A Study on the Mechanical Properties of Aluminium Reinforced With Nano Sic by Powder Metallurgy

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***Abstract*—Reinforcing aluminium matrix with much smaller particles, submicron or nano-sized range, is one of the key factor in producing high-performance composites, which yields improved mechanical properties. The aluminium based metal matrix composites reinforced with nano SiC using powder metallurgy process is to increase the mechanical properties like low density, high elastic modulus, wear resistance and strength. Production of a homogenous, high strength and net shape structural components made from aluminium-silicon carbide composites can be achieved using powder metallurgy (PM) technology. The composition is mixed with required ratio and is compacted in the die for obtaining the green compact. Generally the results show the tendency for both the strength and ductility to increase upon increasing the sintering temperature and almost there are very small changes above specific sintering temperature which mainly depends upon the silicon carbide content. And the final stage process consists of sintering the billet at suitable aluminium temperature range. The billets are tested for SEM, compression test, ring compression test and micro-hardness test for investigating the different micro structural and mechanical properties of a metal matrix composite.**

Keywords*— *Metal Matrix Composite, powder metallurgy, SEM, micro hardness test.

I.INTRODUCTION

The aluminium which known for its low density, high elastic modulus and wear resistance are used as main MMC. The nano SiC is used as reinforcement for aluminium and the proper bonding of nano SiC with the surrounding particles of aluminium particles depends upon the compaction and sintering process of the billet. Using powder metallurgy (PM) method to produce aluminium composites reinforced with SiC particulates produce a homogenous distribution of reinforcement in the matrix [1].

Figure:1 Pure Aluminium Powder

Aluminium 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 [2]. In the Fig.1 shows the pure aluminium which has the mesh size of 300 which was for this project. Powder metallurgy is a process in which parts are produced from metallic powders and is used to manufacture the parts to near net shape. In the usual powder metallurgy production sequence, the powders are blended into the certain ratio and are compacted (pressed) into desired shape and then heated (sintered) to bond the particles into a hard and rigid product. It is an important method to produce the parts to net shape, eliminating or reducing the need for subsequent machining and the waste is very about negligible of 3%. In the powder metallurgy process there are three steps which required forming the billet namely: the mixing (blending), compacting, and sintering. Industrial applications of powder metallurgy parts are several which include: self lubricating bearings, porous metal filters and a wide range of engineered shapes such as gears, cams, brackets, sprockets, etc. The reinforcement that are present abundantly and are highly used to strengthen the application parts nowadays are aluminium oxide, silicon carbide and tungsten carbide. Silicon carbide is comparatively high than aluminium oxides in physical properties such as stiffness, improved wear resistance and low when compared to tungsten carbide.

Figure:2 Nano Silicon Carbide

The Fig.2 shows nano silicon carbide which has the nano size of less than 100µm. When nano SiC is used as reinforcement with aluminium it further increase the mechanical application of aluminium and used in automobile and aerospace industries. Scanning Electron Microscope, X-Ray diffraction, Energy dispersive X-ray analysis, micro-hardness test, ring compression test and wear test are conducted to identify the characteristics and the study of aluminium and nano silicon carbide composites. The testing involves both micro-structural study and normal mechanical testing.

II.EXPERIMENTAL DETAILS

A) Introduction:

Powder metallurgy is a process in which parts are produced from metallic powders and is used to manufacture the parts to net shape. In principle, continuously reinforced materials offer better specific strength, and the effort involved in their development has been higher than for other composites[5]. The powder metallurgy process generally consists of four basic steps: powder manufacture, powder blending, compacting, and sintering. Compacting is generally performed at room temperature, and the elevated-temperature process of sintering is usually conducted at atmospheric pressure. In the Fig.3 shows the various stages involved in powder metallurgy to manufacturing the complete product.

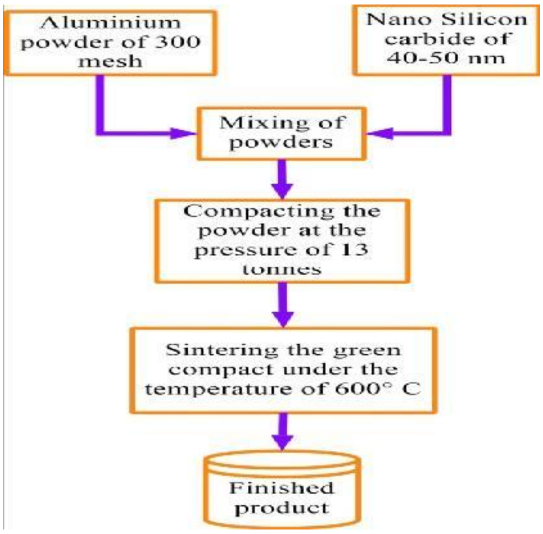

Figure:3 Flowchart of powder metallurgy process

B) Fabrication of Die:

The die is made up of D2 steel (It is an air hardening, high-carbon, high-chromium tool steel and it has high wear and abrasion resistant properties). The punch is made up of EN24 steel (It is supplied in the condition with a tensile strength of 850/1000 N/mm^2). The Fig.4 shows the parts of the die which was fabricated for the present project work. The most basic consideration is being able to remove the billet from the die after it is pressed, along with avoiding sharp corners in the design. Die consists of two punches namely the upper punch and lower punch which are positioned at Universal Testing Machine [UTM] for compaction of powder material to the required shape.

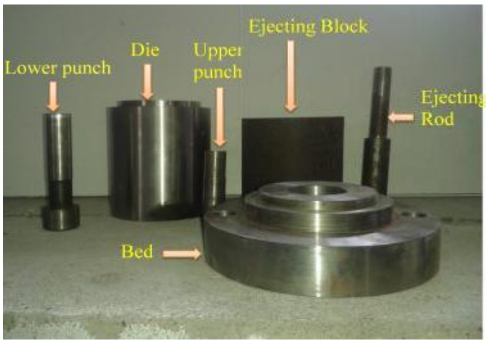

Figure 4: Photograph of fabrication die and its components

C) Compaction:

Powder compaction is the process of compacting metal powder in a die through the application of high pressure. Generally the tools are held in the vertical orientation with the punch tools forming the bottom of the cavity. Al-based metal matrix composites with high strength combined with considerable plastic deformation were maintain the temperature of 600° C and then it is synthesized using P/M methods[6]. The metal matrix composites of aluminium are reinforced with 0%, 2%, 4%, 6%, 8% and 10% of SiC particles. The powders is then compacted into a shape and ejected from the die cavity. The density of the compacted powder is directly proportional to the pressure applied. The work piece after the pressing is called a green compact. The powders are compacted according to the composition shown in Table:1

TABLE:1 COMPOSITIONS OF THE POWDERS

Sl.No	Compositions of Al	Composition of SiC
1	90%	10%
2	92%	8%
3	94%	6%
4	96%	4%
5	98%	2%
6	100%	0%

But the punch adopted here is single punch since the size of the billet which was manufactured for testing is flat billet withstands the extreme pressure without deforming or bending. Tools must be made from materials that are polished and wear-resistant. Filling a die cavity with a known volume of the powder feed-stock, delivered from a fill shoe compaction of the powder within the die with punches to form the compact. The powder is compacted at the pressure of 13 tonnes in the die and zinc state is used as the lubricant for the ejection of punch.

D) Sintering:

Sintering is the process of compacting and forming a solid mass of material by heat and without melting it to the point of liquefaction. Heat treatment process is done to bond the metallic particles, thereby increasing strength and hardness. Moreover, the melting point of aluminium is high enough to satisfy many application requirements, yet sufficiently low to render composite processing reasonably convenient[4]. Usually it is carried out between 70% and 90% of metal’s melting point. However, the hardness of the sintered part

increases remarkably the density of the sintered part becomes smaller than that of the green compact [7]. Once compacted into the mould the material is placed under a muffle furnace which is shown in for a period of time (six hours) and

left for cooling naturally. Under heat, bonding takes place between the porous aggregate particles and once cooled the powder has bonded to form a solid component. And the green compact is kept inside the muffle furnace with the help of silica crucible.

E) Preparation of the samp ϵ:

Polishing is defined as the process of making the fine surface of the specimen performed after manufacturing of that using specimen polishing methods. It is the most important step in preparing a specimen for micro-structural analysis. Aluminium powders are also used as a material to achieve the weight reduction of the compacts[8]. It is the step which is required to completely eliminate previous damage. After the completion of sintering process the billets are polished by two methods

- Rough polishing.
- Fine polishing.

Rough polishing is the method in which the billets are rubbed in the various scales in emery sheets by rubbing the billets into horizontal and vertical direction. After completion of rough polishing the billets are rubbed in a specimen polishing machine for getting fine polishing for micro-structural analysis. The billets are dipped in the distilled water for viewing the clear surface and then the alumina paste is applied to the billet and the surface of polishing machine. And the Fig. 5 shows the billets of different compositions having fine surface for the micro-structural analysis.

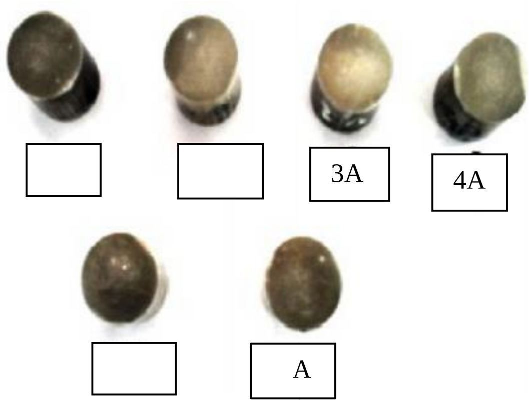

Figure:5 Billets of different compositions

III.TESTING DETAILS

A)Scanning Electron Microscope (SEM) analysis:

Scanning electron microscopy (SEM) uses a focused electron probe to extract structural and chemical information point-by-point from a region of interest in the sample. The high spatial resolution of an SEM makes it a powerful tool to characterise a wide range of specimens at the nanometre to micrometre length scales. And the name of the samples for the required composition are shown in table.4

TABLE:4. SAMPLE NAME FOR REQUIRED COMPOSITION

Sl no	Sample name	Composition of aluminium	Composition of nano sic
1.	1A	90%	10%
2.	2A	92%	8%
3.	3A	94%	6%
4.	4A	96%	4%
5.	5A	98%	2%
6.	6A	100%	0%

B) Micro-hardness test:

The term Micro Hardness Testing usually refers to static indentations made by loads of 1kgf. or less. The Baby Brinell Hardness Test uses a
1mm carbide ball, while the Vickers Hardness Test employs a diamond with an apical angle of 136°, and the Knoop Hardness Test uses a narrow rhombus shaped diamond indenter. The test surface usually must be highly polished. The smaller the force applied the higher the metallographic finish
required. Microscopes with a magnification of
around 500x are required to accurately measure the indentations produced. From six to four indentations were made for each sample**.** According to the reputability of the reading and an average of these reading was calculated. The position of indentation in the sample was chosen randomly in the sample to take in consideration the effect of present of two distinct materials the matrix and the reinforcement.

D) Ring compression test:

The method of free ring compression is the most widely applied method for determining contact conditions in bulk forming processes; therefore it is treated as the standard, universal method for determining coefficient / factor of friction. In each compression step, deformation was made to half the total fracture height. The final compression test was the one, which resulted in immediate crack observation[3]. And the hole is made on the surface of the billet by the help of the
10 mm drill bit in the drilling machine. The billet is compressed with the help of the Universal Testing Machine [UTM] for the time period of 1minute.

III.CONCLUSION

This paper has highlighted mechanical parameters like hardness, strength, porosity and wear resistance of aluminium increased by reinforcement with nano SiC by powder metallurgy method. The grain factor and density factor is obtained from its microstructure study. Sintering temperature of 600° C was enough to produce a successful sintering for the aluminium with no silicon carbide content. Hence the proper bonding of nano SiC to aluminium must occur at high optimum level and in order to achieve the material that are used for industrial application or uses. The microstructure examination showed that composite has a homogenous distribution and the interaction between the constituents.

REFERENCES

[1] W. M. Khairaldien, A.A. Khalil and M. R. Bayoumi, production of aluminium-silicon carbide composites using powder metallurgy at sintering temperatures above the aluminium melting point
[2]I.Mobasherpour, A.A.Tofigh, M. Ebrahimi, Effect of nano- size Al_2O_3 reinforcement on the mechanical behaviour of synthesis 7075 aluminium alloy composites by mechanical alloying, Materials Chemistry and Physics 138 (2013) 535-541.
[3] Mohamed A. Taha, Nahed A. El-Mahallawy, Ahmed M. El-Sabbagh, Some experimental data on workability of aluminium particulate-reinforced metal matrix composites, Journal of Materials Processing Technology 2 0 2 (2 0 0 8) 380–385.
[4] C. Srinivasa Rao and G. S. Upadhyaya, 2014 and 6061 aluminium alloy-based powder metallurgy composites containing silicon carbide particles/fibres.
[5] J.M. Torralbaa,, C.E. da Costab, F. Velascoa, P/M aluminium matrix composites: an overview, Journal of Materials Processing Technology 133 (2003) 203–206.
[6] S. Scudino, G. Liu, K.G. Prashanth, B. Bartusch, K.B. Surreddi, B.S. Murty, J. Eckert, Mechanical properties of Al- based metal matrix composites reinforced with Zr-based glassy particles produced by powder metallurgy, Acta Material 57 (2009) 2029–2039.
[7] Akira Fujiki, Present state and future prospects of powder metallurgy parts for automotive applications, Materials Chemistry and Physics 67 (2001) 298–306.
[8] K. Yamaguchi, N. Takakura and S. Imatani, Compaction and Sintering Characteristics of Composite Metal Powders, Journal ofMaterials Processing Technology 63 (1997) 364-369