EFFECT OF MILLING PERIODS ON THE IRON MILL SCALE PARTICLE SIZE AND PROPERTIES

M.Z. Ruhiyuddin, Khairel Rafezi Ahmad, A.R.M. Nazri, M.W.M. Fitri, S.S. Rizam
School of Materials Engineering, Kompleks Pusat Pengajian Taman Muhibah, Universiti Malaysia Perlis (UniMAP), 02600 Arau , Perlis, Malaysia
ruhiyuddin@unimap.edu.my

Abstract
The relations between the milling periods with the iron mill scale particle size have been studied. Iron mill scale has been chosen for this research due to the nature of itself, as a by-product. From this research, the average optimum size for the final iron mill scale particle size intended to produce is at 300 μm. Raw iron mill scale received from the industries was in the form of chip with the average size of 10 mm across and 1.5 mm thickness. Three different samples from three different steel mill companies have been used for this study. Rolling ball mill has been used to mill the iron mill scale with two different milling periods, which were two hours and six hours. After the milling process, the iron mill scale was sieved using sieving machine to a few specified grating sizes. Weight of each sample collected from each grating size was calculated in order to get the percentage of the particle size distribution of the iron mill scale after the milling process. Sample collected from Steel Mill 1 (SM1) and Steel Mill 3 (SM3) showing finer particle size produced after the milling period of six hours as compared to two hours. However sample from Steel Mill 2 (SM2) showing different trend of particle size collected as compared to SM1 and SM3. Coarser particle size was collected after the milling periods of six hours as compared to two hours. Characterization process have been conducted to all mill scale samples from each steel mill company in order to determine the relationship between the mill scale properties and the result gathered after the milling process.

Keywords: Iron Mill Scale, by-product, rolling ball milling

Introduction

Iron mill scale has been chosen for this research due to the nature of itself, as a by-product. During the processing of steel, iron oxides will form on the surface of the metal. This oxide which was called as iron mill scale occur during continuous casting, reheating and hot rolling operations [1].Most of the steel making company does not recycle the mill scale produced during their production process. This by product was kept piling at most of their factory compound. Considering the volume and quantity produced, this fact brings out the necessity and interest in finding an economical way to reprocess them by other alternative methods. Therefore it has come to a great interest for the author to explore the possibilities of recycling this by-product into a useful material; especially for the Powder Metallurgy process as the future and advantages in the Powder Metallurgy process is so great. The increasing of starting material costs used in the powder metallurgy process and also the increasing of the energy costs in the last few years have stimulated the researchers to develop new methods that allows to reuse the iron mill scale providing a low-cost starting material, in the powder form, which is appropriated to fabricate several sintered components and parts. The objectives of this research were to find the optimum milling period to produce the average optimum size for the final iron mill scale particle size at 300 μm as the magnetic separator machine will operate better for material at this size [2]. Apart from that, there was research conducted showing that the iron mill scale grinded to particle size less than 300μm giving poor responds to the oxidation and reduction process done to it [3]. Furthermore, this research also intends to study the properties of the iron mill scale after the milling process so it could be recycled for others powder metallurgy process.

Experimental

Materials

As mention earlier, iron mill scale is a by-product from the steel industry thus the iron mill scale composition basically contains iron and iron oxide with some impurities such as Mn, Si and some other gangue materials [4]. As received iron mill scale is in the form of metal chips or flake with 80% of it size is 80 mesh. Three different samples of iron mill scale collected from three different steel mill companies in Malaysia were used for this research labeled as Steel Mill 1 (SM1), Steel Mill 2 (SM2) and Steel Mill 3 (SM3).

Apparatus and Procedures

In order to reduce the particle size, rolling ball mill with porcelain balls of 10mm diameter has been used as the grinding media. Rolling ball mill has been used to mill the iron mill scale with two different milling periods, which were two hours and six hours. The milling speed was fixed at 231 rpm for both period of milling and the quantity of mill scale used was about 1/3 of the jar volume. After the milling process, the iron mill scale was sieved using sieving machine (Ro-tap Sieve Shaker) to a few specified grating sizes starting with >5.00mm and followed by 2.36mm, 1.18mm, 600μm, 300μm, 150μm, 75μm and <75μm as the base. Weight of each sample collected from each grating size was calculated in order to get the percentage of the particle size distribution of the iron mill scale after the milling process.

Result and Discussion

All samples which have been milled and undergo sieving process were than weighed from each sieve. The result for percent of sample retained in each sieve was shown in Table 1 for SM1, Table 2 for SM2 and Table 3 for the SM3.

From the result shown in Table 1 and Table 3, it can be seen that sample collected from SM1 and SM3 showing finer particle size produced after six hours of milling period as compared to two hours of milling period. Sample SM1 shows that the iron mill scale particle size was highly distributed between 600μm to 150μm after six hours of milling with the major particle size was 600μm. Sample SM3 showing the particle size was highly distributed between 600μm to 75μm after the milling period of six hours however the major particle size collected was 300μm. This phenomenon was believed to be related to the microstructure of the iron mill scale from each sample. Figure 1 and Figure 2 show the micrograph of the iron mill scale microstructure for sample SM1 and sample SM3. It was clear that the microstructure for sample SM1 showing coarser particle size but with high porosity, while sample SM3 showing a spongy like structure with high quantity of fine pores exist.

Table 1: Weight percentage for sample SM1

Sieve size (μm)	Milling period (2 hours)		Milling period (6 hours)	
	Weight (g)	Percentage (%)	Weight (g)	Percentage (%)
>5000	23.89	17.11	4.88	3.49
2360	26.61	19.05	4.36	3.11
1180	25.71	18.41	27.66	19.79
600	26.44	18.93	41.68	29.82
300	14.95	10.70	26.66	19.07
150	7.96	5.69	14.87	10.64
75	7.42	5.31	9.42	6.74
<75	6.68	4.78	10.22	7.31
Total	139.66	100.00	139.75	100.00

Table 2: Weight percentage for sample SM2

Sieve size (μm)	Milling period (2 hours)		Milling period (6 hours)	
	Weight (g)	Percentage (%)	Weight (g)	Percentage (%)
>5000	27.36	18.02	32.93	19.18
2360	12.60	8.30	21.90	12.75
1180	17.10	11.26	20.50	11.94
600	28.38	18.69	40.88	23.81
300	28.56	18.81	32.83	19.12
150	17.62	11.60	15.87	9.24
75	10.51	6.92	6.77	3.94
<75	9.67	6.37	0	0
Total	151.80	100.00	171.68	100.00

From the EDS analysis done to sample SM1 and sample SM3 showing that the composition between these two samples almost the same as shown in Table 4. However from sample SM2, as shown in Table 2 showing different trend of particle size collected as compared to SM1 and SM3. Coarser particle size was collected after the six hours of milling period as compared to the two hours of milling period. The pattern of the particle size distributed was almost the same between the samples undergo milling period of two hours and the samples undergo milling period of six hours.

The particle size was highly distributed above 300μm. Figure 3 shows the micrograph of the iron mill scale microstructure for sample SM2. It was obvious that the microstructure for sample SM2 looks denser as compare to sample SM1 and SM3. From the EDS analysis done to sample SM2, there was significant different can be detected in the chemical composition as compare to sample SM1 and SM3.

Table 3: Weight percentage for sample SM3

Sieve size (μm)	Milling period (2 hours)		Milling period (6 hours)	
	Weight (g)	Percentage (%)	Weight (g)	Percentage (%)
>5000	0	0	0	0
2360	0.40	28.46	0.07	0.05
1180	27.60	19.63	3.10	2.16
600	77.71	55.29	44.88	31.27
300	24.05	17.11	46.38	32.31
150	4.84	3.44	15.55	10.83
75	2.64	1.87	19.18	13.36
<75	3.30	2.35	14.41	10.04
Total	140.54	100.00	143.57	100.00

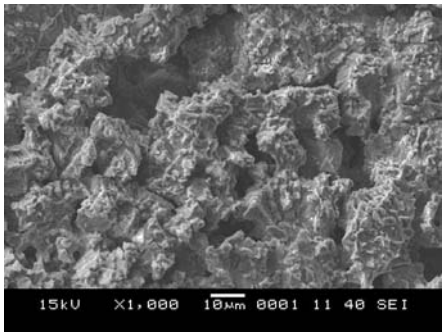

Figure 1: SEM micrograph for sample SM1 with 1000x magnification

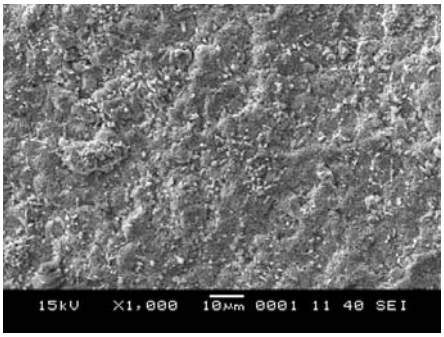

Figure 2: SEM micrograph for sample SM3 with 1000x magnification

Table 4: Element percentage for sample SM1 and sample SM3

Element	Mass percentage (%)	
	Sample SM1	Sample SM3
Carbon (C)	0.10	1.03
Oxygen (O)	22.63	22.15
Silicon (Si)	0.22	0.17
Iron (Fe)	77.05	76.65

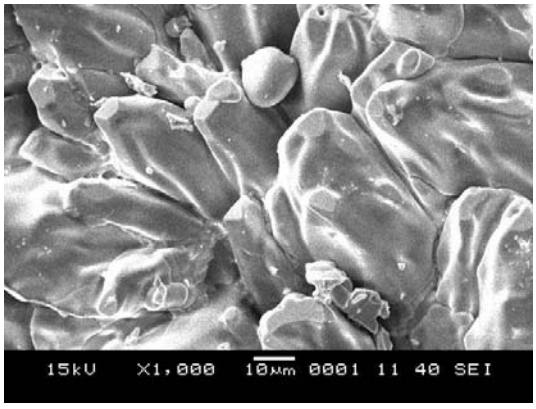

Figure 3: SEM micrograph for sample SM2 with 1000x magnification

From Table 5, it can be seen that there was aluminum (Al) detected while no silicon (Si) present. Sample SM1 and SM3 show no aluminum detected but there was silicon exist. This was probably due to the product produce from SM1 and SM3 were using silica killed process, while product produce from SM2 was using aluminum killed process.

Table 5: Element percentage for sample SM2

Element	Mass percentage (%)
	Sample SM1
Carbon (C)	0.27
Oxygen (O)	22.35
Aluminum (Al)	0.30
Iron (Fe)	77.08

Conclusion

From the sieving result it was obvious that sample SM1 and sample SM3 showing the same pattern of particle size distributed after the milling process, which were higher percentage of fine particle size collected after longer milling period. Meanwhile sample SM2 showing a reverse pattern from sample SM1 and SM3 with higher percentage of coarser particle size collected after the longer milling period. The quantity of pores detected from both samples and the different composition between sample SM1 and SM3 with sample SM2 were believed to be the reason of why the particle size distributed differently. Therefore if the preferred particle size to be collected was bigger than 300μm, than for sample SM1 and SM2, the best milling period will be two hours while for sample SM2, the best milling period will be six hours.

References

[1] Iron and Steel Byproducts; Portland Cement Association Sustainable Manufacturing Fact Sheet; llinois;July,2005 (http://www.cement.org/bookstore/download.asp?mediatypeid=1&id=8336&itemid=IS326)

[2] Wills, B.A (Barry Alan), *Mineral Processing Technology*, Pergamon Press, 4th ed. (1988), 253-305, 596-633

[3] Ruhiyuddin bin Mohd Zaki, *Sintesis dan Pencirian Serbuk Besi Yang Dihasilkan Daripada Sisik Besi*, Final Year Project, Universiti Sains Malaysia, Februari 2000

[4] Alberta Research Council, *Feasibility of P/M Grade Iron Powders from Mill Scale and DRI Powders*, Project #685-9564, 1995