Asia-Pacific Journal of Science and Technology: Volume: 23. Issue: 03. Article ID.: APST-23-03-07. Research Article

APST

Asia-Pacific Journal of Science and Technology

https://www.tci-thaijo.org/index.php/APST/index

Published by the Research and Technology Transfer Affairs Division,
Khon Kaen University, Thailand

Development of Nam Phi Iron Ore smelter from local knowledge to find engineering properties

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Abstract

This research has developed a Nam Phi iron ore smelter with a combination of traditional method and modern technology (mix method). Smelter center was designed as refractory bricks. Its walls were plastered by mixing natural clay and local materials, such as husk, sand and water. Steel pipes from the blower were connected to the combustion chamber. It took three days to dry the smelter. The strength of smelter's walls is tested via Rebound Hammer Test machine. The strength was 109.65 kg/cm^2 before smelting. The smelting used 20 kg of Nam Phi iron ore, resulting in 2.3 kg of formed Nam Phi iron rods. Then the Test Pieces were fabricated for Vickers Hardness Test (HV) which included the Test Piece Group A and Test Piece Group B. For hardness value, it could be found that the average hardness value of Group A (105.67 HV) was higher than the value of Group B (100.30 HV). Microstructure of samples were determined using scanning electron microscope technique. The SEM micrographs showed that the combination of ferrites and pearlite structure was observed. And the microhardness of each sample showed that average microhardness of Group A was 102.2 HMV and 146.9 HMV for the white and black stripes, respectively. For Group B, it was found that the average microhardness value of white stripes was 123.2 HMV whereas the value of black stripes was 107.9. Thus, it could be concluded that mechanical properties of Nam Phi iron was improved with the new mixed method fabrication.

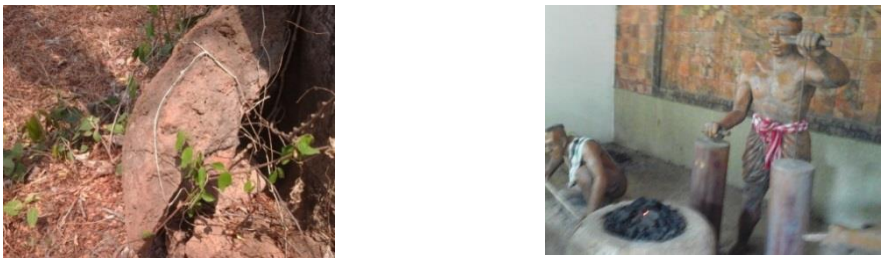
Keywords: Nam Phi iron ore, Nam Phi iron ore smelting, Traditional method, Modern technology

1. Introduction

There are many types of iron ore discovered, Magnetite (Fe_3O_4), Limonite ($Fe_2O_3nH_2O$), Pyrite (Fe_3S_2), Siderite ($FeCO_3$). Each type gives a different percentage of iron, which is more or less depending on the type of iron. In the area of Ban Nam Phi, they are Hematite (Fe_2O_3) [1], [2]. Nam Phi iron ore from 2 sources were tested at Office of Primary Industries and Mines, Region 3. Firstly, the Borlek Nam Phi Folk Museum area (currently not allowed to public and iron mining operators due to the conservation of the province) was found that the average percentage of Nam Phi iron ore was 61.85. Secondly, the current mining area behind the museum (currently used for iron mining to make products) was found that the average percentage of Nam Phi iron ore was 59.06 [3], [4]. The percentages of the two iron sources were not significantly different. In the museum, there are also traces of mines in the past, namely, Bo Phra Saeng and Bo Phra Khan. Both mines were the source of iron ore for making Nam Phi iron swords and Phra Khan (a krislike weapon used by a king) in ancient times according to the words of people. In Europe countries, a blast furnace is used in the smelting process. Coke and limestone are used high temperature furnace [5] for being pig iron, slag and hot gas. Raw iron can be adjusted properties within a smaller furnace, such as Cupola furnace, which has a high efficiency in increasing elements.

From the wreckage of the smelters found in the area, in the past, Nam Phi villagers smelted iron ore by using smelters made of natural clay mixed with local materials such as husk, sand and water. They are cylindrical with

a diameter of about 60-70, height 80 centimeters, using compressed air pressure in 1-2 cylinders, employing manpower to generate wind force, as shown in Figure 1.



(a) (b)

Figure 1 Wreckage of Ancient Nam Phi Iron Ore Smelter a. Wreckage of ancient smelter in the area and b. Form of ancient smelter

The research of Adul Phuk-in [3] "Logistic Costs of Entrepreneurs of Nam Phi Steel Products for the Trading Route of Luang Prabang" and "Development of Nam Phi Steel Quality from Newly Smelted Nam Phi Steel" [6], found many traces of iron smelting, slag and old iron ore in the area of Ban Nam Phi and nearby, as shown in Figure 2.

Figure 2 Old Smelter and Raw Nam Phi Iron Ore

Based on the material found in Nam Phi village, it proves that such area has been the largest and best iron ore smelter source in Thailand from the past to the present (Figure 3 a.) equivalent to iron smelted abroad (Figure 3 b.) and other areas in the country, due to the high demand in the past for making various products such as weapons, instrument, agricultural equipment and hunting tools for livelihood [7], as shown in Figure 3.

(a) (b)

Figure 3 Smelting Iron Ore in the Past (a) Smelting in Nam Phi Village and (b) Smelting in United Kingdom [4]

2. Materials and methods

2.1 Structural design

Of smelter is a combination of traditional method and modern technology. Lower smelter or combustion chamber with combustion range ($CO_2 + C \rightarrow 2CO$) and ($C + O_2 \rightarrow CO_2$) [8] has a rectangular size of 660 mm. width, 710 mm. length, and 500 mm. height, refractory brick used for the core, 4 steel pipes with a diameter size of 31.75 mm. and 600 mm. length used for inlet pressure. Upper smelter ($3Fe_2O_3 + CO \rightarrow 2Fe_3O_4 + CO_2$) is made

of 450 mm. length rolled steel, 350 mm. height, inner wall covered with heat-resistant mortar, 30 mm. thick. It is an anti-rapture traditional design by mixing natural clay and local materials, such as husk, sand and water, being molded by hand and dried for 3 days, as shown in Figure 4 and Figure 5.

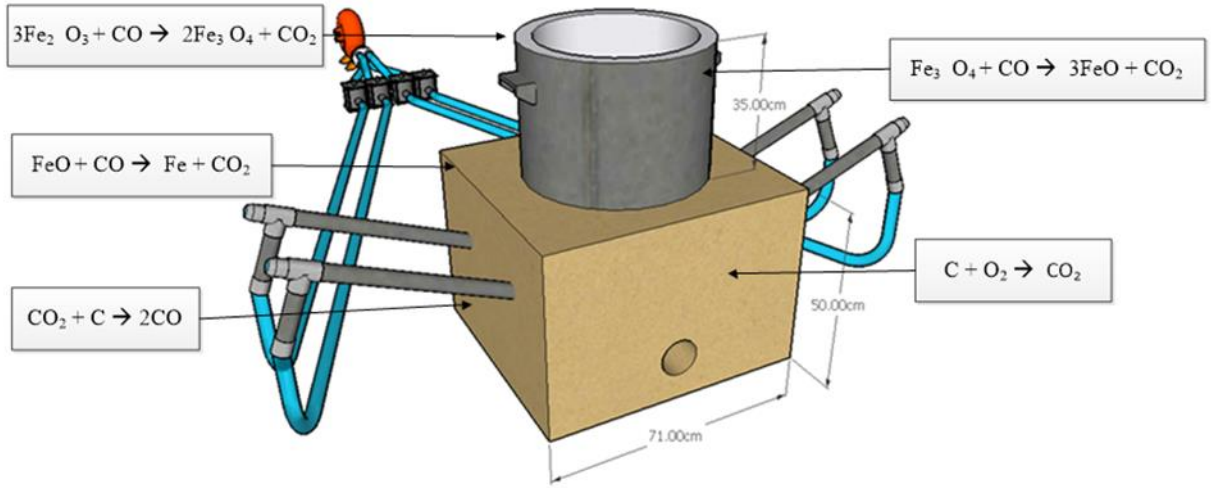


Figure 4 Designs of Smelter and Combustion Ranges

(a) (b) (c)

Figure 5 Building Smelter and Testing Smelter Wall (a) Structure of Smelter, (b) Putting Blower Tube and (c) Testing Smelter Wall

After the Nam Phi iron ore smelter is completely dried, it is tested with Rebound Hammer Tester. The specific 16 points outside walls were tested and the average strength is 109.65 kg/cm^2, closed to that of the average strength of refractory brick (18 – 35 kg/cm^2) at the normal temperature [9].

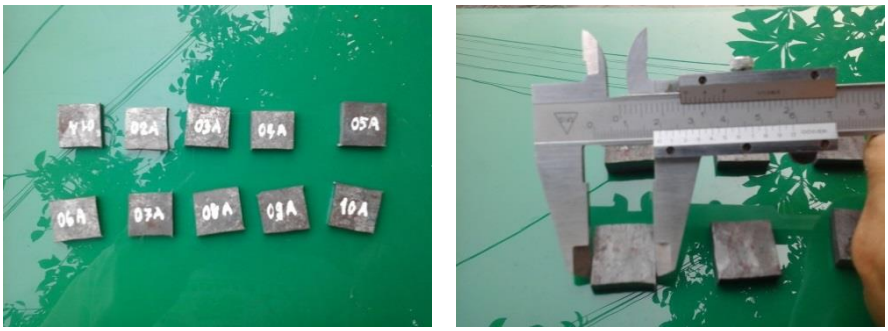
2.2 Smelting Nam Phi iron ore

In a mixed-method smelter is divided into 5 stages as follows. Stage 1: heat up the smelter for 20 mins, Stage 2: put charcoal as fuel into the upper smelter, then light up, turn on the air blower, and adjust the speed of air blow to level 1 (3.7 m/s) for 20 mins, Stage 3: adjust the speed of air blow to level 2 (2.6 m/s), fill one bag of ore at a time, every 6 mins, until 14 bags (each bag contains 1.4 kg , total 20 kg), Stage 4: during soaking and slag removal, adjust the speed of air blow to level 3 (1.8 m/s) for 20-30 mins, and Stage 5: remove the iron from the smelter with a metal plier. When getting raw steel, the ironsmith at Ban Nam Phi area forges and removes slag from the iron to form iron bars. In forging, a small size of smelter with temperature over 1,600 degree Celsius is used to obtain 2.3 kg of iron, as shown in Figure 6.

Figure 6 Nam Phi Iron Ore Smelting in Traditional Mixed-method Smelter

2.3 Nam Phi Iron Test Using Vickers Hardness Test (HV)

In this research, the work piece was divided into 2 groups, Group A were fabricated from mix method Smelter and Group B were fabricated from Traditional method Smelter to find the average hardness [8,10] as shown in Figure 7.



(a) (b)

Figure 7 Test Pieces for Finding Quantity of Elements in Nam Phi Iron from Traditional Mixed-method Smelter (a) Test Pieces of Group A and (b) Test Pieces of Group B

Test pieces of Group A and Group B are tested with Vickers Hardness Tester (HV) in diamond shape rectangular pyramid with an angle of 136 degrees, pressing load 30 kg and holding for 15 sec. Hardness of pressing is recorded to determine the average hardness of pressing test, as shown in Figure 8.

Figure 8 Vickers Hardness Test (HV)

3. Results and Discussion

3.1 To study the hardness of Nam Phi iron ore

From Figure 8 Vickers Hardness Test (HV) on Nam Phi iron ore from the mixed-method smelter, is found that Group A: hardness of pressing piece 1 is 99.00 HV, pressing piece 2 is 105.00 HV, pressing piece 3 is 113.00 HV, and average hardness of Nam Phi iron ore of Group A is 105.67 HV.

Group B: hardness of pressing piece 1 is 104.00 HV, pressing piece 2 is 92.90 HV, pressing piece 3 is 104.00 HV, and average hardness of Nam Phi iron ore of Group B is 100.30 HV, as comparison shown in Table 1.

Table 1. Comparison of Vickers Hardness Test (HV)

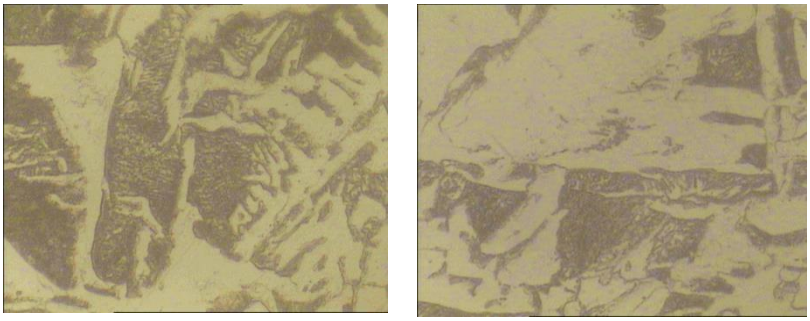
Vickers Hardness (HV)	Group A	Group B
1	99.00	104.00
2	105.00	92.90
3	113.00	104.00
Average	105.67	100.30

3.2 To study the structure of Nam Phi iron ore

From the mixed-method **s**melter, specimen of Group A and Group B are selected to be rubbed with sandpaper number 80, 120, 220, 320, 400, 600, 800, 1000 and 1200, respectively, and then be polished with alumina (Al_2O_3), in order to study the physical properties of Nam Phi iron ore structure and the arrangement of atoms in metals. Studying the metallurgical structure is an important process in quality inspection, as shown in Figure 9.

Figure 9 Preparation of Microstructure Test Pieces

The metallurgical structure of Nam Phi iron ore Group A and Group B is studied by 2000X magnification in shooting as shown in Figure 10.



(a) (b)

Figure 10 Microstructure of Nam Phi Iron from Mixed-method **S**melter (a) Group A and (b) Group B

Microstructure of Nam Phi iron from the mixed-method smelter was shown in Figure 11. It is found that both Group A and B shows a combined structure of ferrite (black stripes) and pearlite (white stripes). The structure is medium ductility, so it can be well forged and hardened. Microhardness Tester using diamond shape rectangular pyramid with an angle of 136 degrees, pressing load 0.200 kg and holding for 25 sec was used for determining microstructure of work piece, which showed in Figure 11 and Figure 12.

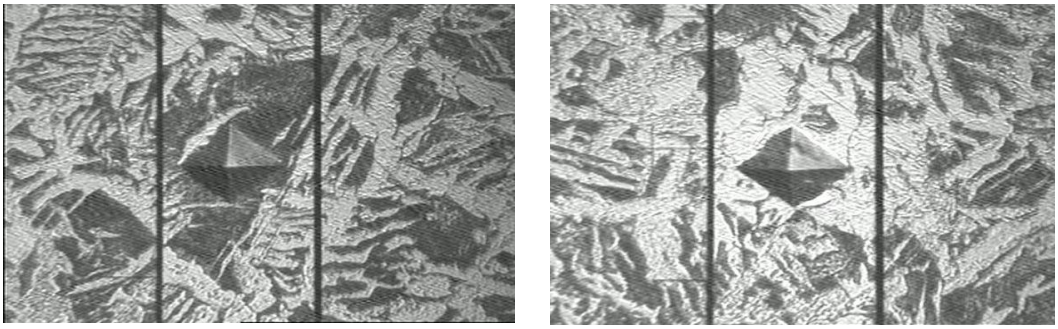


Figure 11 Microstructure Hardness Test of Group A

From Figure 11 the average microhardness value of white and black stripes Group A is 102.2 and 146.9 HMV, respectively. Moreover, the average microhardness value of white and black stripes Group B is 123.2 and 1107.9 HMV, respectively which showed in Figure 12.

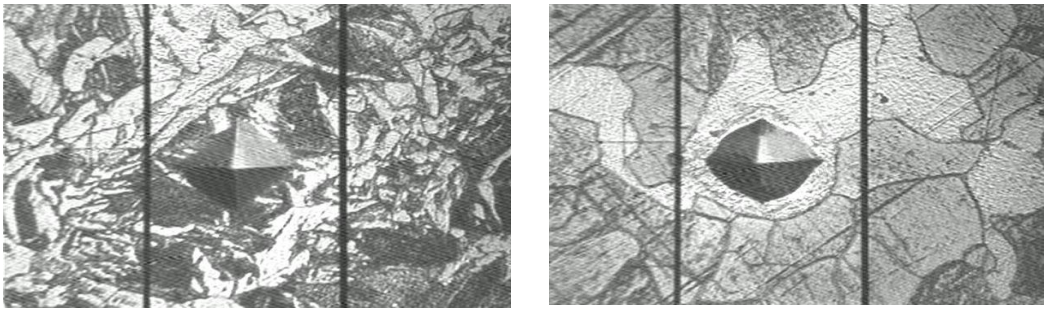


Figure 12 Microstructure Hardness Test of Group B

4. Conclusions

In this work, the Nam Phi iron ore smelter was developed via new mixed method ant traditional method using local raw materials. Smelter was designed and built to shape of refractory brick with the size of 70 x 50 cm. Its walls were plastered with mixed clay and let to dry for 3 days. Thereafter, mechanical properties of each smelter sample such as strength and hardness were examined using Rebound Hammer Test and Vicker hardness Test, respectively. For hardness testing, Nam Phi iron ore was separated to 2 groups, Group A and Group B which the fabricated sample obtained from new mixed method and traditional method, respectively. From the results, it was observed that the smelter could smelt Nam Phi iron of 2.30 kg per bag by using the dressed ore of 20 kg. Strength of smelter was 109.65 kg/cm2. For hardness value, it could be found that the average hardness value of Group A (105.67 HV) was higher than the value of Group B (100.30 HV) [6, 11,12,13].

Moreover, microstructure of samples were determined using scanning electron microscope technique. The SEM micrographs showed that the combination of ferrites and pearlite structure was observed. Generally, the combined structure exhibits medium ductility which mean that sample could be well forged and hardened. Therefore, the microhardness of each sample was examined and compared. The results showed that average microhardness of Group A was 102.2 HMV and 146.9 HMV for the white and black stripes, respectively. For Group B, it was found that the average microhardness value of white stripes was 123.2 HMV whereas the value of black stripes was 107.9. Thus, it could be concluded that mechanical properties of Nam Phi iron was improved with the new mixed method fabrication.

5. Acknowledgements

The author would like to thank the Thailand Research Fund for supporting this research. And the author also would like to express his sincere thanks to the Industrial Technology Program, Faculty of Industrial Technology, Uttaradit Rajabhat University for all the facilities.

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