The Complete Book on Ferroalloys (Ferro Manganese, Ferro Molybdenum, Ferro Niobium, Ferro Boron, Ferro Titanium, Ferro Tungsten, Ferro Silicon, Ferro Nickel, Ferro Chrome)

An alloy is a mixture or solid solution composed of metals. Similarly, Ferroalloys are the mixture of Iron with high proportion of other elements like manganese, aluminium or silicon. Alloying improves the physical properties like density, reactivity, Young's modulus, electrical and thermal conductivity etc. Ferroalloys thus show different properties as mixture of different metals in different proportion exhibit a wide range of properties. Also, Alloying is done to alter the mechanical properties of the base metal, to induce hardness, toughness, ductility etc.

The main demand of ferroalloys, nowadays is continuously increasing as the major use of such products are in the field of civil construction; decorative items; automobile; steel industry; electronic appliances. The book provides a wide idea to readers about the usage of appropriate raw material and the treatment involved in the processing of raw material to final produce, safety, uses and properties of raw material involved in the processes.

This book concisely presents the core principles and varied details involved in processing of ferroalloys. The work includes detailed coverage of the major products like ferroaluminium, ferrosilicon, ferronickel, ferromolybdenum, ferrotungsten, ferrovanadium, ferromanganese and lesser known minor ferroalloys. Progress in thermodynamics and physico-chemical factors in ferroalloy production has developed rapidly during the past twenty-five years or so. The book presents the principles and current knowledge of processes in the production of various ferroalloys.

The production of a particular ferroalloy involves a number of processes to be followed in order to give the alloy desired physical and mechanical properties. The slight difference in the temperature or heating or
composition can lead to entirely different alloy with different properties. This book is not only confined to the different processes followed in the production of ferroalloys but also describes the processes used and other information related to product, which are necessary for the manufacturer’s knowledge. Also, the book gives the reader appropriate knowledge regarding the selection the best of available raw materials.

Contents

1. INTRODUCTION
   Theory
   Terminology
   Interstitial Alloy
   Classification of Alloys
2. FERROALLOYS
   Ferroalloys
   Ferro Aluminium
   Ferro Boron
   Ferro Chromium
   Ferro Manganese
   Ferro Molybdenum/Molybdic Oxide
   Ferro Molybdenum Molybdc Oxide
   Ferro Niobium
   Ferro Phosphorus
   Ferro Selenium
   Ferro Silicon
   Ferro Silico Manganese
   Ferro Silicon Magnesium
   Ferro Silicon Zirconium
   Ferrous Sulphide
   Ferro Titanium
   Ferro Vanadium
   Calcium Silicon Manganese
   Calcium Silicon
   Ferro Tungsten
   Iron
3. PRODUCTION OF FERROALLOYS
   Primary Processes
   Secondary Processes
   Applied Processes and Techniques
   Ferro-chrome
   Raw Materials
   Pre-treatment Techniques
   Production of Ferro-chrome and Silico-chromium
   High-carbon Ferro-chrome
4. PRODUCTION OF FERRO MANGANESE
   Raw Materials
   Pre-treatment Techniques
   Production of Ferro-manganese and Silico-manganese
   High-carbon Ferro-manganese
   Medium-carbon Ferro-manganese
Low-carbon Ferro-manganese
Silico-manganese
Types of Ferromanganese
Production of Ferromanganese
Production of High Carbon Ferromanganese
Blast Furnace Production
Electric Furnace Production
High Manganese Slag Practice
Discard Slag Practice
Production of Medium-Carbon Ferromanganese
Silicothermic Production of Medium-Carbon Ferro-manganese
Production of Medium-Carbon Ferromanganese by Oxygen Refining of High-Carbon Ferromanganese
Production of Low-Carbon Ferromanganese
Thermodynamics of Reduction of Manganese Oxides
High Carbon Ferromanganese Slags
Refining of Ferro Manganese
Introduction
The Sintering Pilot Facility
Preparation of the Sinter Mix
Sintering
Characterization
Performances
Eramet Research Mn Alloys Smelting Pilots
Background
Pilot Campaign Approach
Transfer of the Pilot Results to the Plants
The New Pyrometallurgy Piloting Facility
Constraints and Stakes for the New Facility
Definition of the Power Supply Characteristics
Design of the New Power Supply
Design of the Furnace
Furnace Diameter
Furnace Height
Side Wall Furnace Lining
Hearth Lining and Bottom Electrode
5. PRODUCTION OF FERRO MOLYBDENUM
Production of Ferro-molybdenum
Raw Materials
Carbo-thermic Production of Ferro-molybdenum
Metallo-thermic Production of Ferro-molybdenum
6. PRODUCTION OF FERRO NIOBIUM
Introduction
Basic Technology of FeNb Manufacturing
The Evolution of Ferro-niobium Manufacturing
Recent Developments in Ferro-niobium Manufacturing
Pyrometallurgical Refining of Concentrate
Sintering
Electric Arc Furnace Smelting
Ferro-Niobium Production
Crushirm and Packaging
Future Developments in Ferro-niobium Manufacturing
7. PRODUCTION OF FERRO BORON
Ferro-niobium
8. PRODUCTION OF FERRO TITANIUM

Transferred-arc Plasma Furnaces

The Reduction of TiO2

Enthalpy Considerations

Constitution of the Charge

Choice of Raw Material

Reasons for the Choice of a d.c. Transferred-arc Plasma Furnace

Small-scale Batch Tests in a 50 kVA Water-cooled Furnace

Equipment and Procedures

Objectives of the Experimental Work

Interpretation of Results of the Small-scale Tests

Large-scale Continuous Tests

Further Experimental Work

Melting Point of the Alloy

The Addition of Iron to the Charge

Further Furnace Modifications

Small-scale Sealed Furnace

9. PRODUCTION OF FERRO TUNGSTEN

Production of Ferro-tungsten and Tungsten Melting Base

Tungsten Melting Base (TMB)

Ferro-titanium

10. PRODUCTION PROCESS OF FERRO SILICON

Raw Materials

Production of Ferro-silicon, Silicon Metal and Silico-calcium

Ferro-manganese and Manganese Alloys

Refining of Ferro-silicon

Introduction

Processes for the Refining of Ferro-silicon

Solid/Liquid Oxide Method

Oxidising Treatment with Gaseous Oxygen/Enriched Air

Refining with Chlorine Gas

Purification by Carbon Dioxide Injection Method

Typical Results from Studies on the Refining of Ferrosilicon Carried Out at NML

The Chlorine Donor Method

The Carbon Dioxide Injection Method

The Oxygen Injection Method

Conclusions

Ferro Silicon Operation at IMFA—A Critical Analysis

Introduction

Quality Norms of Raw Materials at IMFA

Quality Deviations Experienced By IMFA

Ferro Silicon Process Description

Formation of Slags in Ferro Silicon

Types of Slag

Characteristics of Different Kinds of Slags

Incompletely converted charge (Slagging)

SiC with Si at the Bottom

Crusts of Sintered Charge Materials in the Upper Parts of the Furnace

Description of the Furnace

Operating conditions of the Furnace

Problems in the Furnace
Observations on the Deteriorating Conditions
Introduction of Lime Stone in the Burden
Variation in the Slag Properties
Operating Data
Improvements in the Furnace Performance
Comparison of Output Alloy Analysis
Detrimental Effects of CaO in the Burden Charge
Overcoming the Problem of Alloy Disintegration
Remarks and Conclusion
Controlled solidification of Ferrosilicon
Introduction
Experimental Work
Equipment
Casting
Investigation
Results and Discussion
Primary Silicon Grains
Eutectic
Distribution of Aluminium and Calcium
Cracking
Porosity
Conclusions
11. PRODUCTION OF FERRO NICKEL
Raw Materials
Production of Ferro-Nickel from Primary Raw Material
Production of Ferro-Nickel from Secondary Raw Material
“Ferronickel Ladle Furnace Refining Process”
Introduction
Process Description
Equipment
Process Theory
Oxidation
Desulfurization
Development
Oxidation
Desulfurization
Observation
Conclusions
Design of a Modern Large Capacity FeNi Smelting Plant
History, Applications and Trends
Experiences in FeNi-Smelters and Rectangular Furnaces
General Trends in the FeNi-production; Industry Demand
Design Principles of Large Scale FeNi-smelters
Calcine Transport System
Submerged Arc Furnace (SAF)
Principle of Submerged Arc Furnaces
Design Principle of a Large-Scale Rectangular FeNi-smelter
Process and Furnace Dimensioning
3-D Fluid Dynamic Coddelling
Control and Operation
Furnace Integrity and Cooling
Further Application of Side Wall Copper Cooling for Rectangular Furnace
Additional Technological Highlights
SMS DEMAG Tapping Machines
Off-gas System
Plant Start Up
Refining of FeNi
Conclusions and Outlook

12. PRODUCTION PROCESS OF FERRO CHROME
Medium-Carbon Ferro-Chrome
Low-Carbon Ferro-Chrome
Silico-Chromium
Ferro-Silicon and Silicon Alloys
Various Techniques to Produce Low Carbon Ferrochrome

Introduction
Problems of Carbon
Decarburization
Decarburization Techniques
Conventional Techniques
Refining of Ferrochrome by Chromium Ore
Refining of Ferrochrome by Blowing Oxygen
Refining of Ferrochrome with the Presence of Silica
Silicothermic Process for the Production of Low Carbon Ferrochrome
Production of Carbon Free Ferrochrome by Aluminothermic Method
Non Conventional Techniques
Decarburization of Solid Ferrochrome
Decarburization using Oxidizing Gas Mixture
Production of Low Carbon Ferrochrome from Chromite Ore
Khalafala’s Method
Other Methods
Conclusion

Modern Practices of Post Taphole Operation in Ferro Chrome Production and its Advantages
Introduction
Mechanized Flow Sheet for Handling High Carbon Ferro Chrome Metal 62000 T/Y and Corresponding Slag
Post Taphole Concept
Taphole Installation
Conventional and Freeze Lining Concept
Taphole Configuration
Taphole Lining
Taphole Operation
Temperature Monitor and Control
Important Aspect for Effective Taphole Operation
Movable Tapping Platform
Receptacles
Skimming System
Casting, Crushing, Screening & Handling of Finished Product
Liquid Slag Handling and Disposal
Granulation Process
Recovery of Entrapped Metal from the Slag

13. PRODUCTION OF FERROALLOY FROM SECONDARY RAW MATERIALS
Raw Material and Raw Material Preparation
Preprocessing
Mixing and Drying (Plasma Dust Process only)
Submerged arc Furnace Process
Plasmadust Process

NIIR Project Consultancy Services (NPCS) 6/11
14. PRODUCTION TECHNIQUES OF FERROALLOYS

General
Process Description
Submerged Electric Arc Process
Exothermic (Metallothermic) Process
Electrolytic Processes
Emissions and Controls
Aluminothermic Reduction of Oxides with Liquid Start
Description
Innovative Aspect and Main Advantages
Areas of Application
Atomisation of Ferroalloys
The Atomisation Process
Why Atomise (or Granulate)?
To Produce a Saleable, Dust-free Brittle Product
To Produce a Small-sized Ductile Product
To Produce a Reactive Intermediate Product
To Produce a “Rapidly Solidified” Product
To Produce Special Powder Products
Atomisation Processes
Water Atomisation
Gas/Air Atomisation
Centrifugal Atomisation
Atomised Products and Their Markets
Ferrosilicon 15% Dense Medium
Ferrosilicon 45% for the Welding Industry
Ferromanganese for the Welding Industry
Injectables
Higher Melting Alloys
Silicon
Process Selection
The Improvements to Copper Casting Machine for Ferroalloys
Brief Description of Casting Machine
Artificial Vision System
Monitoring of Main Parameters of the Casting
New Improvements of the Casting Machine
Advantages of the Casting Machine
From the Metal Quality Point of View
From the Economical Point of View
Application of Fluid Bed in Ferroalloy Industry
Introduction
Particle Characterization and Flow Regimes
Fluidized Beds in the Ferroalloy Industry
Ferrochromium Production
Ferronickel Production
Ferromanganese Production
Conclusions
Low Cost Ferroalloy Extraction in DC-ARC Furnace at Middleburg Ferrochrome
Introduction
The Process Principle of Ferroalloy Recovery
Description of Electrical System in Place
Designing the Electrical System According the Process’ Need
Keeping the Arc under Control
Advantage of the DC-arc for Ferroalloy Recovery
The Furnace’ Conductive Bottom
The Merits of the DC-arc
Optimized Furnace Design
Refractory Lifetime and General Maintenance
Power Quality Considerations
System Overview
What is Flicker?
Flicker Calculation and Measurements
Harmonics
Power Factor
DC Reactor Size
Flicker Mitigation
Production Increase
Thermodynamics Applied to Ferroalloys Smelting
Introduction
Thermodynamic Data
Chromium
Titanium
Niobium
Vanadium
Thermodynamic Slag Models and Computer Software
Regular Solution Models
Sublattice Models
Quasi-chemical Models
Other Models
Optical Basicity
Industrial Applications
Dephosphorization of Ferromanganese Alloys
Effect of Slag Composition
Effect of Ferroalloy Composition
Effect of Temperature
Dephosphorization under Reducing Conditions
Titanium Behavior Description in Silico-manganese Alloys
Thermodynamic Modeling
Industrial Application
Conclusions
Techno Economics of Recovering Ferroalloys from Dust and Slag
Introduction
Technology
Metal Recovery from Slags
Metal Separation
Metal Fines Remelting/Refining
Metal Recovery from EAF Dust
Hydrometallurgical Processes
Pyrometallurgical Processes
Carbon Steel Dusts
Stainless Steel Dusts
Metal Fines Remelting/Refining
Metal Recovery from EAF Ducts
Pyrometallurgical Processes
Carbon Steel Dusts
Stainless Steel Dusts
Conclusion
Atomisation of Ferroalloys
The Atomisation Process
Why Atomise (or Granulate)?
To Produce a Saleable, Dust-free Brittle Product
To Produce a Small-sized Ductile Product
To Produce a Reactive Intermediate Product
To Produce a “Rapidly Solidified” Product
To Produce Special Powder Products
Atomisation Processes
Water Atomisation
Gas/Air Atomisation
Centrifugal Atomisation
Atomised Products and Their Markets
Ferrosilicon 15% Dense Medium
Ferrosilicon 45% for the Welding Industry
Ferromanganese for the Welding Industry
Injectables
Higher Melting Alloys
Silicon
Some considerations of future developments in ferroalloy furnaces
Introduction
Present Constraints on the Scale up of Submerged-arc Furnaces
Scale up of the Electrical Circuit
Scale up of the Electrodes
The Supply of Electrical Energy
The Smart Grid
Some Possible Ways for the Ferroalloy Industry to Adapt to Changes
Submerged-arc Furnaces
Plasma Furnaces
Constraints on Electrodes
Swinging the Load
A Larger Furnace
Conclusions
SHS-Technology of Ferroalloys Nitriding
Introduction
Ferrosilicon Nitride Synthesis
Combustion Temperature
Filtration Combustion
The Phase Composition and the Structure of the Products
The Industrial Production
Conclusions
Changing Requirements of Ferroalloys for Flat Products
Introduction
Manganese (MN) Ferroalloys
Vanadium (V) Ferroalloy
Other Ferroalloys
Ti Sponge & Low Al Fe-Ti
Fe-Al lump
Fe-Nb lump
Plasma Technology in Ferroalloy Processing
Introduction
Plasma - A Basic Definition
Plasma Furnaces for Ferroalloys Smelting
Process Chemistry Consideration
Thermodynamics
Kinetics and Mechanisms
Slag Chemistry
Energy Related Issues
Power Input and Furnace Type
Energy Requirement and Distribution
Energy Efficiency
Advantages over Conventional Process
Relevance in the Indian Context
Application of Magnesia Ramming Material in Ferroalloy Refining Furnace
Introduction
Development of Ramming Material
Characteristics of Ramming Material in Ferroalloy Furnace
High Smelting Temperature
Good Sintering Property
Homogeneous and Rational Structure
Mineral Compositions and Effect of C2F
Mineral Composition
The Effect of C2F
Furnace Dissection Analysis
Analyses of Erosion Mechanism of Furnace Bottom
Conclusions

15. POLLUTION CONTROL IN FERROALLOY PRODUCTION
Introduction
Pollution in Ferroalloys Production
Assessment of Pollution
Selection of a Pollution Control Device
Equipments Employed for Pollution Control in Ferroalloy Production
Process of Pollution Control in Ferroalloys Production
Illustrations of Stack emissions from a Few Ferroalloy Plants
Emissions of Particulates and Dust from Ferroalloy Furnaces
Illustrations of Pollution Control Systems in Ferroalloys Production
Two Stage Venturi Scrubbing System for Air Pollution Control from Closed Ferroalloy Furnace
Conclusions and Remarks

About NIIR

NIIR PROJECT CONSULTANCY SERVICES (NPCS) is a reliable name in the industrial world for offering integrated technical consultancy services. NPCS is manned by engineers, planners, specialists, financial experts, economic analysts and design specialists with extensive experience in the related industries.


NPCS also publishes varies process technology, technical, reference, self employment and startup books, directory, business and industry database, bankable detailed project report, market research report on various industries, small scale industry and profit making business. Besides being used by manufacturers, industrialists and entrepreneurs, our publications are also used by professionals including project engineers, information services bureau, consultants and project consultancy firms as one of the input in their research.

Our Detailed Project report aims at providing all the critical data required by any entrepreneur vying to venture into Project. While expanding a current business or while venturing into new business, entrepreneurs are often faced with the dilemma of zeroing in on a suitable product/line.