



شبكة المعلومات الجامعية





شبكة المعلومات الجامعية

جامعة عين شمس

التوثيق الالكتروني والميكرو فيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
على هذه الأفلام قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأفلام بعيدا عن الغبار

في درجة حرارة من ١٥-٢٥ مئوية ورطوبة نسبية من ٢٠-٤٠%

To be Kept away from Dust in Dry Cool place of
15-25- c and relative humidity 20-40 %



شبكة المعلومات الجامعية التوثيق الالكتروني والميكرو فيلم

بعض الوثائق
مكتبة الفقه
Ain Shams University
International Network
جامعة عين شمس

شبكة المعلومات الجامعية
@ ASUNET

بالرسالة صفحات لم

بالأحلى



شبكة المعلومات الجامعية
@ ASUNET

540

RECYCLING OF MILL SCALE WASTE IN STEEL MAKING PROCESS

A THESIS

SUBMITTED TO

CHEMISTRY DEPARTMENT

FACULTY OF SCIENCE –CAIRO UNIVERSITY

BY

RAAFAT MOHAMMED ABDEL WAHAB FARAHAT

B.Sc., MENOUEFIYA UNIVERSITY, 1996

IN PARTIAL FULFILLMENT FOR THE REQUIREMENTS OF

THE DEGREE OF MASTER OF SCIENCE

(CHEMISTRY)

2010

C2C7 up

APPROVAL SHEET FOR SUBMISSION

Title of the M.Sc. thesis:

Recycling of Mill Scale waste in Steel Making Process

Name of Candidate: **Raafat Mohammed Abdel Wahab Farahat**

This thesis has been approved for submission by the supervisors:

1 Prof. Dr. Amin Mahmoud Baraka

Signature: A.M. Baraka

2 Prof. Dr. Mamdouh Mahmoud Eissa

Signature: Mamdouh

Prof. Dr. Mohammed Ahmed Badawy

Chairman of Chemistry Department

Faculty of Science, Cairo University

Examiners Names

1. Prof. Dr. Dorte Stachel

Address: Friedrich-Schiller-Universität Jena

Fraunhoferstraße 6

D-07743 Jena - Germany

Fax: (03641) 98502

E-mail: Doerte.stachel@rz.uni-jena.de

2. Prof. Dr. Amin Mahmoud Baraka

Professor of physical chemistry,

Faculty of science

Cairo University

3. Prof. Dr. Fouad Taha Abde- Halem

Professor of physical chemistry,

Faculty of science

El-Menia University

ABSTRACT

Name: Raafat Mohammed Abdel Wahab Farahat

Title of the M.Sc. thesis: Recycling of Mill Scale waste in Steel Making Process

Degree: (Master) thesis, Faculty of Science, Cairo University, 2010

Mill scale is a layer of iron oxides formed on the steel surface due to continuous exposure of hot metal to air. It is one of the by-products produced during steel processing and its generation is about 19-40 kg/ ton of hot rolled product, depending on the process used. The global production of steel during 2008 was 1125 million tons and the mill scale produced was estimated to be around 33 million tons. Mill scale is considered a rich source of iron (up to 74% Fe) with minimal impurities. Extensive research is being carried out for the recovery and utilization of iron oxide from the mill scale. Mill scale is used for magnetic storage, polishing, manufacturing of chemicals as well as pigment and for biomedical applications. The production of sponge iron from mill scale could be considered a highly profitable method of beneficiation. In this study, the reduction of composite pellets produced from mill scale using anthracite coal has been investigated. Laboratory trials were conducted to study the effect of amount of reducing agent, reduction temperature and reduction time on the reduction process. The trial results show possibility to use mill scale as raw material in blast furnace or in direct reduction plants to produce sponge iron containing up to 84% total Fe, 82% metallic Fe and metallization more than 97%.

Recycling of mill scale in electric arc furnace by charging scale/coal mixture into EAF in the charge mix is the highest beneficiation method since it needs no new process. Pilot plant experiments were conducted using a 5Kg submerged electric arc furnace to determine the percent of required reducing agent. Semi industrial trials were also carried out using one 100KVA electric arc furnace (capacity 100 Kg) to investigate the extent of mill scale recycling in EAF steelmaking process. The trial results show possibility to use mill scale in EAF up to 20% of the metallic charge. The best carbon percent for reduction was found to be around 20%.

Key words: sponge iron; mill scale; metallization; steelmaking; electric arc furnace; composite pellets.

Supervisors: Prof. Dr. Amin Mahmoud Baraka

A.M. Baraka

Prof. Dr. Mamdouh Mahmoud Eissa

Mamdouh

Prof. Dr. Mohammed Ahmed Badawy

*Chairman of Chemistry Department
Faculty of Science, Cairo University*

ACKNOWLEDGMENTS

I am deeply grateful to EZZ FLAT STEEL Company for the supporting of this study.

I am deeply grateful to Professor A. Baraka and Professor M. Eissa for their excellent guidance, close supervision and continuous encouragement during the course of this study.

I give my honest thanks to Dr G. Megahed for the guidance and continuous support during the course of this study.

I would like to thank Dr. S. K. Paul and Dr. A. Fathy for revising the thesis and the fruitful discussions during the study.

I would like to thank Mr. Omar Bazaraa for the great assistance and encouragement.

I am extremely appreciative of Mr S. Fadeel, Mr Tarek Latif, Mr Ehab Nabil, Mr. M. Bakry, Mr. A.Kamel, Mr. M. Mekhzangy, Mr. Kamal and Mr. Shaban for their guidance and setting up of the facilities.

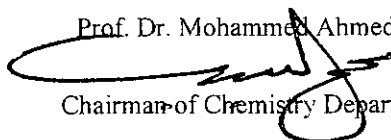
I express my deep thankfulness and appreciation to Mr. M.haridy, Mr. M. Kader, Mr. A. Labib, Mr. A. Wahed for their help and for their suggestions in the thesis.

I would also like to thank Mr. A. Ibrahim, Mr. M. Hassan, Mr. A. Zakarya, Mr. E. Arabi, Mr. A. Mohsen, Mr. A.Gamal, Mr. M. Shaban, Mr. M. Labib, Mr. A. Taha, Mr. S. maghrapy, Mr. M. Zohdy, Mr. E. Salah, Mr. W. Raafat, Mr. A. Sayed, Mr. F. Mohamed for their help in setting up of the facilities.

Qualifying Examinations

Beside the work carried out in this thesis the candidate "Raafat Mohammed Abdel Wahab Farahat" passed successfully a qualifying examination for partial fulfillment of the award of M.Sc. degree (2008) in the following courses:

1. Metallurgy
2. X-Ray and Thermal Analysis
3. Catalysis and Colloids
4. Electrochemistry
5. Thermodynamics
6. Statistical Thermodynamics
7. Cyclic Voltammetry
8. Electrode Kinetics
9. Adsorption
10. Quantum Chemistry
11. Nuclear Chemistry
12. Molecular Structure Elucidation
13. Chelatimetry
14. Inorganic Reaction Mechanism
15. Advanced Inorganic Chemistry
16. Advanced Analytical Chemistry
17. Physical Chemistry of Polymers
18. Solar Energy
19. Group Theory
20. German Language


Prof. Dr. Mohammed Ahmed Badawy
Chairman of Chemistry Department
Faculty of Science, Cairo University

LIST OF CONTENTS

Subject	Page No
ACKNOWLEDGMENTS	
ABSTRACT	
LIST OF CONTENTS	
LIST OF TABLES	
LIST OF FIGURES	
NOMENCLATURES	
LIST OF PUBLICATIONS DURING MASTER COURSE	
Chapter 1 Introduction	1
Chapter 2 Literature Survey	4
2.1 Formation of mill scale	4
2.1.1 Scaling of Steel During Reheating	4
2.1.2 Scaling Rate and Quantity of Mill Scale Generated	6
2.1.3 Factors Affecting Quantity of Mill Scale Generated	7
2.1.4 Scale composition	8
2.1.4.1 Morphology of Oxide Scale	9
2.1.4.2 Chemical and Phase Analysis of Mill Scale.....	9
2.1.4.3 Physical Properties of Mill Scale	10
2.2 Usage of Mill Scale	11
2.2.1 Magnetic Storage.....	11
2.2.2 Polishing	11
2.2.3 Chemicals Manufacturing	11
2.2.4 Pigment Manufacturing.....	12

LIST OF CONTENT

2.2.5	Biomedical Applications	12
2.3	Recycling of Mill Scale into Iron and Steel Making Process.....	13
2.3.1	Iron Making Process	13
2.3.1.1	Agglomeration.....	13
2.3.1.2	Reduction	14
2.3.1.3	Blast Furnace.....	14
2.3.1.4	Direct Reduction	14
2.3.2	Steel Making Process	15
2.3.2.1	Oxygen Steelmaking	15
2.3.2.2	Electric Arc Furnace Steelmaking.....	16
2.4	Comparison Between Iron Ore and Mill Scale	17
2.5	Recycling of Mill Scale Waste in Iron Making Process	18
2.5.1	Pelletizing of Fine Iron Oxides.....	18
2.5.1.1	History and Application of Cold Bonded Pelletizing.....	18
2.5.1.2	Factors Affecting the Properties of Cold Bonded Pellets	18
2.5.1.3	The Role of Calcium Hydroxide in the Production of Iron Oxide (Mill Scale) Pellets	20
2.5.2	Reduction of Mill Scale	21
2.5.2.1	Kinetics of Reduction of Iron Oxides by Carbon.....	21
2.5.2.2	Thermodynamics of Reduction of Iron Oxides by Carbon	23
2.5.2.3	Reduction of Iron Oxides in Solid Wastes Generated by Steelworks	23
2.5.2.4	Effect of Mechanical Milling on Reduction Rate of Mill Scale	26
2.5.2.5	Effect of Carbon Content in DRI/Reduced Mill Scale on Steelmaking Process	26
2.6	Smelting Reduction of Mill Scale	27

LIST OF CONTENT

2.6.1	Slag Foaming in Smelting Reduction and its Control With Carbonaceous Materials	27
2.6.2	Foamy Slag Formation & Various Additive Materials	
2.6.3	Characteristics of Foaming Slag in Smelting Reduction Processes	
2.7	Reduction of Mill Scale in EAF and Slag Composition	30
2.7.1	The Role of Slag	31
2.7.2	Foaming Index for Smelting Reduction Slag	32
2.8	Mill Scale/Coke Contaminants.....	32
2.9	Oxidation of Carbon	33
Chapter 3	Experimental	35
3.1	Raw Materials Reduction and Melting Equipments.....	35
3.1.1	Muffle Furnace.....	35
3.1.2	Submerged Arc Furnace (Pilot).....	35
3.1.3	Electric Arc Furnace	35
3.2	Raw materials preparation equipments.....	36
3.2.1	Vibrating Mill.....	36
3.2.2	Briquetting Machine.....	36
3.2.3	Vibratory Sieve Shaker	36
3.2.4	Drying Oven.....	36
3.3	Raw Materials Analysis Equipments.....	36
3.3.1	Total Carbon Analyzer	36
3.3.2	Carbon and Sulfur Analyzer.....	37
3.3.3	Oxygen and Nitrogen Analyzer.....	37
3.3.4	X-ray Fluorescence Spectrometer	38
3.3.5	X-ray Diffraction Spectrometer	38

LIST OF CONTENT

3.3.6	Optical Emission Spectrometer	38
3.3.7	Wet Chemistry Method	38
3.4	Raw Materials.....	39
3.4.1	Mill scale	39
3.4.2	Anthracite Coal	40
3.4.3	Burnet Lime.....	40
3.4.4	Steel Scrap.....	41
3.5	Experimental Work Execution Program	42
3.5.1	Studying the Effect of Amount of Reducing Agent, Reduction Temperature and Reduction Time	42
3.5.1.1	Effect of Amount of Reducing Agent,	42
3.5.1.2	Effect of Reduction Temperature	42
3.5.1.3	Effect of Reduction Time	43
3.5.2	Determination of the Optimum Carbon Percent Required for Reduction.....	43
3.5.3	Amount of Mill Scale to be Added with Charge Mix	43
Chapter 4	Results and Discussions	45
4.1	Reduction of Mill Scale (production of reduced iron from mill scale)	45
4.1.1	Effect of Reducing Agent.....	46
4.1.2	Effect of Temperature	49
4.1.3	Effect of Reduction Time	52
4.2	Recycling of Mill Scale into EAF	57
4.2.1	Determination of Anthracite Coal Percent Required for Reduction of Mill Scale	57
4.2.2	Determination of Percent of Mill Scale Used Along with Scrap in EAF Charge Mix	59
4.2.3	Economical Aspects	64