Characterization of Fe-Cr-Al_2O_3 Composites Fabricated by Powder Metallurgy Method with Varying Weight Percentage of Alumina

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Abstract: *This study focused on fabricating and characterizing composites of iron-chromium alloy reinforced with 5–25 wt. % of alumina particles fabricated using powder metallurgy method. The diffraction patterns of X-Ray diffraction (XRD) reveal the influence of varying weight percentage of alumina. Comparisons on the mechanical properties are also being made on the unreinforced iron matrix (0 wt. %). The compatibility between matrix and reinforcement was indicated from the microstructure examination showing homogeneous distribution of alumina particles in the alloy matrix. Bulk density and porosity of the composites were calculated using standard Archimedean testing. Micro-hardness was measured using micro-Vickers hardness instrument. The data obtained showed that the 20 wt. % alumina produced the highest hardness reading.*

Keywords: iron, chromium, alumina, composites, powder metallurgy

Abstrak: *Kajian ini tertumpu kepada fabrikasi dan pencirian komposit aloi besi-kromium ditetulangi dengan 5–25 peratus berat serbuk alumina. Komposit difabrikasi menggunakan kaedah metalurgi serbuk. Corak pembelauan XRD menunjukkan pengaruh peratus berat alumina yang berbeza. Perbandingan terhadap ciri-ciri mekanikal juga dilakukan bagi matriks besi tanpa tetulang (0 peratus berat). Kesesuaian antara matriks dan tetulang telah diperhatikan dari kajian mikrostruktur yang menunjukkan taburan serbuk alumina adalah homogen di dalam matriks aloi. Ketumpatan pukal dan keliangan komposit dihitung menggunakan ujian Archimedes. Mikro-kekerasan ditentukan menggunakan peralatan kekerasan mikro-Vickers. Data yang diperolehi menunjukkan 20 peratus berat serbuk alumina menghasilkan bacaan kekerasan tertinggi.*

Kata kunci: besi, kromium, alumina, komposit, metalurgi serbuk

1. INTRODUCTION

Metal matrix composites of iron reinforced with hard ceramic particles are of interest due to several advantages in terms of mechanical properties and easy fabrication. These materials are used in the aerospace, aircraft, automotive and many other manufacturing and industrial fields.[1–3] The technique that has consistently produced higher property composites has been powder metallurgy, which is competitive because of its low cost, ability to produce composites with high volume fraction, high productivity and possibility to fabricate components with complex geometry. Iron matrix composites reinforced with alumina particles are interesting candidates as wear resistance materials such as brake disc.[4–7] This study aims to fabricate iron matrix composites reinforced with alumina particles and to characterize the properties of the composites. The parameters studied were based on varying weight percentage of alumina particles.

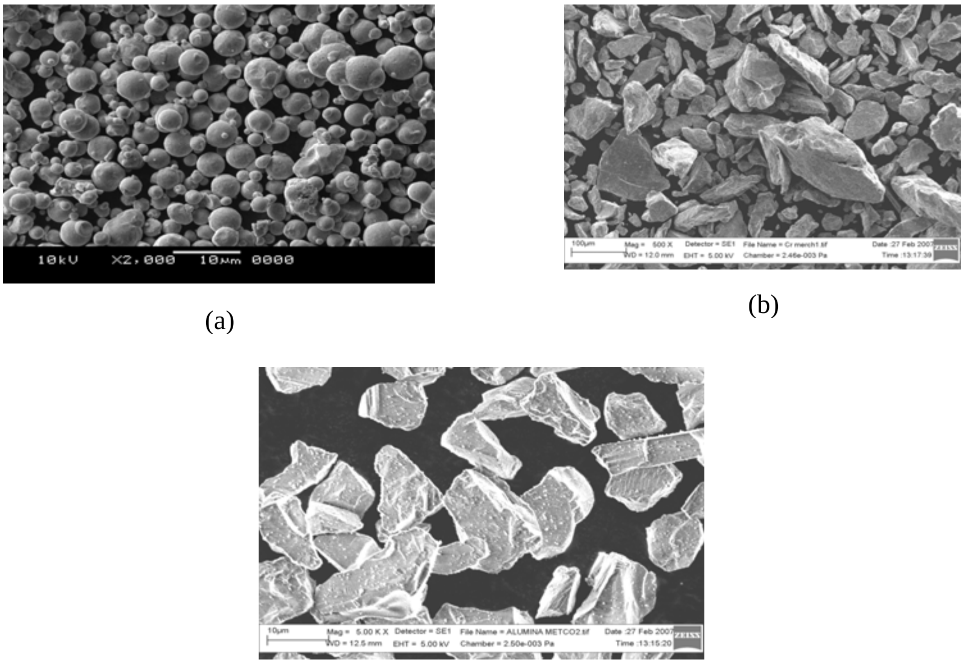
2. MATERIALS AND EXPERIMENTAL METHODS

The composites were prepared by powder metallurgy route. Characterizations of raw powders were carried out using SEM analysis to study the surface morphology and particle size of the respective powders. The samples were prepared based on 0 wt. %, 5 wt. %, 10 wt. %, 15 wt. %, 20 wt. % and 25 wt. % of alumina particles. 12 wt. % of chromium (Cr) was added as alloying element to give better corrosion resistance.[8] The initial powders of the matrix alloy, the reinforcement and 2 wt. % of stearic acid as a binder were blended for 30 min at 250 rpm in a drum shape plastic container to prevent segregation due to free-fall and vibration during mixing. The mixed powder was poured into a die of 10 mm diameter and uni-axially pressed at a pressure of 750 MPa. The prepared green compacts were sintered in vacuum furnace at a temperature of 1100°C for two hours with 10°C/min heating rate. The bulk density and apparent porosity of each of the composites was determined using the Archimedean principle according to ASTM B311-93. HM-114 Mitutoyo Hardness Testing Machine was used to determine the micro-Vickers hardness value. Scanning elektron microscope (SEM) and energy dispersive X-ray spectrometer (EDX) from JEOL JSM-6460LA were used to reveal the microstructures and the presence elements. XRD-Bruker AXS D8 Advance was used for the identification of phases.

3. RESULTS AND DISCUSSION

Figure 1 shows the scanning electron micrographs of iron, chromium and alumina raw powder and their particles sizes respectively. From the experimental results observed in Figure 2, it shows that composites reinforced with 20 wt. % alumina produced the highest micro-Vickers hardness value. The reinforcement resulted in higher micro-Vickers hardness reading compared to the composite without reinforcement. As the weight percentage of alumina is increased, the hardness also increased until the optimum value of 20 wt. % alumina. The same pattern of experimental results is observed in evaluating the percentage of thickness shrinkage. It increased correspondingly until 20 wt. % alumina and then it started to decrease. Consequently, increasing the weight percentage of alumina resulted in a decreased in the percentage of bulk density but the percentage of porosity is increased.

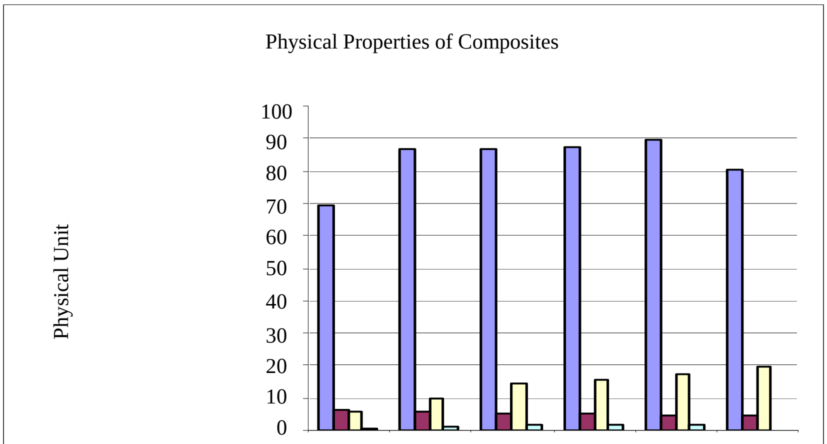
Figure 3 shows the SEM photomicrographs of the composites at different weight percentage of reinforcement. A sufficient uniform reinforcement distribution is observed when the weight percentage of reinforcement is 5 wt. %. For higher reinforcement content, reinforcement clusters are observed but the distribution of reinforcement is quite homogeneous. A uniform distribution of reinforcement becomes impossible when the content of reinforcement is higher because of inadequate ratio of the surface areas of matrix alloy particles and reinforcement particles.[9] This phenomenon is obvious in a composite with 25 wt. % reinforcement as shown in the microstructure of Figure 3(f).



(a) (b)

(c)

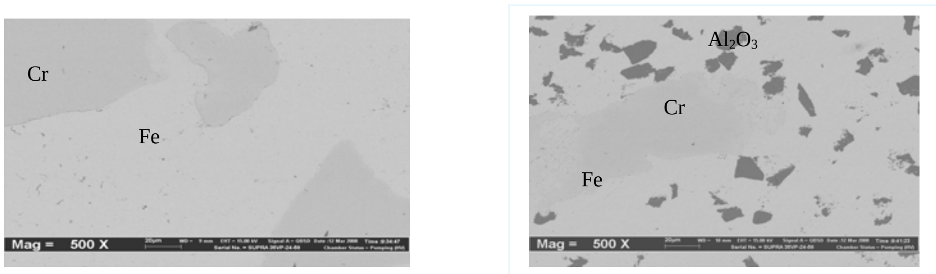
Figure 1: SEM micrograph of raw powders and their respective particle sizes. (a) Iron powder (5.83 μm); (b) chromium powder (24.53 μm); and (c) alumina powder (13.31 μm).



	A0	A5	A10	A15	A20	A25
MicroVickers Hardness (HV)	69.34	86.68	86.96	87.56	89.51	80.16
% Bulk Density (gcm^{-3})	6.153	5.727	5.32	5.12	4.774	4.54
% Porosity	5.971	9.836	14.6	15.81	17.11	19.71
% Shrinkage	0.83	1.12	1.53	1.68	1.86	0.2

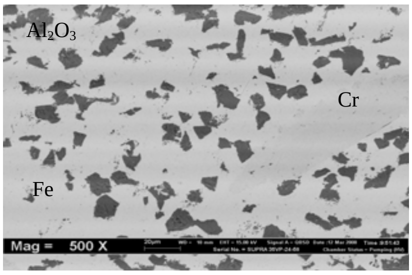
Weight Percentage of Alumina

Figure 2: Experimental results of composites properties.



(a) (b)

Figure 3: SEM micrographs of the composites at varying weight percentage of alumina (a) 0%; (b) 5%; (c) 10%; (d) 15%; (e) 20% and (f) 25%.



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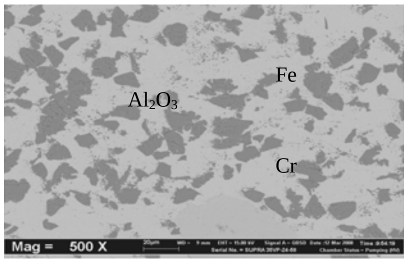
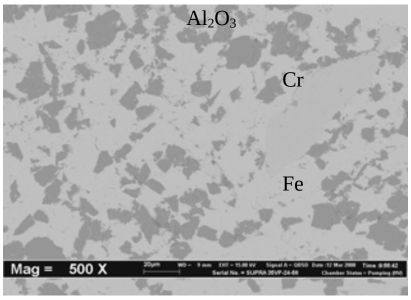
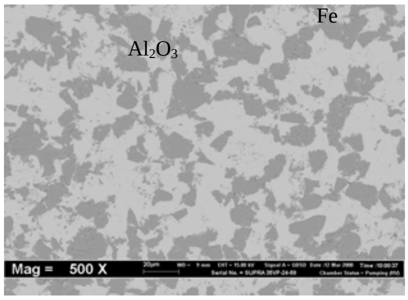


(d)



(e)



(f)

Figure 3: *(continued)*

The reinforcement clustering depends on the reinforcement concentration. The effect of reinforcement clustering on the composite is a decrease in the bulk density and an increase in porosity, as shown in Figure 2. From the experimental observations, the optimum concentration of reinforcement is 20 wt. % of alumina particles.

Figure 4 shows the EDX analysis of the composites to confirm the existence of iron, chromium and alumina. XRD phase analysis of the composite is shown in Figure 5. The peaks have been identified as belonging to the phases of the iron, chromium and corundum. It was noted that as the weight percentage of reinforcement increases, the intensity of corundum's peak becomes stronger.

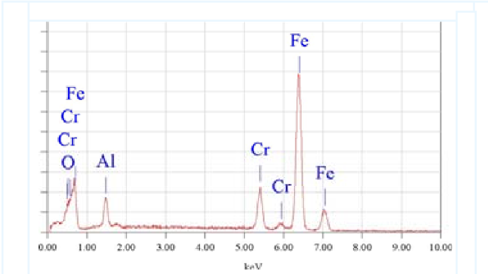


Figure 4: EDX diffractogram of the composites showing the presence of elements and oxygen.

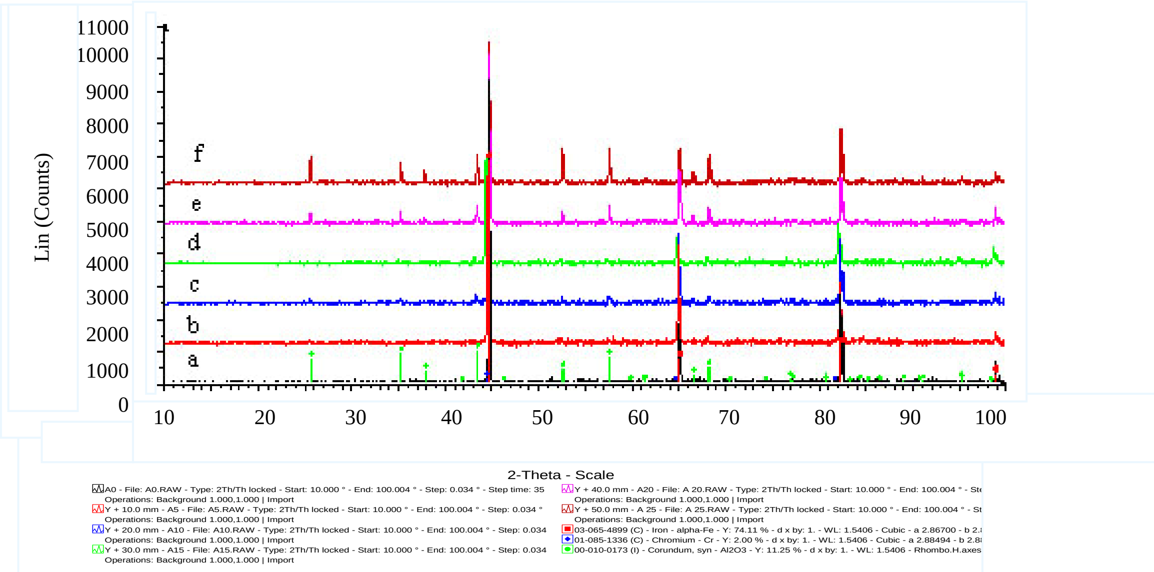


Figure 5: XRD diffractogram showing the phases of Fe, Cr and Al_2O_3 in the composite at varying weight percentage of alumina (a) 0%; (b) 5%; (c) 10%; (d) 15%; (e) 20% and (f) 25%.

4. CONCLUSION

Composites powders of Fe-Cr-Al_2O_3 have been fabricated by powder metallurgy route. The varying weight percentage of alumina particles studied have an effect on the final physical properties of the composites namely the density, shrinkage, porosity and hardness. Experimental data showed that the optimum weight percentage of reinforcement in the matrix is 20 wt. %. Higher weight percentage of reinforcements resulted in clustering of the reinforcement in the matrix, which causes higher porosity and lower density of the composites, consequently resulted in a decrease in hardness.

5. ACKNOWLEDGEMENT

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