Microstructural Analysis of Iron Aluminide Fabricated from Iron Mill Scale by Powder Metallurgy Method

S. Nurul Syuhada, M. Z. Ruhiyuddin, and A. Khairel Rafezi

Abstract— This research describes the microstructural of iron aluminide which fabricated from iron mill scale by powder metallurgy method. The raw material used consists of iron mill scale and aluminum powder. Iron mill scale is obtained from steel plant company in north Malaysia. This mill scale was milled for 4 hours with grinding media to produce a fine particle size and then the mill scale was sieved into a different size. After that, the premix of iron mill scale and aluminum powder was compacted with 5.7 ton load and the process was conducted at room temperature. The green compact were subjected to sinter in condition of nitrogen atmosphere at 500˚C with 8°C/min heating rate and soaking time was set for 30 minute. The structural characteristics of sintered sample and raw material investigated by scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) methods are presented. SEM result of the sintered sample obtained at 500˚C showed that some particle of iron mill scale do not react with aluminum powder to create bonding together. This means the temperature that used for sintering do not reached the suitable sintering temperature.

Keywords: *Iron mill scale, green compact, sintering, SEM, EDS*

I. INTRODUCTION

IRON oxide will form on the surface of metal during the processing of steel. These oxides known as mill scale occur during continuous casting, reheating and hot rolling operations [1]. Most of the steel plant company does not recycle the mill scale produced during their production process. This mill scale was kept piling at most of their factory compound [2]. In the United State alone, more than five billion kilograms of metallic and non metallic scrap which produced in operations such as sheet forming, casting and molding are discarded each year [3]. The adverse effects of this activities, their damage to our environment and to the earth's ecosystem, and their effect on the quality of human life are by well recognized. One way to prevent pollution at the source and to promote recycling is reuse instead of disposal (mill scale) into a useful material. This fact brings out the necessarily and interest in finding an economical way to reprocess them by other alternative methods and also offers a low-cost raw material [2]. There are many studies in the literature that deal with different methods for reprocess this mill scale. Some of this method have been commercialized but then have been abandoned because of economic aspect. Powder metallurgy method has been choosing because these methods are an economical way to reuse the iron mill scale into a useful material and providing a low cost starting material. Powder metallurgy parts are used in variety of ends product such as lock, hardware, automobile engines and transmissions, auto brake and steering system, power tools and many more [4]. Powder metallurgy consist the following operations: powder production, mixing and blending, compaction and sintering.

II. EXPERIMENTAL

Materials

The iron mill scale was obtained from steel plant company in north Malaysia and aluminum powder with high purity (99.7%) was supplied from Merck KGA, Germany. Iron mill scale and aluminum powder, mixed in the ratio of Fe_3Al (Fe-23 at.% Al) according to the FeAl phase diagram shown in figure 1.

Equipment and Procedures

Iron mill scale was milled for 4 hours in the mill jar with porcelain ball mill as the grinding media to produce a fine particle size. Milling process was operating at 175rpm according to 47% of critical speed. Then, it was sieved with Ro-tap vibrating shaker machine into 6 different sizes which is 1.18mm, 0.6mm, 0.3mm, 0.15mm, 0.075mm and 0.063mm.

Iron mill scale and aluminum were dry mixed in a ball mill for 1 hour. It is necessary to prepare unique particle

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size distribution and to obtain uniformity between iron mill scale and aluminum powder. In this step, 2g stearic acid ($C_8H_{36}O_2$) was added as a binder. Others function of stearic acid is to reduce friction between the compact sample and the die wall and between powder particles. Then, the mixture was placing into pallet mould. The 5.7 ton (225Mpa) load was supplied by using hydraulic press machine and the compaction process was carried out in the room temperature. The green compacts were then sintered at 500˚C with 8˚C/min heating rate in condition of nitrogen atmosphere. The presence elements and microstructures of sintered samples and raw material that used in this experiment were examined using scanning electron microscope (SEM) and energy dispersive spectroscopy (EDS).

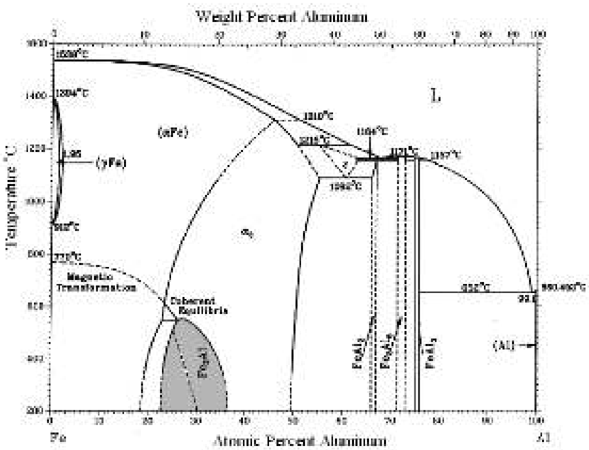

Figure 1. FeAl phase diagram [4].

III. RESULT AND DISCUSSION

Raw Material Analysis

Figure 2 and 3 show SEM microstructures of raw material that used in this experiment which is iron mill scale and aluminum powder. In figure 2, iron mill scale particles appear in the irregular shape after it was milled for 4 hours with roll mill and sieved with Ro-tap vibrating shaker machine. This iron mill scale had a mean particle size of about 63μm. For aluminum powder which is supplied from Merck KGA,Germany is in the form of spherical and cylindrical shape with average particles size 45μm, shown in figure 3.

Figure 2. SEM micrograph of iron mill scale

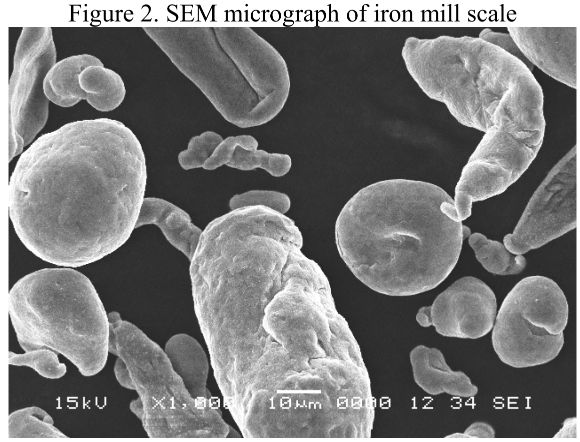

Figure 3. SEM micrograph of aluminum powders

The particle size is important parameter in determining the quality of the final powder metallurgy product. These parameters have a major influence on processing characteristic. The uniformity of particle size and shape gave good physical and mechanical properties to the product for example, if the particle shape is angular shape, it will gave the brittle properties [5].

Sample Analysis

A high magnification SEM micrograph highlighting the reaction between iron mill scale and aluminum powder at 500˚C sintering temperature are shown in figure 4. Chemical composition which obtained from EDS result was performed on the Fe-23at.%Al sample and the results are shown in table 1, figure 5 and figure 6.

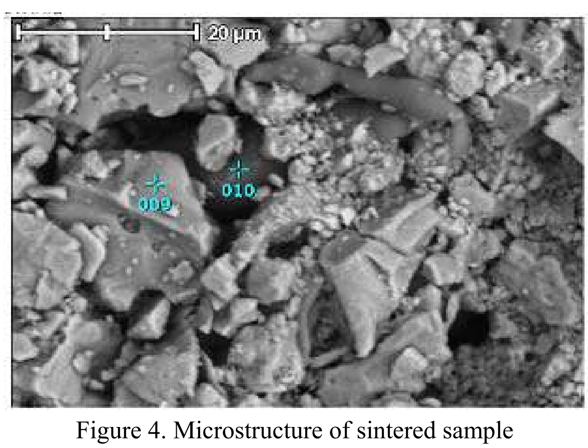

Figure 4. Microstructure of sintered sample

From figure 4, there was evidence that iron mill scale and aluminum particles were still presence. The major reason of this situation is because sintering temperature that used in this experiment is not suitable for both particles to homogenate.

Table 1. Chemical composition analysis of sintered sample

Element	Iron Mill Scale	Aluminum
at.%	55.21	46.79

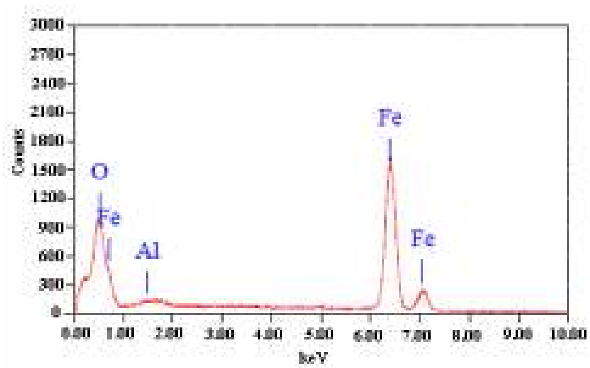

Figure 5. EDS of light area (spot 009) of the sintered sample corresponding to figure 4.

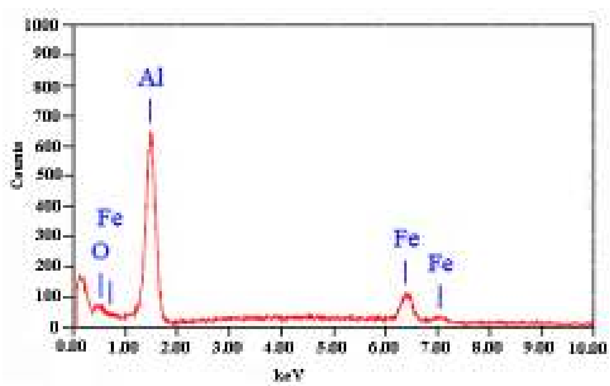

Figure 6. EDS of dark area (spot 010) of the sintered sample corresponding to figure 4.

EDS analysis gave the approximately composition of the light area (spot 009) 46.79at.% aluminum and dark area (spot 010) 55.21 at.% iron mill scale. Although, there are many particles size of iron mill scale and aluminum do not react with each other at 500˚C sintering temperature but the result show this composition is close to $FeAl_2$ according to the phase diagram in figure 1. In figure 5 and figure 6, oxygen also was observed as presence element in the sintered sample. The oxygen content can primarily be attributed to surface oxides on the sample.

IV. CONCLUSIONS

In this study, it was shown that iron mill scale has the potential to be used to produce iron aluminide by using powder metallurgy method based on the formation of $FeAl_2$ phase. Sintering temperature is an important parameter to be controlled in order to form Fe_3Al phase. Sintering temperature that had been used in this study was based on pure iron phase diagram, however in this study the pure iron was substitute with iron mill scale to form Fe_3Al phase.

ACKNOWLEDGMENT

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