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Microstructure and Mechanical Properties of Nano Alumina Particulate Reinforced A356 Nano Composites

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ABSTRACT
A356, which is much lighter than steel, is an attractive replacement material. Therefore, it is of great interest to enhance its properties. There is strong evidence that the microstructure and mechanical properties can be considerably improved if nano particles are used as reinforcement to form metal-matrix- nano-composite (MMNC). In this thesis, a detailed analysis of alumina i.e.., 60µm is reduced to 32nm by high energy ball milling. For every 5hrs alumina powder is taken and calculating the crystallite size by X-Ray Diffraction. In this thesis, a detailed analysis of the microstructure and mechanical properties is provided for an A356 alloy enhanced with alumina nano particles via ultrasonic processing. Each type of the nano particles was inserted into the A356 molten metal and dispersed by ultrasonic cavitation and acoustic streaming technology (UST) to avoid agglomeration or coalescence. The results showed that Microstructures and hardness studies increased significantly. SEM and EDS analyses were also performed to analyze the dispersion of micro and nano particles of Alumina.
Keywords : EDS, High energy ball milling, SEM, Ultrasonication, X-ray Diffraction.

I. Introduction

Aluminum matrix composites have the potential to offer desirable properties, including low density, high specific strength, high specific stiffness, excellent wear resistance and controllable expansion coefficient, which make them attractive for numerous applications in aerospace, automobile, and military industries. Several recent studies revealed that ultrasonic vibration is highly efficient in dispersing nano particles into the melt. Ultrasonic vibration has been extensively used in purifying, degassing, and refinement of metallic melt and for introducing the ultrasonic energy into a liquid that will induce nonlinear effects such as cavitation and acoustic streaming. Among various types of ceramic particles Al_2O_3 widely used as reinforcement particles due to their relatively good thermal and chemical stability as compared to other types of reinforcements[1]. The effects of the ultrasonically dispersed Al_2O_3 nanoparticles on the as-cast microstructure are studied.

II. Materials And Methods

2.1 Alloy Preparation

Cut ingots of A356 were melted in a electric heating furnace in graphite crucible 700℃. In order to prevent excess oxidation of the metal Coverall (0.1%wt of metal) was used. Nano alumina powder is wrapped in a aluminium foil. A356 alloy used as the matrix material and the mixture of nano alumina particles with average particle size of 32nm. For manufacturing of nano composites 1, 2, 3 Wt.% nano alumina were used.

Table 1: Chemical composition of A356 alloy

Si	Cu	Mg	Mn	Fe	Zn	Ni	Ti	Al
7.20	0.02	0.29	0.01	0.18	0.01	0.02	0.11	Bal

2.2 Alumina preparation

As received Alumina sample properties were given in table 1. Alumina has been sieved using BSS meshes ranging in size from 100 to 350 by Rotap Sieve Shaker. Fig 1 shows mesh size and weight fraction distribution of alumina powder by sieving. It clearly shows that maximum weight retained in size of 60µm.

Fig 1: Pure Alumina (Al_2O_3) Powder of 60µm

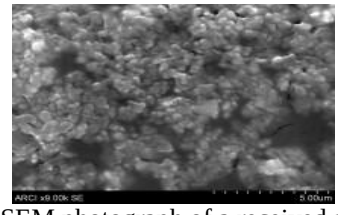


Fig 2: SEM photograph of a received alumina

2.3 High energy ball mill

The reduction on particle size of alumina from micron level to the nano level was carried out using a high-energy planetary ball mill as shown in fig 3. Milling chamber and balls were made of tungsten carbide and the balls were of 10mm diameter. The total duration selected for milling was 30hours. The rotation speed of the planet carrier was 300 rev/min. The ball mill was loaded with BPR (Ball to powder weight ratio) of 10:1 toluene was used as the medium with an anionic surface active agent to avoid agglomeration. The sample was taken out after every 5 hours of milling, dried by using drier and used for characterizing by using X-Ray Diffractometer.

Fig 3: High energy planetary ball mill

Fig 4: Alumina Powder after Ball milling of 30hrs

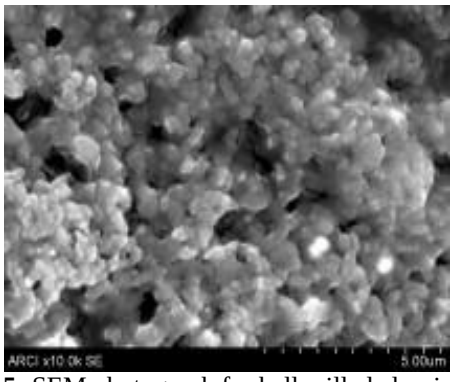


Fig 5: SEM photograph for ball milled alumina of 30hrs

2.4 Synthesis of A356- Alumina Nano composites:

2.4.1 Nano structured Alumina powder addition by Vortex method:

The ingots of A356 alloy were taken in a graphite crucible and melted in an induction furnace.The temperature was slowly raised to 750℃. After attaining the require temperature the molten metal was stirred to create a vortex and the molten metal is stirred at approximately 750 rpm during stirring the preheated aluminum foil containing nano alumina were slowly added into the melt. Aluminum and its alloys are highly prone to hydrogen pickup during the casting process[5]. Hence a layer of Argon gas has been maintained on the bath surface to prevent this. The percentage of nano alumina added by weight Percentage

6(a)

6(b)

Fig 6(a): Mechanical stirrer used for vortex formation in the A356 alloy; **Fig 6(b):** Closer view of stirring

2.4.2 Ultrasonication of the bath of A356 alloy-Nano Structured Alumina powder:

Ultrasonic probe is preheated 20 minutes to reach the temperature in above 500 and below 750℃. After manually stirred melt then the ultrasonic probe is inserted, ultrasonic probe is of 31mm in diameter and 102mm in length specially made for aluminum melt which can withstand high processing temperature with minimum ultrasonic cavitation induced erosion was dipped into the melt and the melt was processed ultrasonically at processing frequency was 20.50 KHz as shown in fig 7. After the nano alumina were fed into the A356 alloy melt, the ultrasonic processing the melt continued for about 15 min before the ultrasonic

probe is removed from the melt. Sonication time is limited by trial and error method by looking at good dispersion of reinforcements in the matrix.

Fig 7: Experimental set up with Electrical Furnace, ultrasonic probe & Transducer

Fig 8: Metallic dies of Cylindrical finger casting

Fig 9: As cast cylindrical fingers of the A356- 0%, 1%, 2%, 3% nano alumina composite

III. Characterization Of Ball Milled Nano Structured Alumina Powder:

3.1 Crystallite Size Calculation:

The average crystallite size was determined from the full width at half maximum (FWHM) of the X-ray diffraction peak using Williamson- Hall equation. The crystallite size is easily calculated as a function peak width (specified as the full width at half maximum peak intensity (FWHM)), peak position and wavelength.

$$\beta_{hkl}\,\mathrm{Cos}\theta = \frac{K*\lambda}{t} + 4\varepsilon\, sin\theta$$

λ = X-Ray wavelength =1.5406

K= Shape factor= 0.9

θ = Bragg angle

t= Effective crystal size

3.2 XRD Studies:

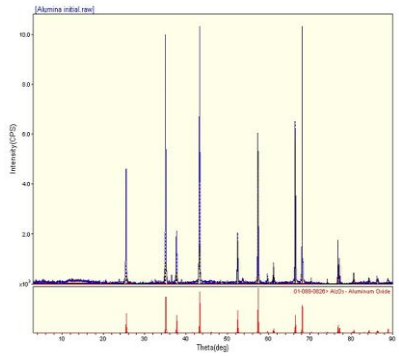


Fig 10: XRD pattern of 0hr ball milled Al_2O_3

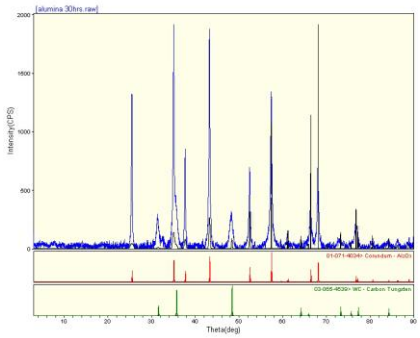


Fig 11: XRD pattern of 30hr ball milled Alumina

IV. Characterization Of A356- Nano Alumina Composites

4.1 Metallographic studies

Specimens for metallographic observations were prepared by standard polishing techniques. The microstructures of the specimen were investigated by means of optical microscopy shown in fig12 (Model: Olympus, C-5060-G x 4- Japan). Keller's reagent with composition of HF=1.0cc, HCl= 1.5cc, HNO_3 = 2.5cc and H_2O= 95cc was used as etching reagent.

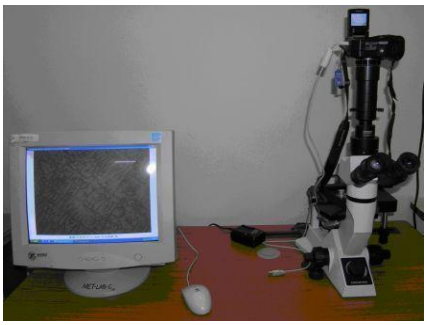
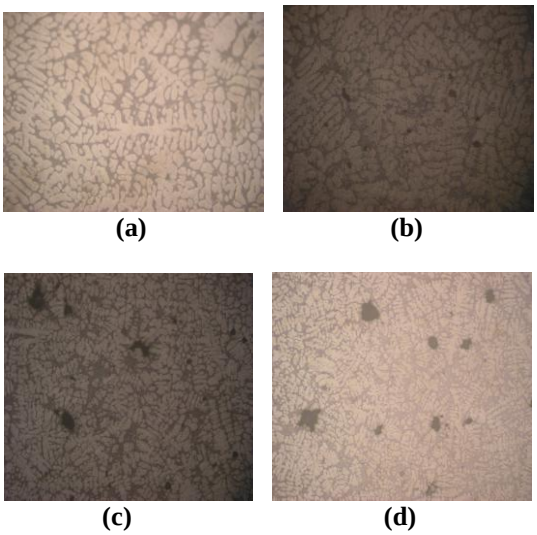


Fig 12: Optical Microscopy (Model: Olympus, C-5060-G x 4- Japan)



(a) **(b)**

(c) **(d)**

Fig 13: (a) Microstructures of as cast A356- 0% nano alumina composite. **(b)** Microstructures of as cast A356- 1% nano alumina composite. **(c)** Microstructures of as cast A356- 2% nano alumina composite. **(d)** Microstructures of as cast A356- 3% nano alumina composite.

4.2 Hardness Studies:

The hardness of the alloy and composites was evaluated using Leco Vickers hardness tester fig 14 (Model: LV 700- USA) with a load of 1kg, 15 sec dwell time. An average to ten readings was taken for each hardness value.

Fig 14: Vickers Hardness testing Machine (Model: LV 700- USA)

Figure shows the hardness values of the A356 –nano alumina composites. As the amount of nano alumina is increasing the hardness value of the composite is increasing. This increase was observed from 56VHN for A356 alloy to 65VHN for A356-3% nano alumina composite.

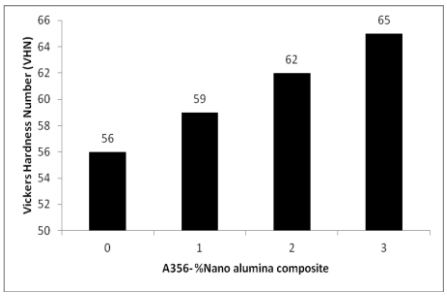


Fig 15: Bar graph for A356-%Nano alumina and Vickers Hardness Number

V. Conclusion

There was a uniform distribution of nano alumina particles in the matrix phase and also existing a good bonding phase between matrix and reinforcement phases.The hardness of the composites is increased with increasing by amount of nano alumina than the base alloy. Enhanced mechanical properties were observed with increasing amount of Nano alumina under compression.

Scope for Further Work:

Further heat treatment studies are to be done to assess the behavior of nano alumina in the fabricated nano composite. Further characterization need to be done by using SEM, TEM etc for well establishing the role of nano alumina in the given matrix. Further characterization like wear and workability studies is to be carried out.

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