AN OVERVIEW ON HIGH MANGANESE STEEL CASTING

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TABLE OF CONTENTS

- Introduction
- Manufacturing process of Hadfield steel
- The influence of chemical composition on Hadfield steel
- Challenges and Development of Hadfield steel based on service life
- Project Plan
INTRODUCTION

- The history of sir Robert Abbott Hadfield
- Manganese Ore reserves in SA and grades of manganese
- Production of manganese ore in the world and the use of manganese as an alloy element
HISTORY OF SIR ROBERT ABBOTT HADFIELD

- High percentage of manganese was added to steel
- He added 7 – 20% of manganese to steel, according to the type of application.
- The carbon to manganese ratio was 1:10
- The steel showed superior properties when having a composition of 1-1.4% C and 10-14% Mn
Why Manganese Steel

- He invented the steel for good toughness and extreme hardness.
- Good work-hardening capacity
- The is no need to strengthen by:
  - Forging, hammering, Rolling, quenching and tempering
Global Manganese reserve for Mn ore (2009)

Figure 1: Global Manganese reserve 2009
MANGANESE ORE PRODUCTION AND STEEL PRODUCTION FOR 2009

Figure 2: Manganese ore production for 2009

Figure 3: Steel production for 2009
Manufacturing process of Hadfield steel

- Importance of steel scrap and Manganese returns
- Effect of melting and pouring temperature
- Heat treatment of manganese steel
- Mechanical properties of Hadfield steel
STEEL SCRAP AND MANGANESE RETURNS

Clean steel scrap

Manganese returns

Figure 4: Clean scrap

Figure 5: Manganese returns
**Effect of Pouring Temperature**

<table>
<thead>
<tr>
<th>HEAT</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEMP °C</td>
<td>1550</td>
<td>1450</td>
<td>1380</td>
</tr>
</tbody>
</table>

Figure 6: Microstructure of Hadfield manganese steel poured at three different temperatures.
HEAT TREATMENT OF MANGANESE STEEL

Figure 7: Heat treatment cycle
MECHANICAL PROPERTIES OF HADFIELD STEEL

Table 1: Mechanical properties of 13% Manganese steel

<table>
<thead>
<tr>
<th>YS MPa</th>
<th>UTS MPa</th>
<th>Elongation %</th>
<th>Modulus</th>
<th>Hardness Brinel</th>
<th>Impact J/cm²²</th>
</tr>
</thead>
<tbody>
<tr>
<td>414</td>
<td>995</td>
<td>40%</td>
<td>186x10³</td>
<td>200</td>
<td>112</td>
</tr>
</tbody>
</table>

Figure 8: Stress-strain curve for 13%Mn
The influence of chemical composition on Hadfield steel

- Chemical composition of Hadfield steel
- The Influence of carbon and manganese
- Effect of carbide forming element
CHEMICAL COMPOSITION OF HADFIELD STEEL

Table 2: Chemical composition of Hadfield steel

<table>
<thead>
<tr>
<th></th>
<th>Carbon</th>
<th>Manganese</th>
<th>Silicon</th>
<th>Chromium</th>
<th>Phosphorus</th>
<th>Sulphur</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1-1.4</td>
<td>11-14</td>
<td>0.5</td>
<td>-</td>
<td>0.005max</td>
<td>0.005max</td>
</tr>
</tbody>
</table>

Excess carbon will increase yield strength while excess of manganese will decrease it.
Carbon and Manganese content in manganese steels are not only interrelated, they are also related to the casting thickness.

Figure 9: Effect of carbon content on yield strength and elongation
PHASE DIAGRAM FOR A STEEL CONTAINING 13% MANGANESE

Figure 10: Phase diagram of steel containing 13% manganese
Figure 11: Effect of chromium content in 13% manganese
Figure 12: Effect of vanadium content in 13% manganese
Challenges of Hadfield steel based on service life

- Manganese steel is widely used:
  - Earthmoving
  - Mining
  - Quarrying
  - Oil and gas drilling
  - Steel making
  - Dredging

Mechanical properties for high manganese steel will vary with:
- Application and type of wear involved.
APPLICATION OF HADFIELD STEEL

Figure 13: Jaw

Figure 14: Mantle

Figure 15: Shredder Hammer

Figure 16: Excavator buckets
TYPES OF WEAR

- Gouging abrasion (Primary crusher)
- High-Stress grinding abrasion.
- Erosion or Low-Stress scratching abrasion.

Figure 17: Erosion
Figure 18: High-Stress grinding abrasion
Figure 19: Gouging abrasion
Many considerations are involved in the selection of the proper grade of abrasion-resisting steel. These include:

- Type of service
- The type of material being handled
- The type of abrasion
- The economics of operation
Figure 20: Type of service

Figure 21: Type of material being handled

Figure 22: The type of abrasion
The rate of work hardening is affected due to the crushing efficiency of the modern jaw and cone crushers.

It is also insufficient for excavator buckets and loader shovels when loading fine grain materials.
CONCLUSION

- An overview of high manganese steel casting was conducted; the emphasis was based on the effect of chemical composition on Hadfield steel where it was shown how chemical composition can affect the final mechanical properties of the steel.

- The manufacturing process of high manganese steel casting was analysed and this includes the important of foundry steel scrap, the effect of high melting temperature, the heat treatment cycle for manganese steel and the final mechanical properties of the said steel.
DEVELOPMENT
OF
HIGH MANGANESE STEEL CASTING
PROJECT PROPOSAL
Table Of Content

• Introduction
  ✓ Technical development
  ✓ Objective
  ✓ Justification
• Research methodology
• Experimental Procedure
Technical development

- The development was based on adding different vanadium and chromium content into molten manganese steel.
- This development improved the hardness and wear resistance of high manganese steel used in the mining industry.
Research Objective

1. Reinforce vanadium and chromium carbide particles into the austenitic matrix
2. Increasing the hardness and wear resistance of austenitic manganese steel used in the mining industry.
3. Prolonging the service life of wear resistant high manganese steel used for secondary and tertiary crushers.
Justification of research

- If the rate of work hardening and the wear resistance are not sufficient for modern jaw and cone crushers the following will result:
  - Loss of material
  - Service life is compromised
  - Equipment inefficiency
  - Low production rate
  - High cost
Justification of research

• The reinforcement of carbide particles within the austenitic matrix will bring forth an increase in hardness and wear resistance for secondary and tertiary crushing system.

• This increase in hardness and wear resistance for secondary and tertiary crushing system will make the service life of the component to be prolonged.

• Thus the overall objective of this research will save on cost to the company because component will have a longer service life.
RESEARCH METHODOLOGY

- Batch makeup

Table 1: Specified Chemical composition for Mn steel alloyed with vanadium (Phase 1)

<table>
<thead>
<tr>
<th></th>
<th>C%</th>
<th>Mn%</th>
<th>Si%</th>
<th>Cr%</th>
<th>V%</th>
<th>S%</th>
<th>P%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hadfield</td>
<td>1-1.4</td>
<td>11-14</td>
<td>0.1-0.5</td>
<td>0.5max</td>
<td>-</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Alloy1</td>
<td>1-2</td>
<td>11-14</td>
<td>0.5-1.00</td>
<td>0.5max</td>
<td>2</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Alloy2</td>
<td>1-2</td>
<td>11-14</td>
<td>0.5-1.00</td>
<td>0.5max</td>
<td>5</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Alloy3</td>
<td>1-2</td>
<td>11-14</td>
<td>0.5-1.00</td>
<td>0.5max</td>
<td>8</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>

Table 2: Specified Chemical composition for Mn steel alloyed with Chromium (Phase 2)

<table>
<thead>
<tr>
<th></th>
<th>C%</th>
<th>Mn%</th>
<th>Si%</th>
<th>Cr%</th>
<th>S%</th>
<th>P%</th>
</tr>
</thead>
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<tr>
<td>Hadfield</td>
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<td>0.5max</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Alloy1</td>
<td>1-2</td>
<td>11-14</td>
<td>0.5-1.00</td>
<td>2</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Alloy2</td>
<td>1-2</td>
<td>11-14</td>
<td>0.5-1.00</td>
<td>5</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>Alloy3</td>
<td>1-2</td>
<td>11-14</td>
<td>0.5-1.00</td>
<td>8</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>
**Experimental Procedure**

- Phase 1: Alloying with vanadium at a range of 1%- 2% carbon content
- Phase 2: Alloying with Chromium at a range of 1%- 2% carbon content

**Diagram:**
- Melting
  - Hadfield Steel
  - Alloy 1
  - Alloy 2
  - Alloy 3
- Heat Treatment
- EDS Cutting
- Optical Microscope
- SEM
- Micros & Mechanical Properties
- Hardness (Macro Hv)
- Impact Test
- Wear Test
The model will have a theoretical equation of a plane of the form:

\[ Ax + By + Cz = d \]

Where \( x = \%C \) \( y = \%V \) and \( Z \) will be either Hardness number, impact energy or wear rate.

- From this modelling one can create an alloy theoretically.
QUESTIONS?