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Studies on Mechanical Properties and Microstructure of Al_2O_3 Reinforced AA5083 Matrix Composite

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ABSTRACT : *The expectations over novel composite materials have been increased especially in automotive and aerospace applications due to its superior weight to strength ratio and tailored mechanical properties. In this frame work, aluminum alloy AA5083 alloy matrix reinforced with micron (10% wt – 5% wt) and nano-particles (1% wt – 5% wt) of Al_2O_3. The composite samples were fabricated through powder metallurgy route. Optimum amount of reinforcement were determined by evaluating mechanical properties like micro-hardness and compressive strength of composites. The results reveal that the composites containing 2% wt of nano Al_2O_3 and 8 % micro Al_2O_3 reinforcement witnessed superior mechanical properties due to its combined effect of concentration and particulate scale and the great isotropic behavior was achieved by homogenous dispersion of reinforcement in the matrix phase.*

Keywords *- Powder Metallurgy, Micro Structure, Micro-hardness, Compressive Strength, Aluminum Alloy*

I. INTRODUCTION

Aluminum Alloys are preferred engineering material for automobile, aerospace and mineral processing industries for various high performing components that are being used for varieties of applications owing to their lower weight, excellent thermal conductivity properties[1].Aluminum Alloy AA5083 plays a predominant role and one of the promising material in Aerospace and Automobile applications as it possess the superior mechanical properties such as high strength, stiffness, fracture toughness, wear resistance. Al_2O_3 and SiC particulates and fibers are the most commonly used reinforcements in MMCs and the addition of these reinforcements to Al alloys been the subject of a considerable amount of research work [2].The elongation, ultimate tensile strength and yield strength of micro/nano composites are enhanced with markedly higher than that of Al composites synthesized by of particulate volume fraction [3]. Mechanical milling can provide the combined advantage of significant grain refinement and homogenous distribution of the reinforcement and homogenous distribution of the reinforcement particles. It has already been demonstrated as a feasible method to synthesis fine Al-based powder mixed with Al_2O_3. [4]. Equivalent conventional micro-composites exhibit significantly lower strength compared to nano-structured materials motivating the need to better understand the micro-structural features of the metal matrix nano composite (MMNC) [5,6]. In the present study we focus on the effect of increase in weight fraction of Al_2O_3 on microstructure and mechanical properties of AA5083 based composites.

II. RAW MATERIALS AND SAMPLE MATERIAL PREPARATION

Initially the constituent elements were procured and mixed homogenously to prepare aluminum alloy AA5083 mechanically in the laboratory through milling process for 4 hours with an intermediate cooling to avoid micro aggregation due to increase in heat inside the vials of a two station planetary ball mill [9,10]. Hardened stainless steels balls of dia 16mm and vials were employed to mill the starting material. The chemical composition of the aluminum alloy AA5083 is Cr 0.05%, Cu 4.45%; Fe 0.50%; Si 0.50.6%; Mg 0.80–0.9%; Mn 0.80%; Ti 0.15%; Zn 0.25; Balance Al 92.50% volume fraction. The average density of the matrix sample material is 3.0527. Then the matrix material was blended with the reinforcement material of Al_2O_3 in nano and micron range of different weight ratio as follows: AA5083/0% Al_2O_3, AA5083/10% Al_2O_3(in µm), AA5083/9% Al_2O_3(in µm)/ 1% Al_2O_3(in nm), AA5083/8% Al_2O_3(in µm)/ 2% Al_2O_3(in nm), AA5083/7% Al_2O_3(in µm)/ 3%

Al_2O_3(in nm), AA5083/6% Al_2O_3(in µm)/ 4% Al_2O_3(in nm), AA5083/5% Al_2O_3(in µm)/ 5% Al_2O_3(in nm). The weighed powders were blended for 2 hours in the presence of Toluene which acts as a process control agent to avoid contamination during the milling process at 300 rpm using planetary ball mill. Then the blended powders were milled continuously for keeping 15 min on and 15 min off alternatively in order to avoid excessive temperature rise. The vials were rotated in alternate directions for each cycle. ball–powder ratio was kept at 10:1. Hardened stainless steel balls and vials were used as the grinding medium. Then the milled powder was uniaxially compacted in universal testing machine (Krystal UTK60) at 25Ton to obtain compacted cylindrical samples of Φ30mm×∼10mm height. Zinc-stearate and silicon spray were used on the die wall and punches for lubrication before compaction to reduce the die wall frictional effect. Cold pressed compacts were coated with molybdenum di sulphate (Mo S_2) in order to avoid the excessive grain growth during sintering of samples at 550 ◦C for 3 h using argon gas as inert atmosphere to avoid excessive grain growth. Sintered samples were soaked for 2 hours at a temperature of 550 ◦C and it was cooled in the furnace.

III. RESULT AND DISCUSSION

3.1. Micro-Hardness

The Micro-hardness tests were carried out on the prepared composite samples in micro vickers hardness tester (Wilson Wolpert – Germany). The tests were conducted at constant loading of 0.5 kg load for 30 seconds at 25ºC. In an each sample, four trails were made and the mean value was taken to avoid the higher deviation of results and it is observed that the result deviation was not exceeding 2% of the mean value.

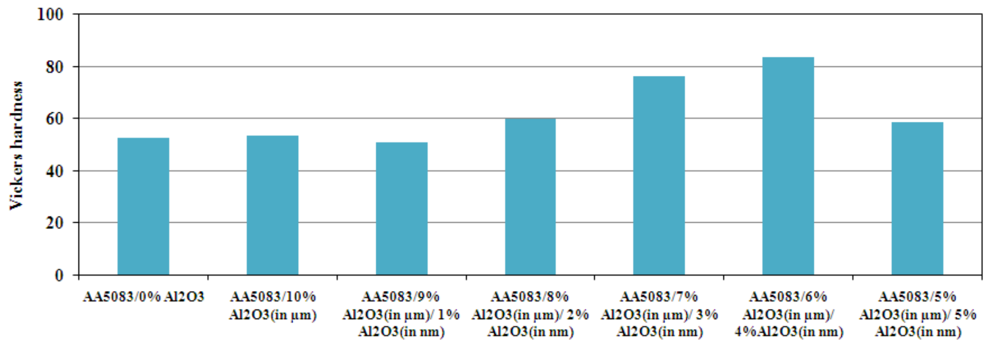


Fig. 1 Hardness of various compositions

It was observed from the Fig.1 the hardness value of specimens seems varies significantly with variation of reinforcements of nano & micro particles for the prepared samples. Among the 7 samples AA5083/6% Al_2O_3 (in µm) 4% Al_2O_3 (in nm) micro hardness and the hardness values witnessed the less deviation in the samples 2,34,5 and 6.

The above observation is due to inhomogeneous blending and non-uniform distribution of reinforcements in matrix phase that results in lack of isotropic behavior among prepared samples. Also, from the microstructure it is found that the poor intermetallic bonding in between the matrix and reinforcing phase during the sintering. Whereas the AA5083/6% Al_2O_3 (in µm) 4% Al_2O_3 (in nm) shows the highest hardness value due to the good compatibility in between the matrix and reinforcement phase. From the microstructure graphs, it is also observed that the 6% Al_2O_3 (in µm) 4% Al_2O_3 (in nm), sample made a remarkable change in the reinforcements. In general lesser porosity (not more than 2.5%) was identified on the prepared samples. The black dots in the microstructure indicate the Al_2O_3 reinforcements in the white colored aluminum matrix phase.

3.2 Compressive strength

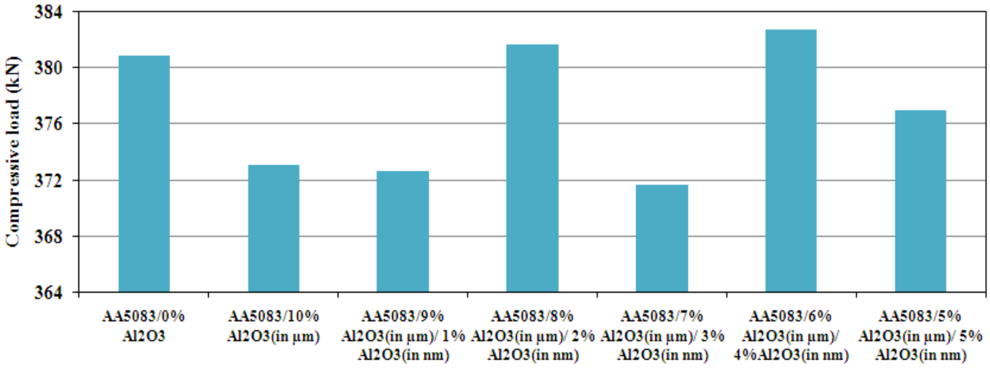
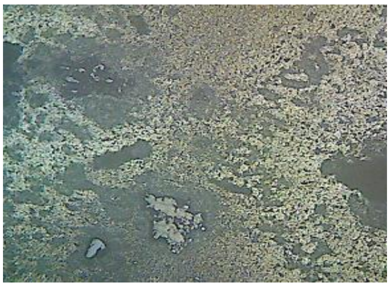


Fig.2 Compressive strength of various compositions

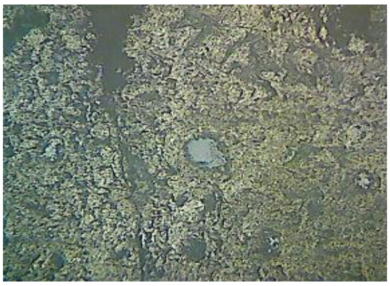
The compressive strength of the composites were tested in the tensile testing machine (FIE Make India). The compressive strength is depicted in the graph (Fig. 2). The effect of Al_2O_3 content at each volume fraction is evaluated. The compressive strength shows high value for the case of AA5083/6% Al_2O_3 (in µm)/ 4% Al_2O_3 (in nm). The compressive strength varies due to variation in weight concentration of reinforcements that possess different size range from microns to nano.

3.3 Microstructure Analysis

The microstructure studies were made on the etched surface samples with HF solution. From the micrographic analysis Al-Si precipitates in the matrix phase. From the Fig.3 Voids and porosity are observed in all the 7 samples that results the inhomogeneous distribution of reinforcement and poor bonding occurred due to the aggregation of reinforcements in some selective regions. The micrograph of sample 4 exhibits the well distribution compared all other 6 samples



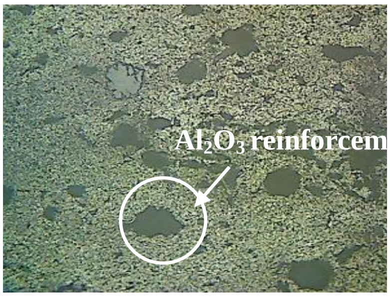
a) AA5083/0% Al_2O_3



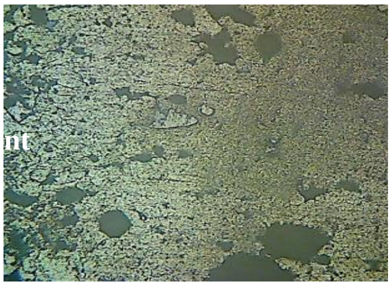
b) AA5083/10% Al_2O_3(in µm)

c) AA5083/9% Al_2O_3(in µm)/ 1% Al_2O_3(in nm)

d) AA5083/8% Al_2O_3(in µm)/ 2% Al_2O_3(in nm)



e) AA5083/7% Al_2O_3(in µm)/ 3% Al_2O_3(in nm)



f) AA5083/6% Al_2O_3(in µm)/ 4% Al_2O_3(in nm),

g) AA5083/5% Al_2O_3(in µm)/ 5% Al_2O_3 (in nm).

Fig.3. Micrographic views of samples

IV. CONCLUSION

The process of preparation of different weight fraction Al_2O_3 particulate reinforced AA 5083 composites were done through the powder metallurgy route. The microstructure and mechanical tests like hardness and compressive strength were evaluated and the following observations were drawn:

1. Al AA5083 MMCs reinforced with different sizes and weight percentages of Al_2O_3 particles (up to 10 wt. %, size micron - nano) was successfully fabricated by powder metallurgy route which starts from blending of samples of interested weight fractions, compacting of composite samples by applying the 25 ton compressive loading in universal testing machine. Then it was sintered in the furnace for 2 hours at the temperature of 450°C in the presence of argon gas environment that prevents the excessive growth of grains and followed by 2 hour soaking and furnace cooling, then the samples surface were sprayed over by molybdenum di sulphate (Mo S_2) to avoid oxidation.
2. The characterization and microstructure was made by optical micrograph. The observations of the microstructures showed that the nano particles distribution in Al matrix is more uniformly, while the coarser particles led to agglomeration and segregation of particles results in porosity.
3. The mechanical properties such as hardness and compressive strength have improved. AA5083/6% Al_2O_3 (in µm) 4% Al_2O_3 (in nm) proves the higher hardness and also exhibits the higher compressive strength due to the combined effect of oxide addition and the higher nano particle concentration.

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