

## Acid-insoluble Substances in Reduced Iron Powder from Ores

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### Abstract

X-ray analysis on iron ores and reduced iron powders revealed that the main acid-insoluble substances were hexagonal and tetragonal quartz, another substances were sillimanite, alumina-silicate, an unnamed zeolite, all contained Si and Al. Their particle size was in the range of 3~7  $\mu\text{m}$ . Statistics analysis showed that the AIC for high-grade magnetite powder was (0.130 $\pm$ 0.010) % during the latest five months. The predicting value for reduced iron powder should be 0.179 %. However, the testing value for reduced iron powder was (0.192 $\pm$ 0.014) %. The limited difference of 0.013% might imply rare pollution coming from the reduction and milling processes. The most important step for control AIC should be the separation process of iron ore powders.

**Keywords :** iron powder, inclusion, AIC

### 1. Introduction

Iron reduced powders made from iron ore have a sponge morphology and very low and stable Mn, Si, P and S contents. The contents of Si and Mn are less than 0.05% and that of P and S could be controlled in 0.005% or less. Because the iron ores are composed mainly by magnetite and less wüstite or hematite and gangue, iron ores powders inevitably contain some objectionable impurities. Additionally the powder was produced in a plant near Mongolia, where wind always brings fine sands, which would be an inclusion in sintered body and damage its mechanical properties as the resource of cracking [1]. An important task is to reduce its Acid Insoluble Content (AIC) as lower as possible in iron powder from iron ores [2]. The aim of this work is firstly to inquire which matter of this acid-insoluble impurity is and secondly to investigate its change rules in different production sequence in order to prepare higher grade iron powder.

### 2. Experimental and Results

The crude iron ore was first crushed ground and milled into desired fineness and were separated by magnetic separator and floatation process to obtain high grade magnetite powder, which were reduced in tunnel kiln at temperatures 1150-1170°C for 33 hrs to get iron sponge. Then it was milled and second reduced in continuous belt furnace with dissociated ammonia at 880-900°C to produce reduced iron powder. AIC can be measured by the percentage of matter insoluble in dilute hydrochloric acid for each batch of ore powder and iron powder [3]. X-ray experiments were performed with Ricon D/max2400, attached a computer analyzed system according to ASTM-card. The morphology of these insoluble matter was observed using JSM-6301F scanning Microscopy by secondary electron imaging (SEI).

X-Ray analysis of acid-insoluble matters for ore powder and iron powder are shown in Fig.1-2 and listed in Table 1, from which an interesting facts can be found, that nearly 60% substance are different quartzes and no phase transformation

after heating to 1200 °C. Another 40% substances are composite of SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub>, which may have crystal change to stable phase mullite according to phase diagram of SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> after reduction process at high temperature [4].

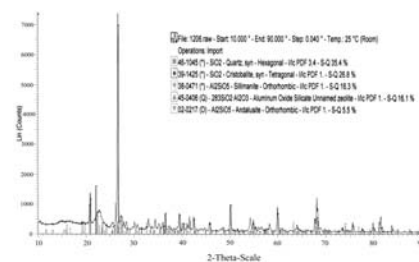


Fig. 1. X-spectrum of insoluble matter for ore powder.

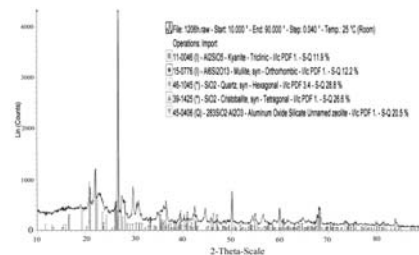


Fig. 2. X-spectrum of insoluble matter for iron powder.

Table 1. X-ray analysis for inclusion substance

Chemical formula	Substance name	Crystal system	Content for ore powder wt. %]	Content for Iron powder, wt. %]
SiO <sub>2</sub>	Quartz	hexagonal	35.4	28.8
SiO <sub>2</sub>	Crystobalite	tetragonal	26.8	26.6
Al <sub>2</sub> SiO <sub>5</sub>	Sillimanite	orthorhombic	16.3	-
Al <sub>2</sub> SiO <sub>5</sub>	Andalusite	orthorhombic	5.5	-
Al <sub>2</sub> SiO <sub>5</sub>	Kyanite	trilic	-	11.9
Al <sub>6</sub> Si <sub>2</sub> O <sub>13</sub>	Mullite	orthorhombic	-	12.2
283SiO <sub>2</sub>	Unnamed zeolite		16.1	20.5
*Al <sub>2</sub> O <sub>3</sub>				

SEM images are displayed in Fig.3. It can be seen many acid-insoluble particles are attached on the filaments of the fine papers. The particle size was in the range of 3~7  $\mu\text{m}$  or less.

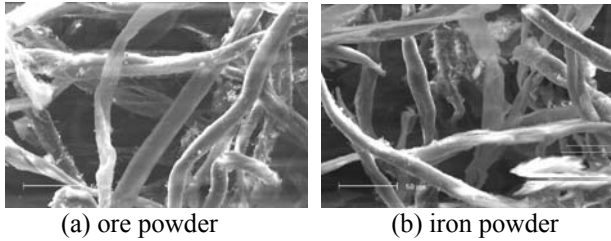


Fig. 3. SEM photograph for acid-insoluble substances.

A series of testing results are shown in Fig. 4 and Fig. 5 for in November, 2005. The average value and standard error of AIC for iron ore was  $(0.125 \pm 0.026) \%$ . Because during reduction the oxygen should be released, its acid-inclusion content of iron powder would increase by a factor of 1.38 for from  $\text{Fe}_3\text{O}_4$ . These predicted values are drawn as a dashed line in Fig. 4. However the testing results of  $(0.249 \pm 0.044) \%$  for iron sponge were higher than that prediction curve. The reason for this may be its higher carbon content of  $(0.180 \pm 0.025) \%$ , which should occur as the cementite in iron and it is not easy to solve in hydrochloric acid. It should add nitric acid to solvent in order to get true values<sup>[3]</sup>.

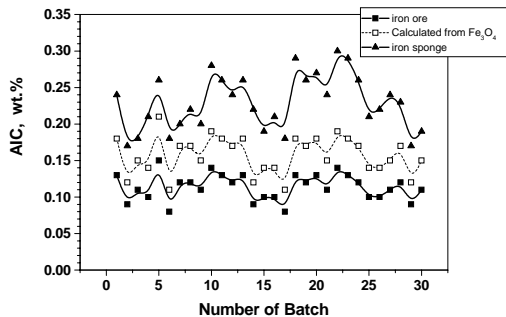


Fig. 4. AIC changes in ore and sponge.

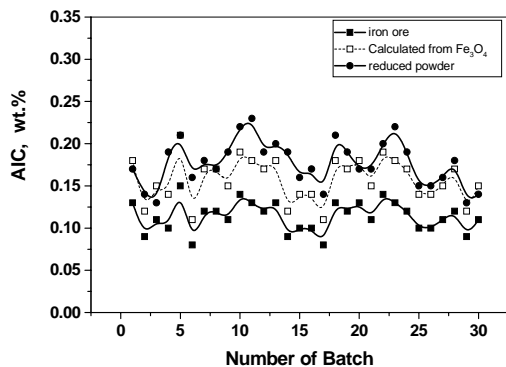


Fig. 5. AIC changes in ore and iron powder.

The AIC changes for ore and reduced iron powder in November, 2005 re shown in Fig. 5, from which the AIC value of iron powder was very close to the predicted curve. In the latest five months of 2005, the average value and standard error for every month are shown in Fig. 6. The AIC value for iron ore was  $(0.130 \pm 0.010) \%$ . The predicting values for reduced iron powder should be  $(0.179 \pm 0.014) \%$ . However the testing result for it was  $(0.192 \pm 0.011) \%$ . The difference between predicting and testing value was only 0.013 %, which might imply rare pollution came from the reduction and milling processes. The most important step for control AIC should be the separation process for iron ore powders.

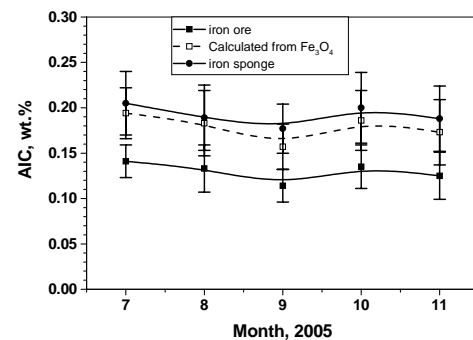


Fig. 6. AIC changes during in five months.

### 3. Summary

The main acid-insoluble substances are different quartzes and no phase transformation after heating to  $1200^\circ\text{C}$ , and another substances are sillimanite or alumina-silicate, an unnamed zeolite. Their particle size is in range of 3~7  $\mu\text{m}$ . In order to produce high-grade reduced iron powder with lower AIC of 0.14-0.20%, it should be noticed as follows: First the crude iron ore should be milled into desired fineness and separated carefully by magnetic separator and floatation process to obtain high grade magnetite powder. Second during reduction process it should avoid any pollution from ceramic tanks and air. Third the reduced iron powder should be purified by magnetic concentration.

### 4. Reference

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