Analysis of Mechanical Properties and Microstructure of Al-SiCp Metal Matrix Composite

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Abstract
According on development of technology, composite materials are given first preference due to its high strength and less weight ratio. The main application of metal matrix composites is used in aeronautical and automobile applications. Aluminium is light weight materias, but it has lower mechanical strength. To improve the mechanical properties of Aluminium (Al), silicon carbide particle (SiCp) is added as reinforcement to Aluminium powder for preparing metal matrix composite. The metal matrix composite is produced by powder metallurgy method. This method is cheap and very effective. The composites was fabricated by variation of SiCp reinforcement from 0 % , 5 %, 10 % and 15 % wt. Four samples of the composite materials have been prepared according to testing for bulk density, compressive strength, vickers hardness and crystal structure. From the results obtained, the composition of SiCp reinforcement can influence siqnificantly on bulk density, compressive strength and vickers hardness. If the composition of SiCp reinforcement increase, the bulk density, compressive strength and vickers hardness tend to increase. The highest density, highest hardness and compressive strength are achieved at sample with 15 % SiCp at sintering temperature 650^{o}C. According the XRD results show that it is found two phases such as Al phase and SiC at samples with 5 to 15 % wt. of SiCp.

Keywords: Aluminium, composite, compressive strength

1.0 Introduction

Material like Aluminium and it alloys become important and strategis materials in the world, due to the excellent properties, such as low density, good plasticity or high ductility and good corrosion resistance [Manoj Singla et al, 2009]. They find extensive applications in house hold, industrials (aeronautics, astronautics, and automobile) and high speed train fields. However, disadvantages of Aluminium such as low hardness and poor impact resistance results in their limited application in heavy duty environments [Manoj Singla et al, 2009, Gyanendra singh et al, 2016].The weaknesses of aluminum material can be corrected in several ways such as by alloying or making composite materials. Composites are combined of two or more different materials by mechanically or metallurgically binding them together to obtain better properties than individual material properties.

There are several types of composites, where composites that can be applied to high temperatures are composites that use metal-based matrix and reinforcing ceramic materials. Ceramic material is classified as a very stable material with a melting point that is generally quite high (above 1000^{o}C), some types of ceramics that are often used for composite metal ceramics (CMC) are: silica (SiO_2), alumina (Al_2O_3) and silicon carbide (SiC) [Dinesh Kumar Koli et al, 2013]. The parameters of fabrication of composite such as the kinds and composition of reinforcement material, the shape of the reinforcement, the location of the reinforcement, and the fabrication method can influence required properties [Rajesh Agnihotri and Santosh Dagar**,** 2017]. Several authors have tried to conduct research in terms of Al composites with ceramic reinforcement. Where N. Parvina et.al was prepared Al-10% wt. of Al_2O_3 composite by Powder metallurgy technique, the results show that the strength, hardness and wear resistance of composite increased with finer particle size of Al_2O_3 [N.Parvina and M. Rahimian, 2012]. S.Vijayakuma reports that the composite with Al matrix was fabricated by varying the SiC reinforcement from 3% to 18% by Stir Casting method, the test results show that as the percentage of weight in reinforcement increases the tensile strength and hardness also increases [S.Vijayakumar et al, 2016]. Based on the results of several author's studies show that the manufacturing methods of composite, particle size and composition have an influence on the physical, mechanical and thermal properties of the resulting composite. Based on the application of composite materials as components that can later be applied at high temperatures, the research was conducted to make composite Al-SiC systems through the powder metallurgy method, where Al as matrix and SiC as reinforcement. Silicon carbide (SiC) is composed of tetrahedral of carbon and silicon atoms with strong bonds in the crystal lattice. This produces a very hard and strong material, SiC ceramics with little or no grain boundary impurities maintain their strength to very high temperatures, approaching 1600 ^{o}C with no strength loss [Feng Wang et al, 2016]. The purpose of this research is to preparation of metal matrix composite system Al-SiC and to know the influence of SiC composition to bulk density, hardness, compressive strength and crystal structure.

2.0 Material and methods

The metal matrix composite Al-SiCp was produced by powder metallurgy method. The Al-powder from E-Merck (p.a) and SiCp powder were used as raw materials. The composition of SiCp was varried from 0 %, 5 %, 10 % and 15 % wt. The raw materials were weighed and they mixed by using High Energy Milling (HEM) for 30 minutes. Then the mixed powder was compacted to form pellet at pressure 40 MPa, then the pellet samples were sintered at 650^{o}C for 1 hour holding time by using vacuum furnace. The sintered samples were measured bulk density by using archimedes method, hardness by using microhardness tester, compressive strength by using Universal Testing machine (UTM) and crystal strcture by using X-Ray Diffractometer Rigaku.

2.1 Testing

The measurement of bulk density of sintered sample was done by Archimedes method, and the value of bulk density was calculated using following equation [Suprapedi et al, 2017]:

$$\rho = \frac{ms}{(ms - mg)} \times \rho_{H2O}$$

Where ρ is bulk density (g/cm³), ms is weight of sample suspended in the air (g), mg is weight of sample suspended in the water (g) and ρ_{H2O} is density of water (g/cm³). The measurement of vickers Hardnes was done by using Microhardness tester. The applied load for hardness testing was 200 g load and pressure time of 15 seconds. The compressive strength (CS) of sintered samples were conducted by using ASTM C-39, and the value of compressive strength was calculated using following equation:

$$CS = \frac{F}{A} \quad kgf/cm^2$$

Where F is breaking force (kgf) and A is surface area of sample (cm^2)

3.0 Results and discussion

The results of measurement of bulk density of sintered samples are shown on Figure 1.

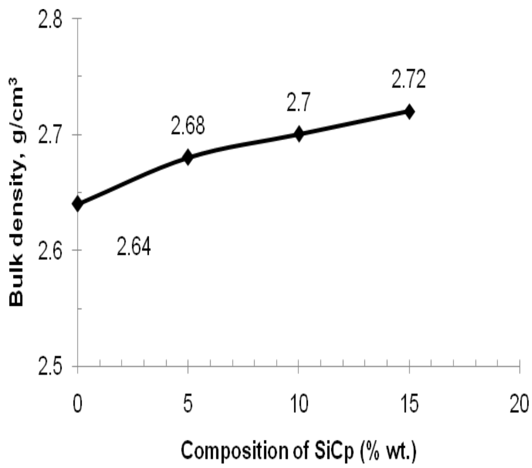

Figure 1. The bulk density curve as function of composition of SiCp

The bulk density value of sample tends to increase with increasing of composition SiCp. This is because of that density of Al (2.70 g/cm³) is lower than density of SiC (3.1 g/cm³). The highest value density is achieved about 2.72 g/cm³ at sample with 15 % SiCp. When compared to the theoretical density of Al-SiCp composites, average densification is achieved about 97.78 %. Figure 2 shows relationship between vickers hardness value and percentages of SiCp composition of sintered samples. It can be seen that vickers hardness value increases with increasing of composition SiCp. It is due to different value hardness of Al and SiCp, where sample with 15 % SiCp has highest hardness value. Hardness value from this study (86 – 185 Hv) is obtained a higher value when compared to other studies made through stir casting method which is about 35-45 Hv [Rajesh Agnihotri and

Santosh Dagar**,** 2017]. If the composite hardness value compared with other studies using powder metallurgy method, where the results obtained from this study (86 – 185 Hv) are lower than other author's studies, which are around 245 - 300 Hv [Venkatesh R et al, 2016].

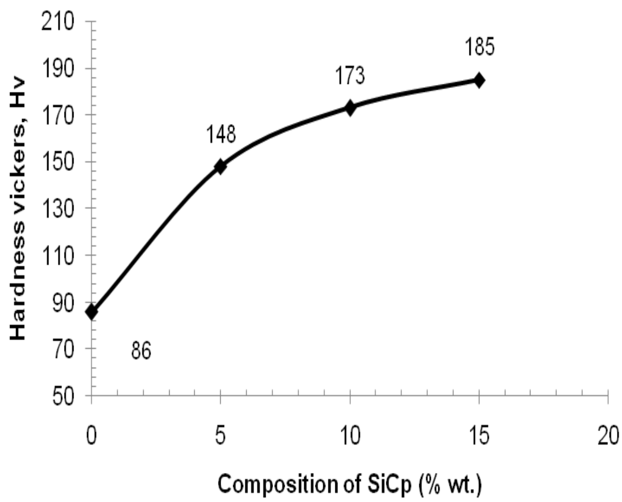

Figure 2 The curve of relationship between vickers hardness with different of SiCp composition.

The results of measurement of compressive strength of sintered samples are shown on Figure 3.

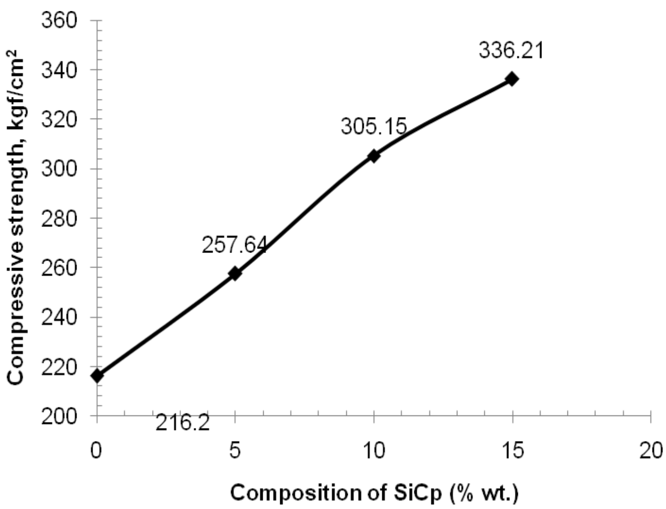

Figure 3. The compressive strength curve as function of composition of SiCp

The compressive strength value tends to increase with increasing of SiCp composition, the highest value of compressive strength is achieved about 336.21 kgf/cm^2 (0.033 kN/mm^2). Based on the results of this study, that the compressive strength value of Al-15% SiC (0.033 kN/mm^2) is higher when compared with the results of other author studies using the same method (0.018 kN/mm^2) [Venkatesh R et al, 2016]. The sintering process of making composites at a temperature of 650^{o}C which can produce a strong bonding between the filler (SiCp) with matrix (Al), this can be seen from the results of the measurement of density and compressive strength, where the densification level can be reached 97.78% and produced a compressive strength value that can reach 336.21 kgf/cm^2 (0.033kN/mm^2) for Al-15% SiCp composites. The analysis of crystal structure of sintered sample by using XRD is shown in Figure 4.

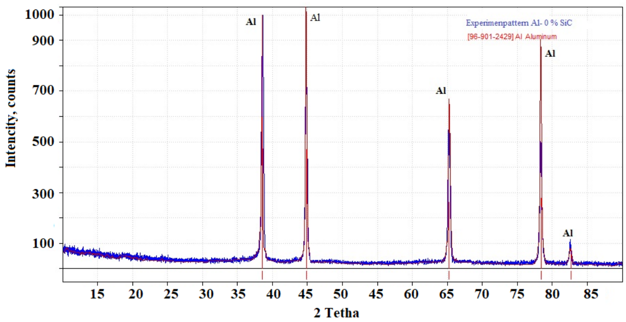

Figure 4.a. XRD pattern of composite Al-0% SiC

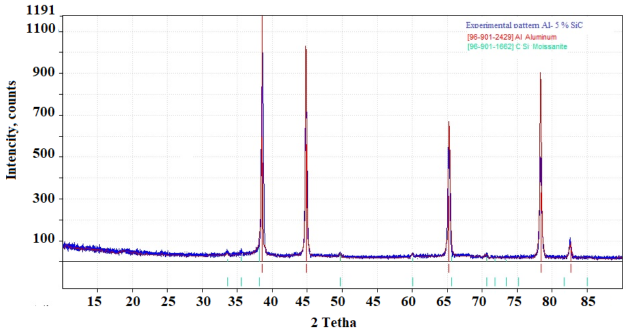

Figure 4.b. XRD pattern of composite Al- 5% SiC

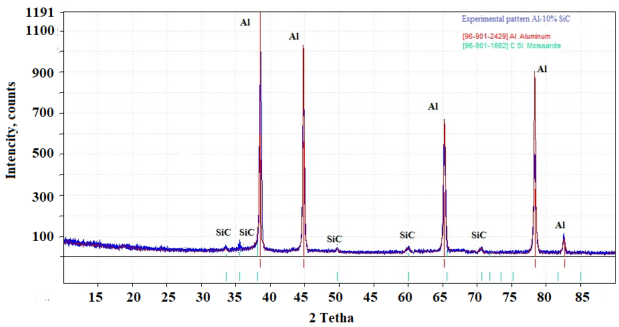

Figure 4.c. XRD pattern of composite Al- 10% SiC

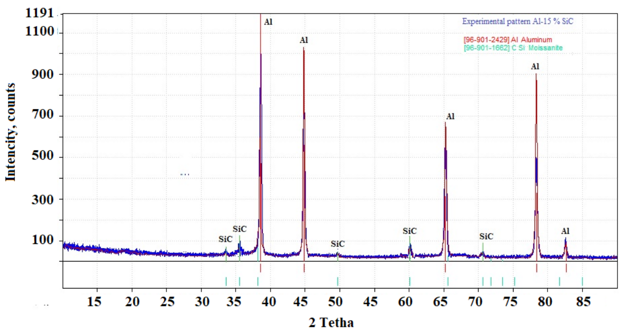

Figure 4.d. XRD pattern of composite Al- 15% SiC

Based on the matching of the diffractogram peaks with JCPDS card 96-901-2429 for Al and JCPDS card 96-901-1682 for SiC. The XRD curve as shown in Figure 4.a for sample composite Al- 0% SiCp has single phases namely Al-phase. The XRD peaks seen in composite samples with 5% to 15% SiCp (Figure 4.b, c and d) consist of two phases, namely the Al phase and the SiC phase. The XRD analysis shows that no other unwanted materials were present instead of Al and SiC.

4.0 Conclussion

The Composite Al-SiCp has been successfully fabricated by powder metallurgy method with filler composition 0%, 5% , 10% and 15% SiCp at sintering temperature 650^{o}C achieved a densification about 97.78%. According to the XRD results that composite Al-SiCp has only two phases namely Al phase and SiCp phase also not seen other follow-up phases. The addition of particle SiC (SiCp) on matrix Al metal improves value of hardness and compressive strength, where highest hardness and compressive strength value achieved about 185 hv and 336.21 kgf/cm^2 respectively.

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