer as well as electromagnetic stirrer. Initially, current was gradually increased up to 25 Amp for stirring the melt with the help of electromagnetic stirring. The melt was rotated up to 500 rpm with the help of hybrid stirring. Heat treatment of reinforcement particles was done at 1100 ºC for 20 min in an inert atmosphere. Injection of the reinforcement particles into the melt is carried out using a stainless steel injection tube and inert argon gas. In this part of equipment, the composite reinforcement powder is placed in a heated chamber and injected to the melt by pressure of the inert gas.

Table 1 Chemical composition of Al 2024 alloy

Element	Si	Cu	Fe	Zn	Mg	Ti	V	Mn	Al
Wt. %	0.16	4.67	0.43	0.14	1.71	0.05	0.001	0.80	92.09

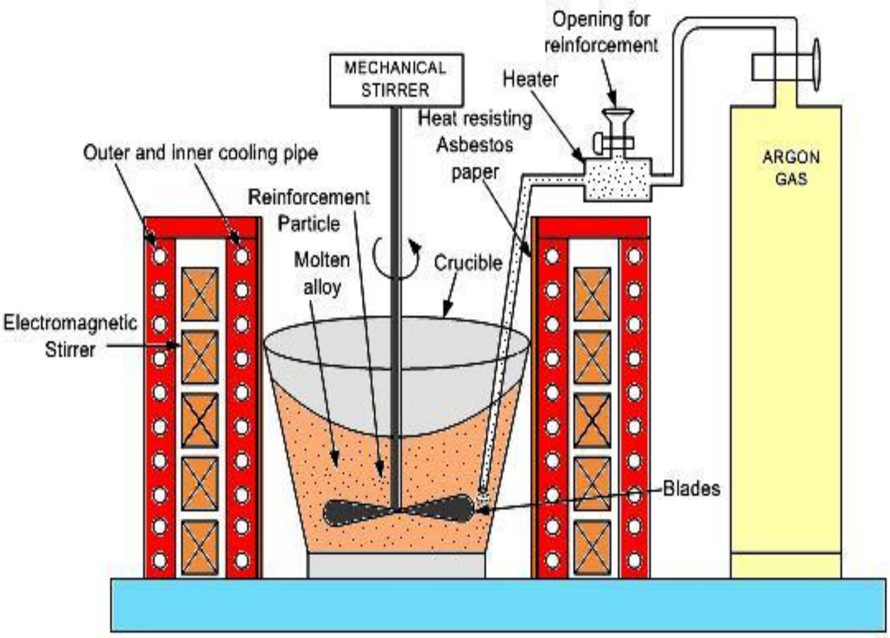

Figure 1 Diagram of Hybrid stir casting

After injection of reinforcements, the mechanical stirrer was driven regularly for 10 min at 400 pm, moved up and down to obtain uniform dispersion of reinforcement in the melt. The melt solidified under the electromagnetic field produced by 5 Amp current because tendency to produce shear stresses in the final product were negligible under such a low magnetic field.

It is believed that strong mechanical bonding made between Al 20204 matrix and B_4C particles by using ball mill, helps to disperse B_4C particles more uniformly in liquid. Ravi Kumar and Dwarakadasa [10] have observed that the properties of composites strongly depend on the processing technique and subsequent thermo-mechanical treatment. The great enhancement in tensile strength is observed in the nano-composite fabricated by hybrid stir casting in comparison to monolithic 2024 Al alloy. It happens due to grain refinement, lack of agglomeration of reinforcement and good uniform distribution of B_4C, which is confirmed by SEM and low degree of porosity which leads to effective transfer of applied tensile load to the uniformly distributed strong B_4C particles.

Tensile test results reveals that the ultimate tensile strength (UTS) of Al 2024 alloy is continuously increased by changing the fabrication method and its maximum value of 161 MPa obtained in hybrid stir casting. Conversely, a least value of ultimate tensile strength (132 MPa) is obtained in 1 wt. % nano- B_4C /2024 Al nano-composite fabricated through EMS method. It may be caused by formation of oxide layer on the top surface of melt due to having great affinity of aluminium melt with the oxygen. When reinforcement is injected in the melt through the steel tube with the assistance of argon gas pressure, clustering of nano- B_4C is formed because sufficient shear force would not be available to break these clustering. The formation of oxide layer on the top surface of melt acts as a barrier for argon gas which is entrapped in the melt and formed the porosity by which flow of melt is greatly reduced and the adequate amount of shear force is not produced to break the agglomeration of the nano-particles. In stir casting, the effect of this layer is reduced by moving the mechanical stirrer up and down in the melt. Aforementioned problems are reduced in the hybrid casting method. Hence, ultimate tensile strength and yield strength (YS) of nano-composite fabricated by hybrid casting are more as compared to the other mentioned methods.

The EDS elemental intensity obtained for 1 wt.% nano B_4C /2024 Al nano-composite fabricated by hybrid stir casting. It shows no extraneous element in the nano-composite, as all these elements are already present in the Al 2024 alloy. The wt. % of Mg element is higher because Mg powder is mixed externally with nano- B_4C particles. In planetary ball milling, the continuous milling of Mg powder and nano B_4C Particles, the temperature of composite powder would increase due to friction. Mg element is more reactive than Al, therefore, Mg element forms a thin oxide layer MgO when it comes into the contact with oxygen, which increases the wetability of composite powder with Al alloy melt. The EDS profile also confirms the presence of oxygen element in the nano-composite which is the main cause of formation of porosity. The ultimate tensile strength and yield strength of 1 wt. % nano B_4C /2024 Al nano-composite fabricated by hybrid stir casting were enhanced by 43% and 86% respectively, compared with the alloy matrix. A nano-composite was also fabricated in [13] with the same matrix and reinforcement materials by stir casting associated with ultrasonic vibration technique. The comparison of results of both nano-composites is shown in Figure 2

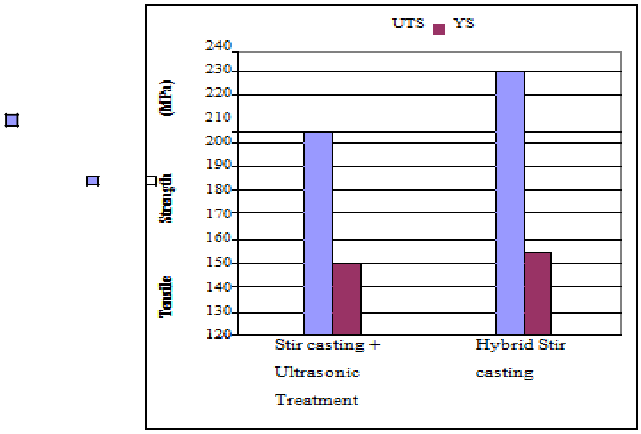

Fig. 2 Comparison of tensile strength of nano-composites fabricated by hybrid stir casting and method used in [13]

III. CONCLUSIONS

1. Based on the present study, the following conclusions can be made:
2. Nano- B_4C /2024 composite was successfully prepared by hybrid stir casting technique. This process may be suitable for the production of other nano-particle reinforced metal matrix composites.
3. Formation of composite reinforcement powder (nano- B_4C + Mg) in ball mill was helpful to alleviate the problems associated with poor wettability and nano-particle distribution in the melt.
4. The injection arrangement of reinforcement in the melt was helpful to reduce agglomeration of nano-particles and porosity in the composite.
5. The ultimate tensile strength and yield strength of Nano- B_4C/2024 composite were approximately enhanced by 47% and 86% respectively as compared with the alloy matrix.

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