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Fabrication of Ferrous based Composites via Different Processes and their Characterization

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Abstract

In the present investigation, white cast iron powders and iron powders were prepared using water atomization process. Both the powders were allowed to mix in 50 is to 50 weight ratio and were consolidated in two different ways for making metal matrix composites. The micro-hardness and micro-structural study of the processed composites were done. The processed composites exhibited very good results.

Keywords: compaction, forging, heating, rolling, microstructure, micro-hardness, composite, rapidly solidified, white cast iron, SEM.

INTRODUCTION

Composite materials are widely accepted in different industrial houses because of their improved properties. The properties of composites are mainly influenced by the size and volume percentage of the reinforcing materials. Wang et al. (1) developed different samples of iron-matrix composites taking SiC particles of 3, 13, 21 and 45μm sizes as reinforcement. They adopted hot pressing sintering method and found that composite with SiC particles of size 13μm exhibited best tensile strength & elongation. Chrysanthous et al. (2) developed ferrous based metal matrix composites (MMC) reinforcing (Ti,V)C. They observed that an increase in vanadium amount refined grain size of carbides and ferrites in the composite. As a result micro-hardness of the composite increased. Yilmaz (3) investigated the abrasive wear resistance of Ferrous based metal matrix composites which were prepared through Powder Metallurgy (PM) route reinforcing FeCr particles. Wear rate was found to be decreased with an increase in volume fraction of FeCr. In the recent years Kim et al. (4) fabricated iron based MMC reinforcing TiC particles and found that compression yield strength of the composite increased with increase in TiC content. Wang et al. (5) produced ferrous based VC reinforced composites through in situ synthesis method. On investigation they found that the composite exhibited good densification and possessed great wear resistance.

As the reinforcing materials are very expensive, the industries are in search of inexpensive reinforcing materials. O.D.Sherby et al. (6-11) revealed that rapidly solidified white cast iron as well as ultra high carbon steel, when consolidated under appropriate thermo mechanical conditions, could be made super-plastic at warm temperature. Again these materials could exhibit, to a maximum, yield strength of 1000MPa and hardness of 68HRC with 4300MPa compressive fracture strength by heat treatment. The most useful property of these materials are that they can make very good solid state bonding with other ferrous based materials even below the lower transformation temperature(727°C) which enables one to produce very high quality laminated composites.

In this investigation, considering these properties of rapidly solidified white cast iron, two different methods have been adopted to produce composites using these white cast iron powders as reinforcement. The micro-hardness of the processed composites have been studied to prove their suitability for the industries.

MATERIALS AND EXPERIMENTATION

Water atomization technique was used to produce white cast iron powders and iron powders. The SEM micrographs of these are presented in Fig.1 and Fig.2 respectively. Coarse powders above 150μm size were sieved out. The rest powders were taken for further processing. The iron powders were annealed at 1000°C for 1 hr and white cast iron powders were annealed at 700°C for 2 hrs. After annealing both white cast iron powders and iron powders were mixed in weight ratio of 50 is to 50. For better compaction,1% Zinc stearate was added to the mixture. The chemical and Physical characteristics of iron powders were studied and are presented in Table1 and Table2 respectively. The chemical and Physical characteristics of white cast iron powders are presented in Table3 and Table4 respectively.

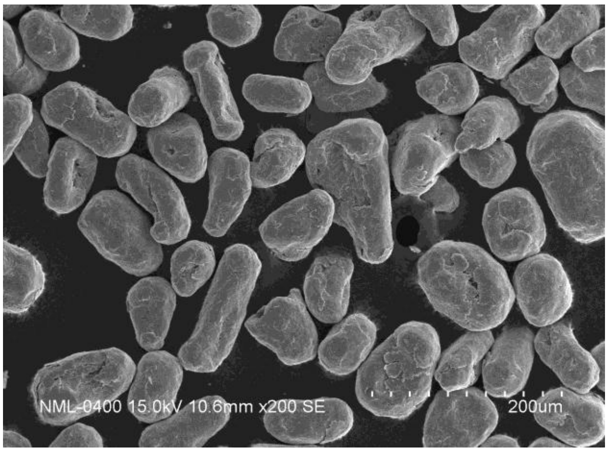

Figure 1. SEM Micro-graph of iron powders

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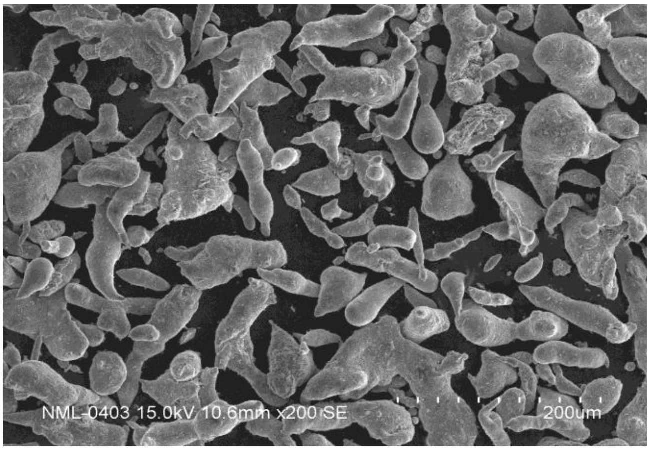

Figure 2. SEM micrograph of white cast iron powders

Table1. Chemical characteristics of annealed iron powders in wt. %

C	S	P	Fe
0.045	0.014	0.025	Balance

Table 2. Physical characteristics of annealed iron powders

Characteristics	value
Apparent Density, gm/cm^3	2.8
Flow rate, sec/50g	25
Approximate particle size range(µm)	10-150

Table 3. Chemical analysis of annealed white cast iron powders in wt.%

C	Cr	Si	S	P	Fe
3.51	2	1.42	0.014	0.022	Balance

Table 4. Physical characteristics of annealed white cast iron powders

Characteristics	value
Apparent Density, gm/cm^3	2.65
Flow rate, sec/50g	24
Approximate particle size range(µm)	10-150

Two different ways, as discussed here, were chosen for consolidation of the said mixed powders.

1. In the first case, a double action die set was used to compact the mixed powders at 500MPa. Cold compacts of 12mm diameter were prepared. Then the cold compacts were heat treated at 720°C for one hour in presence of Nitrogen. Then a 0.5 ton capacity air hammer was used to forge the compacts.
2. In the second case, the powders were properly blended using a blender. The blended loose powders were put inside a mild steel can, which was kept in the furnace and heated at 720°C temperature for one hour in hydrogen atmosphere. After that, this mild steel can was rolled by a rolling mill till a 5mm thick sheet was obtained.

Micro-structural Analysis

The processed materials were put to grinding and polishing followed by etching with 5% nital. Then micrographs were taken by scanning electron micro-scope. These are presented in Fig.3 and Fig.4.

Micro-hardness study of the processed materials

The micro-hardness study was conducted by a micro-hardness tester and the average values at different portions are presented in Fig.5 and Fig.6.

RESULTS AND DISCUSSIONS

Characteristics of iron powders

From Table1, it is found that Sulphur and Phosphorous content in iron powders are 0.014% and 0.025% respectively. Though these are undesirable, these are quite low in weight percent. From the Physical analysis of iron powders, the apparent density i.e. 2.8gm/cm^3 and flow rate i.e. 25sec/50gm are found and these values are good for using these powders for manufacturing different machine parts.

Characteristics of white cast iron powders

As observed from table 3, 2wt% Cr and 1.42wt% Si are present in white cast iron powders. 2% of Cr acted as carbide stabilizer, 1.42wt % Si enhanced the A1 transformation temperature up to 1000°C in the powders. From table4, it is found that flow rate is 24 sec/50gm and apparent density is 2.65gm/cm^3. These are comparable with any quality powder of such kind.

Micro-structural Analysis

It is observed from Fig.1 and Fig.2 that both the powders are irregular in shape. This is good for compressibility of the powders. From Fig.3, it is interesting to note that both the iron powders and white cast iron powders adjusted nicely in the processed material through the process of forging. This led to filling of pores present after compaction stage. No crack is marked on white cast iron powders in spite of heavy strokes of the hammer. Again it is noticed that a specific area inside it is unaffected from forging operation.

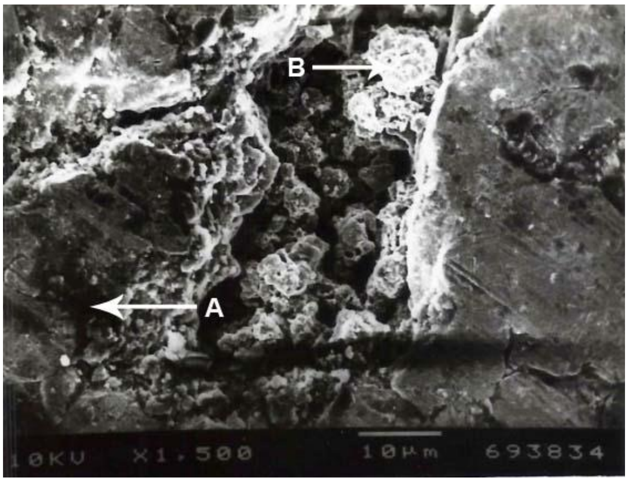

Figure 3. SEM micrograph of the compacted, 700°C heat treated and forged material.

From Fig.4, it is found that very fine (<2µm) equiaxed cementite and ferrite grains are well distributed inside the cast iron particles surrounded by iron matrix.

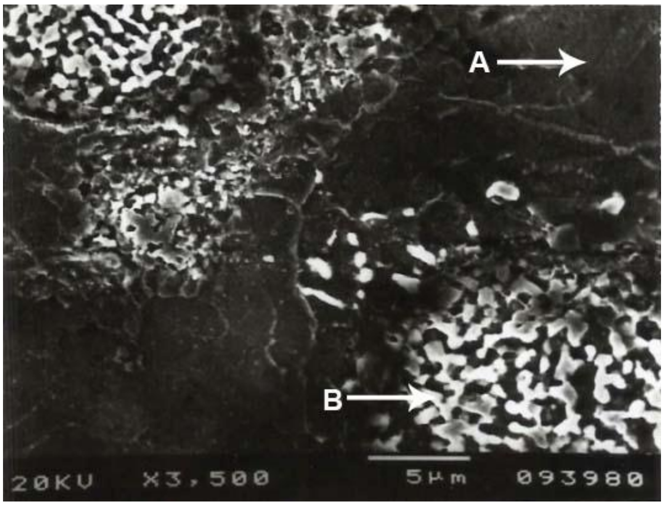

Figure 4. SEM micrograph of the 700°C heat treated, forged and rolled material.

The bonds among cast iron and iron powders are very good. The composite material is good for manufacturing high performance structural components.

3.5. Micro-hardness studies of processed materials

Fig.5 presents the micro-hardness values of the 720°C heat treated, compacted and forged material. An average micro-hardness value of 202HV is observed in ferrite rich area, A .In carbide rich area, B, the average micro-hardness value is calculated to be 505HV.The values are presented with error bars.

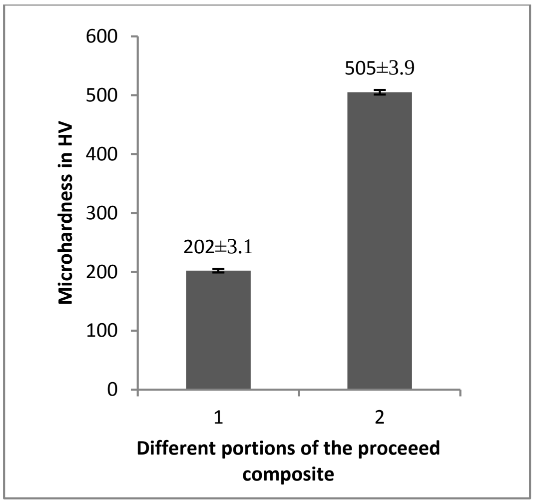

Figure 5. Microhardness values of the compacted, 720°C heat treated and forged material

Fig.6 presents the micro-hardness values of the 720°C heat treated and rolled material at different regions. In ferrite rich area micro-hardness values range from 190HV to 240HV giving an average value of 227HV. Here also the values are presented with error bars. High carbon content ferrous regions, rich with carbides, show hardness values in between 600HV to 640 HV and the average value is estimated to be 615HV.

It is worth mentioning here that composites prepared in both the processes are from the same white cast iron powders and iron powders. Because of variation in processes, difference in hardness values is observed.

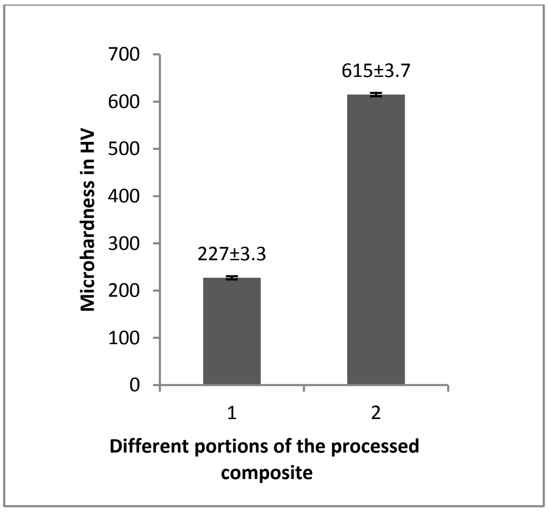

Figure 6.-Microhardness values of the 720°C heat treated and rolled material

It is concluded that the carbide rich area shows higher hardness and ferrite rich area shows lower hardness. Such kind of structure in the processed material makes it a suitable dual phase composite material. This can be effectively utilized for manufacturing different kinds of components for various applications.

CONCLUSIONS

The following conclusions are drawn.

1. Good composite materials can be obtained by processing of mixture of rapidly solidified white cast iron powders and iron powders.
2. The processed materials exhibit very fine microstructure and good bonding.
3. The good hardness values obtained will promote the industries for the use of these materials for manufacturing structural components.

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