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Effect of Stirring Speed and Stirring Time on Distribution of Nano Al_2O_3 Particles in Al7075 Metal Matrix Composite

H. P. Raju[1] and M. S. Prashanth Reddy[2]
[1]Professor and Head, [2]Research Scholar
[1&2]Department of Mechanical Engineering, PES College of Engineering Mandya, Karnataka, India
E-Mail: rajuhp@hotmail.com, preddyms@gmail.com
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***Abstract* - Al7075 was successfully synthesized with the addition of Nano $Al_2O_3$with 1.00Wt% by stir casting method by considering various stirring speeds and stirring times during this study. Scanning Electron Microscopy (SEM) is adapted to examine the microstructure of prepared composites. Tensile strength are tested on composite specimens (as per ASTM E8M-09) using computerized Universal Testing Machine (UTM). Micro Vicker's hardness test was carried out on top of the polished composite specimens. The results showed the microstructure, ultimate tensile strength and hardness of the composite were influenced by the stirring speed and stirring time. From the microstructure it is revealed that, the particle clustering was more at a lower stirring speed with a lower stirring time. Increased mixing speed and mixing time resulted in better particle distribution. The results of the hardness test also demonstrated that, the composite's hardness is affected by the stirring speed and time. At 400 rpm with a stirring time of 10 minutes, the uniform hardness levels are achieved. But the properties degraded again after an interval of certain time. Present study is conducted to determine microstructure, ultimate tensile strength, and hardness of composite and the tendency between processing parameters such as stirring speed and time.**
***Keywords:* Al7075, Al_2O_3, SEM, UTM, Stirring Casting**

I. INTRODUCTION

In recent times, there has been a lot of interest in the development of metal matrix composites (MMC) processes as demands for lightweight materials which have high stability and stiffness [1]. Nanocomposites in the metal matrix are a new class of nanostructured, nano-particulate materials used for strengthening purposes. Micro sized particles are usually used to enhance the ultimate tensile strength. The ductility of MMCs, deteriorates significantly with a high concentration of ceramic particles [2]. Aluminum oxide (Al_2O_3) is a hard refractory ceramic that was tested in structural applications for high temperatures due to its good strength and the low thermal expansion coefficient [3]. Nanoaluminum powders for the use of advanced engineering materials have been the main focus in recent years [4].

The ceramic particles in molten alloys have important advantages like better matrix-particle bonding and cost-effective matrix control, flexibility and applicability for large-scale production and outstanding productivity of newly formed components [5]. The MMC can be processed by various processing techniques, mainly by liquid metallurgy (Stir casting), by powder metallurgy and by other casting techniques. The most commonly used technique is Stir casting compared with to techniques. Compare to other methods, since it is simple, and a economical method. Some issues, such as poor wettability conditions and heterogeneous distribution of the reinforcing material, are associated with stir casting aluminum metal matrix composites. A poor wet ability is caused by molten alloy surface tension, due to tiny nano particle surface, high interface reinforcement energy, and the occurrence of a gas layer on the ceramic particle on the ceramic particle surface [6].

Mechanical stirring can normally be utilized to mix particulates in the molten stage, when the string stops, due to density differences between particles and molten alloy. The particle may be settled in the bottom or floated on the top of molten alloy, so that the dispersion of the ceramic particles is not uniform distribution and cluster form in the molten alloy [7,8]. It is challenging to distribute nanoparticles uniformly in the molten metal. Due to lack of wettability and the higher surface area of nanoparticles which result in agglomeration of the Al_2O_3 particles in molten aluminum, for the uniform distribution of reinforced particle optimizing the stirring speed and time is important.

The present study focused on developing a composite of Al7075/1.00 Wt. % of Al_2O_3 by stir casting technique in considering of different stirring parameters and to show the effect on a microstructure of aluminum metal matrix composite of different stirring time and speed. SEM analysis was carried out to known distribution of particles for different stirring parameters and mechanical properties like ultimate tensile strength and hardness.

II. EXPERIMENTALDETAILS

For fabrication Al7075 alloy as a matrix. The chemical composition of the matrix is represented in Table I. Al7075 is a 7^{th} series aluminium alloy which is rich in Zn and Mg as major constraints. It is the more strengthen alloy compared to all other series of aluminium alloys, which can give similar strength properties compared to steel. Nano- Al_2O_3 with particle size of 80nm with the weight of 1Wt% is used as reinforcement to prepare the Nano aluminium composite. The details of the reinforcement are represented in Table II.

TABLE I CHEMICAL COMPOSITION OF Al7075

Chemical Composition	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Al7075	0.4	0.5	1.6	0.3	2.5	0.15	5.5	0.2	Bal

TABLE II PROPERTIES OF Al_2O_3

Reinforcement	Al_2O_3
Density (solid) g/cm^3	3.95
Crystal structure	FCC
Appearance	White solid
Young's modulus(GPa)	380
Average size(nm)	80
Melting point	2054°C

A batch of Al7075 alloy was melted in a stainless steel crucible and the melt was brought to a temperature of up to its fluidity range of 750° C. Stainless steel impeller at a speed of 300–500 rpm was used to stir this molten metal to make the vortex. The impeller blades were designed to produce a vortex for the mixing of particles. The immersed sprocket depth was at certain molten metal height from the bottom of the crust.

The molten metal was well stirred in the process by creating turbulence movements by a mechanical agitated stirrer. During the testing stirrer speed was maintained at 300, 400 and 500rpm respectively. Al_2O_3 powder with an average of 80 nm is taken and pre-hated in at 400°C for 1 hour, then about 1.00. Wt.% of the reinforcement is fed to the root of the vertex constantly. As mentioned earlier, for a different combination of the processing conditions, the molten metal -Al_2O_3 slurry was stirred continuously at different rpm and time, after adding Al_2O_3 during the process, the stirring time was observed at 5, 10 and 15 min. The molten metal was poured into pre-heated (300°C) steel die and allowed the mixture for solidification.

III. TESTING DETAILS

For microstructure characterization specimen were lapped with 600,800, 1000 and 1200 size grit papers, followed by 1 µm alumina paste, 0.3 µm diamond paste and etched with kellr's reagent and analysis is performed using field emission scanning electron microscope.

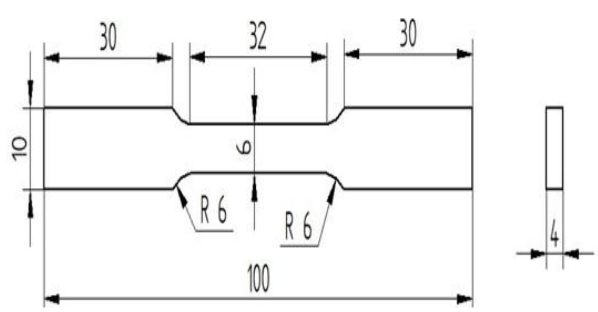

Fig. 1 As per ASTM E8M-09Tensile specimen dimensions

Micro Vicker's hardness values of the sample were measured with 20 µm indenter with a load of 0.5 kgf on polished surface, for 5 different location of the sample and average value are considered. For evaluation of the tensile strength the specimen are prepared according to ASTM E8M-09 standard and tested using computerized UTM. The dimensions are shown in Fig. 1.

IV. RESULTS AND DISCUSSIONS

A. Effect of Stirring Speed and Stirring Time on Microstructure

For many applications, a homogenous particle distribution is desired so that the mechanical properties can be maximized. The process parameters relating to the stir casting method must be examined in order to ensure a good homogeneous distribution of a particle in the matrix. Therefore the effect of stirring speed and stirring time on the particle distribution in MMC is important. SEM micrographs of the composites are presented in Fig. 2 (a-c). Nanoparticles have reduced the grain size of aluminum matrix and it has led to an increase in grain boundary area and subsequently led to an increase in mechanical properties of the composite. At lower stirring speed the distribution resembles the agglomeration of the particulates and as the speed increases the homogeneity levels are improved. At lower speed of 300rpm and at the beginning of 5 minutes duration the agglomeration is clearly noted and further, as the duration increases by holding at the same speed the paleness in the agglomeration is observed. at in higher speeds of 400 rpm and 500rpm there is no sign of agglomeration of the reinforcement particles. This is can be attributed for the generation of clear turbulence by varying stirring speed according to time duration and giving a chance to settle down the reinforcement all over the matrix in a homogeneous way.

Table III shows the results of the sample percentage for porosity. The porosity of the composites is greater as Time and speed of stirring. Enhancement in porosity content is attributed to various sources. It is primarily related to the increase in contact surface area due to adding reinforcement powders in molten aluminum. This is attributed to pore nucleation at the Al2O3 particulate sites. Porosity associated with individual particle and to hindered liquid metal flow due to more particle clustering (porosity associated with the particle clusters) [9]. The clustering is seen in some specific area in the matrix. Better particle distribution has been observed more than the 5 min stirring and increases with string duration of 15 minutes.

TABLE III THE POROSITY CONTENT OF THE 1 WT.% Al_2O_3 / Al 7075 COMPOSITES FOR DIFFERENT STIRRING PARAMETERS

Stirring speed	300	300	300	400	400	400	500	500	500
Stirring Time	5	10	15	5	10	15	5	10	15
Porosity %	2.1	2.18	2.86	2.35	1.96	2.62	2.92	2.98	3.01

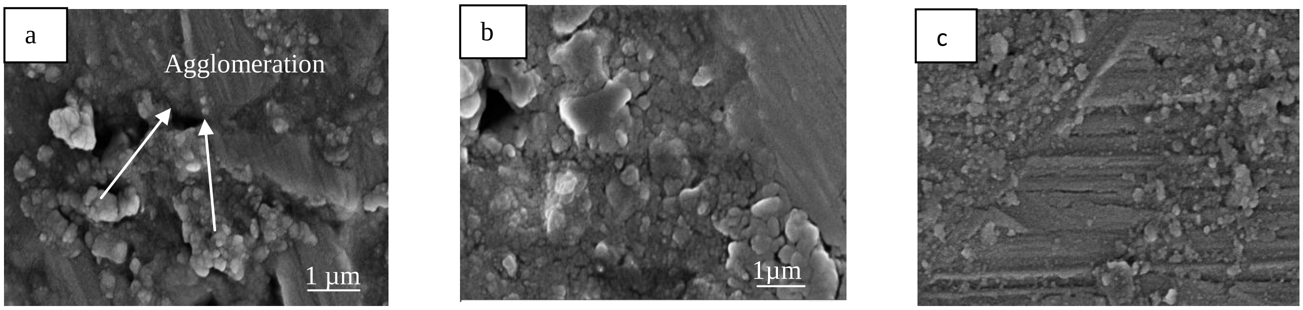

Fig. 2a Effect of stirring speed of 300 rpm at a) with 5 min Stirring b) 10 min Stirring and c) 15 min Stirring

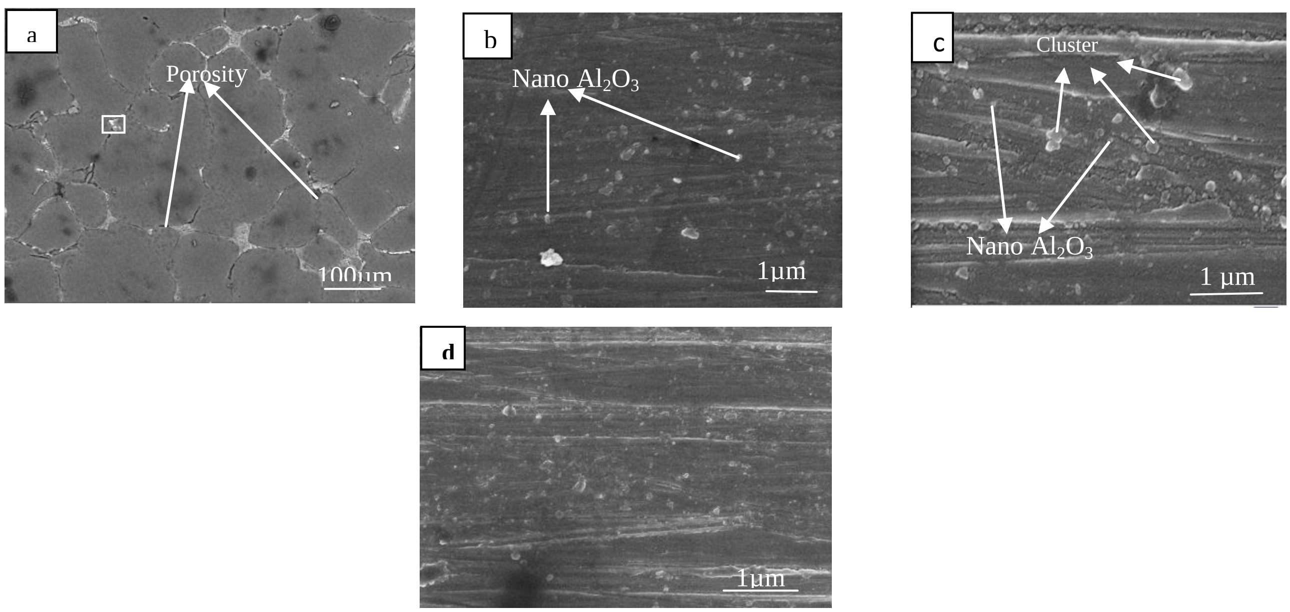

Fig. 2b Effect of stirring speed of 400 rpm at b) with 5 min Stirring, a & c) 10 min Stirring and, d) 15 min Stirring.

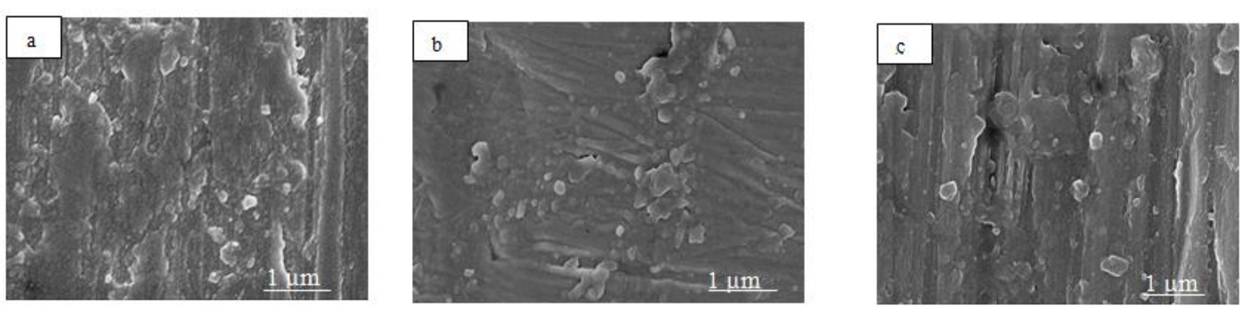

Fig. 2c Effect of stirring speed of 500 rpm at a) with 5 min Stirring b) 10 min Stirring and c) 15 min

B. Effect of Stirring Speed and Stirring Time on Tensile Strength and Hardness

The effect of stirring speed and stirring time which leads to some predominant effects on the physical and mechanical properties are discussed below. Table 4 represents the details of the strength and hardness of the composite samples prepared at different stirring speed and stirring time. At the lower speed of 300 rpm as the time duration increases the tensile strength gradually increased due to the distribution of particulates in partial homogeneous way. As observed in the microstructure the formation agglomeration in the particulates made the composite to show variable hardness but not in total decrement. The presence of hard ceramic particulates in the matrix has shown an increased strength over the base alloy.

As the speed increased to 400 rpm from 300rpm the distribution of the reinforcement is so homogeneous that leads to exhibit a total improvement in both tensile strength and hardness of the composite. This clearly shows the involvement of an optimum stirring speed with the proper time duration will gives a proper space for the mixing or distribution of the particulates in a significant way. The time duration for the solidification also leads to the improvement in the properties. As the speed further increases the tensile strength is reported to an average level as the time duration increase. This is mainly due to the formation of clusters due to the collision of the particulates because of the little higher speed. Overall the properties of the composite both in case of tensile and hardness are shown a significant improvement with the variation in stirring aped and time.

TABLE IV DETAILS OF TENSILE STRENGTH AND HARDNESS AT DIFFERENT STIRRING SPEED AND TIME

Stirring speed	300	300	300	400	400	400	500	500	500
Stirring Time	5	10	15	5	10	15	5	10	15
Ultimate tensile strength (MPa)	162.9	169.6	175.2	186.2	198.3	192.1	180.3	188.6	190.2
Vicars Hardness (HV)	82.5	90.2	85.9	102.1	110.9	106.4	95.2	98.3	105.3

The presence of Al_2O_3 particles in the alloy matrix Al 7075 has a increased on the composite hardness. This is expected because Al 7075 is a ductile material and the hardness of the Al_2O_3 particles contributes to the composite's hardness. Due to the presence of stronger Al_2O_3, during the hardening test, the resistance to plastic matrix deformation increases [10]. However, the limitation on plastic deformation depends on the Al_2O_3 particle distribution in the matrix. The improved distribution of particulates in the matrix depends on speed and time of stirring. The effect of stirring speed and stirring time on hardness is observed in this study. Fig. 3 shows at lower speed, the hardness values are minimal at some points and maximum in other points. The high hardness value is observed where the accumulation of the particles is more and hardness is less where Al_2O_3 inclusions are missing. Higher speed than 400 rpm does not improve hardness at higher stirring times. At 5 minutes of stirrer time, speed of 400 rpm shows a good hardness result and continuous stirring is closer for 10, 15 min at 400 and 500 rpm. The figure 3 shows that 10 minutes of stirring and 400 rpm result in good composite hardness.

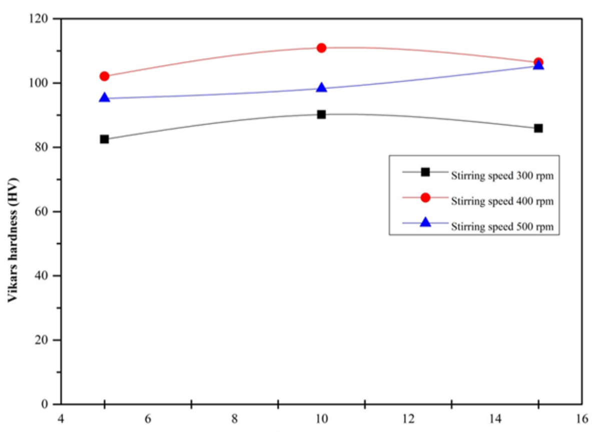

Fig. 3 Effect of stirring time and speed on hardness of 1 wt. % Al_2O_3/Al 7075 Composite

V. CONCLUSION

From SEM micrographs, it was found that particle clusters occurred in some places at lower speed and lower stir time. For the better uniform distribution of Al_2O_3 in the Al 7075 matrix was found by increasing the stirring speed and the stirring time that is 400 rpm and a time of 10 minutes. As the speed increased to 300 rpm to 400 rpm at 10 min time the distribution of the reinforcement is so homogeneous that leads to exhibit a total improvement in both tensile strength and hardness of the composite.

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