Pig Iron: a value-adding feedstock for ferrous casting

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Presentation overview

• What is IIMA and what does it do?
• Types of merchant pig iron
• Pig iron production process
• Merchant pig iron supply, trade and value chain
• Benefits of using pig iron in ferrous casting
• Prevention of value leakage in transport, handling & storage
What is IIMA?

Created in 2011 as the unified voice of the ore-based metallics industry
# Types of merchant pig iron

<table>
<thead>
<tr>
<th>Pig iron Type</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>S</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic</td>
<td>3.5 - 4.5</td>
<td>≤1.25</td>
<td>≤1.0</td>
<td>≤0.05</td>
<td>0.08-0.15</td>
</tr>
<tr>
<td>Foundry</td>
<td>3.5 - 4.1</td>
<td>2.5 - 3.5</td>
<td>0.5 - 1.2</td>
<td>≤0.04</td>
<td>≤0.12</td>
</tr>
<tr>
<td>HPPI/Nodular</td>
<td>3.7 - 4.7</td>
<td>0.05 -1.5</td>
<td>≤0.05</td>
<td>≤0.025</td>
<td>≤0.035</td>
</tr>
</tbody>
</table>

Various tighter specifications are available from specific producers.

Ingots typically weigh 7.5 to 12 kg.

Dimensions vary from producer to producer, e.g. 17.5 x 13.5 x 16 cm, 20 x 15 x 5 cm
Pig iron production process – BF route

The Blast Furnace
Charge: Iron ore, coke, limestone

Carbon dioxide reacts with coke:
\[ \text{CO}_2(g) + \text{C}(s) \rightarrow 2\text{CO}(g) \]

Hot air reacts with coke:
\[ \text{C}(s) + \text{O}_2(g) \rightarrow \text{CO}_2(g) \]

Reduction of iron ore:
\[ 3\text{CO}(g) + \text{Fe}_2\text{O}_3(s) \rightarrow 2\text{Fe}(l) + 3\text{CO}_2(g) \]

Limestone decomposes and slag forms:
\[ \text{CaCO}_3(s) \rightarrow \text{CaO}(s) + \text{CO}_2(g) \]
\[ \text{CaO}(s) + \text{SiO}_2(s) \rightarrow \text{CaSiO}_3(l) \text{ slag} \]

Hot waste gases
Hot air blast
Molten iron
Molten slag
250°C
700°C
850°C
1500°C

Image: DK Recycling
Image: Paul Wurth
Pig iron production process – ilmenite route

Richards Bay Minerals production flowsheet

Source: RBM Sustainable Development Report 2015

Image: Rio Tinto Iron & Titanium, Sorel Tracy

Image: Richards Bay Minerals
Merchant pig iron value chain

TYPICAL CASH COST FOR BRAZILIAN PIG IRON DELIVERED TO US MIDWEST FOUNDRY

- 12% FOB cost
- 4% Iron ore
- 4% Charcoal
- 12% Other cash costs
- 9% Logistics to FOB
- 13% Ocean Freight
- 13% Logistics USA

Typical cash cost for Brazilian pig iron delivered to US Midwest foundry.
Factors affecting pig iron quality

- Raw material specification: iron ore, coke, etc.
  - P, Si, Mn, trace elements, etc.
- Consistency of raw material quality
- Accuracy of raw material analysis
- Production process control
- Material handling and storage
  - fines & chips, dust, rust
Merchant pig iron trade

Cross border Pig Iron trade [mt]

<table>
<thead>
<tr>
<th>Year</th>
<th>Imports</th>
<th>Exports</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>17.5</td>
<td>17.8</td>
</tr>
<tr>
<td>2008</td>
<td>13.4</td>
<td>15.1</td>
</tr>
<tr>
<td>2009</td>
<td>11.7</td>
<td>11.4</td>
</tr>
<tr>
<td>2010</td>
<td>10.8</td>
<td>10.7</td>
</tr>
<tr>
<td>2011</td>
<td>12.8</td>
<td>13.1</td>
</tr>
<tr>
<td>2012</td>
<td>12.1</td>
<td>12.1</td>
</tr>
<tr>
<td>2013</td>
<td>12.7</td>
<td>12.1</td>
</tr>
<tr>
<td>2014</td>
<td>12.9</td>
<td>12.2</td>
</tr>
<tr>
<td>2015</td>
<td>12.6</td>
<td>12.0</td>
</tr>
<tr>
<td>2016</td>
<td>11.7</td>
<td>12.0</td>
</tr>
<tr>
<td>2017</td>
<td>12.0</td>
<td>12.2</td>
</tr>
</tbody>
</table>
Merchant pig iron export distribution

Merchant pig iron exports 2017 - total 12.2 mt

- Russia, 4.8, 39.3%
- Brazil, 2.3, 18.6%
- Ukraine, 2.3, 19.1%
- India, 0.7, 5.3%
- South Africa, 0.5, 4.4%
- others, 1.6, 13.1%

www.afsinc.org  │ CastingConnection.afsinc.org  │ @AmerFoundrySoc
Merchant pig iron import distribution

Merchant pig iron imports 2017 - total 12.0 mt

- USA, 5.1, 43%
- Italy, 1.7, 14%
- Turkey, 1.0, 8%
- Spain, 0.2, 2%
- Taiwan, 0.4, 3%
- South Korea, 0.2, 2%
- others, 3.4, 28%
Merchant pig iron supply

- **Russia**: total 5.7 mt in 2017
  - Tulachermet 2.2 mt
  - Kosaya Gora 0.3 mt
  - Ural Steel 2.0 mt
  - NLMK Lipetsk 0.6 mt

- **China**: multiple producers

- **India**: total exports 0.7 mt 2017
  - Vizag Steel
  - NINL/MMTC
  - private sector mini-BF's

- **Brazil**: 106 BF's
  - 106 BF's
  - Production 2017: 4.0 mt
  - Exports 2017: 2.3 mt
  - Effective capacity: 5 mtpy

- **Ukraine**: total 2.4 mt in 2017
  - Ilyich 1.3 mt
  - DMP 0.3 mt
  - AM 0.4 mt

- **Ukraine TiO₂ slag producers' merchant capacity**: QIT Canada [±0.3 mtpy]
  - Tronox Sands South Africa [±0.7 mtpy]
  - Tizir Norway [±0.1 mtpy]

Others: Turkey, Poland, Malaysia, Vietnam, Iran
New pig iron supply projects in North America

- North Atlantic Iron Corp: planning 0.425 mt merchant pig iron plant, based on purchased iron ore pellets, considering two locations, in Quebec and Ohio.

- Republic Steel / ERP Iron Ore joint venture: plan is to restart the blast furnace at Lorain, OH and sell 1 mt pig iron, based on pellets from ERP’s Reynolds, IN pellet plant.

- BlackRock Metals: plans to exploit V- and Ti- bearing magnetite and ilmenite deposits in Chibougamau, Quebec to produce ferro-vanadium, TiO₂ feedstock and potentially 0.525 mt high purity pig iron
Benefits of using pig iron in ferrous casting

- Being manufactured from selected iron ore or ilmenite sources, Pig Iron has a consistent and predictable chemical and physical analysis which allows better control and variability of melting, tighter control of final casting composition and removes the requirement for costly heat treatment of castings.

- Pig Iron is low in metallic impurities such as copper, tin, chromium, nickel, vanadium, etc. which may be detrimental to the manufacture of certain cast iron qualities and, as such, dilutes such impurities in scrap or enables greater use of cheaper, lower grade scrap.

- Pig Iron is virtually 100% metallic = minimal slag (scrap can be <90% metallic iron) & minimal yield loss.
Comparison of residuals

Typical residual contents in scrap and OBM’s

<table>
<thead>
<tr>
<th>Category</th>
<th>Grade</th>
<th>Cu %</th>
<th>Sn %</th>
<th>Cr, Ni, Mo %</th>
<th>Source: EuRIC - EFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old scrap</td>
<td>E3</td>
<td>≤ 0.250</td>
<td>≤ 0.010</td>
<td>Σ ≤ 0.250</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E1</td>
<td>≤ 0.400</td>
<td>≤ 0.020</td>
<td>Σ ≤ 0.300</td>
<td></td>
</tr>
<tr>
<td>New scrap, low residuals, uncoated</td>
<td>E2</td>
<td>Σ ≤ 0.300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E8</td>
<td>Σ ≤ 0.300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E6</td>
<td>Σ ≤ 0.300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shredded</td>
<td>E40</td>
<td>Σ ≤ 0.250</td>
<td>Σ ≤ 0.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel turnings</td>
<td>E5M</td>
<td>≤ 0.400</td>
<td>Σ ≤ 0.030</td>
<td>Σ ≤ 1.0</td>
<td></td>
</tr>
<tr>
<td>High residual scrap</td>
<td>EHRB</td>
<td>≤ 0.450</td>
<td>Σ ≤ 0.030</td>
<td>Σ ≤ 0.350</td>
<td></td>
</tr>
<tr>
<td></td>
<td>EHRM</td>
<td>≤ 0.400</td>
<td>Σ ≤ 0.030</td>
<td>Σ ≤ 1.0</td>
<td></td>
</tr>
<tr>
<td>Fragmented scrap from incineration</td>
<td>E46</td>
<td>≤ 0.500</td>
<td>≤ 0.070</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ore-based metallics *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>pig iron, DRI, HBI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.002</td>
</tr>
</tbody>
</table>
* Dependent on source iron ore                |       |            |            |              | trace               |

| Σ ≤ 0.015 |
Benefits of using pig iron in ferrous casting

- Pig iron will facilitate the production of as-cast ferritic ductile grades and in particular those grades which require good low temperature impact properties.
- The use of pig iron in the electric induction furnace will allow accurate and consistent charge calculations and provide faster melting rates.
- Pig iron is available in a variety of qualities to suit all iron foundry requirements.
Benefits of using pig iron in ferrous casting

- Lower energy consumption when using pig iron compared to steel scrap in electric melting furnaces (Donsbach, 2006). The lower melting temperature and higher charge density can result in KW man hours per tonne reductions of up to 10% when adding 10 - 20% pig iron to the charge at the beginning of the melting cycle.

- Higher metallic recoveries have been observed when using pig iron compared to steel scrap (Trueba, 2005). Low surface area:volume ratios play an important role in the metallic recovery of charge materials, higher ratios generally result in lower metallic recoveries. Steel scrap has typically three times the SA:V ratio of pig iron.

- Clean charge. Pig iron is generally free from extraneous materials such as oil and dirt, which can produce noxious fumes and harmful slag.
Fact Sheets

What are OBM (OBM)?

- Direct Reduced Iron (DRI), Hot Briquetted Iron (HBI), and Pig Iron are OBM.
- OBM is produced from iron ore or non-ferrous metal scrap.
- OBM is used in steelmaking as a scrap supplement.

OBM can be used in:

- Steelmaking: pigs iron is blended with scrap and other feedstocks.
- Foundry: to improve casting properties.
- Typical Benefits of OBM:
  - Consistent quality and low residual content.
  - Predictable results and high production.
  - Can be added to the furnace as metal or scrap.

Typical Benefits of OBM in Steelmaking:

- Consistent quality and low residual content.
- Predictable results and high production.
- Can be added to the furnace as metal or scrap.
- Higher yields in use for many applications.

The Use of Foundry Pig Iron in Grey Iron Castings:

- Pig iron is produced mainly from scrap.
- High Fe, low residual material.
- Can be used as a scrap supplement.

Foundry Pig Iron Characteristics:

- Consistent quality and low residual content.
- Predictable results and high production.
- Can be added to the furnace as metal or scrap.

Use of High Purity Pig Iron for Foundries Producing Ductile Iron Castings:

- High Purity Pig Iron (HPPI) is different from other types of pig iron.
- HPPI is produced from iron ore meal in electric furnaces.
- HPPI is also used as a nodular or spheroidal graphite iron.

HPPI Characteristics:

- Consistent quality and low residual content.
- Predictable results and high production.
- Can be added to the furnace as metal or scrap.
Metallics price development

Metallics price development $/tonne [data source: Scrap Price Bulletin]

Pig Iron @ Chicago = FOB NOLA + $25/tonne
Avoid chips and fines generation

- Fines and chips can be generated along the supply chain:
  - handling and storage at the production site
  - loading into vessels, barges, railcars, etc.
  - during discharge of vessels, etc.
  - handling and storage at the steel plant
    - excess chips and fines impact furnace yield and productivity
    - fines and chips are more susceptible to oxidation

- Minimise the risk:
  - avoid unnecessary material handling
  - minimise transfer points and drops
  - don’t overload conveyors and avoid spillage
  - minimise drop during loading – use soft loading techniques
  - careful handling with frontend loaders, etc.
Aspirations

- to be the collective voice of the OBM industry
- strong partnerships with customer industries
  - EAF steel through SMA in USA
  - metal casting through AFS in USA
- engagement with ferrous casting industry to establish informed value chains
- foundries welcome!
  - as members
  - as guests at our meetings
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