Manganese Slag
Socio-economic Assessment

Presentation to
IMnI
June 2018, Kuala Lumpur

Meg Postle
Director, Risk & Policy Analysts
Overview

1. Background
2. Study aim and approach
3. Mn slag - production
4. Mn slag - use
5. Mn slag - socio-economic value
6. Mn slag – regulatory status
Background

➢ Historically, the outputs of alloy production have been considered “waste” and discarded

➢ Companies are finding new ways to capture the inherent value of these materials and convert them into useful, saleable products

➢ Governments are beginning to create policies and regulations to promote the development of circular economic systems

➢ Manganese (Mn) slag is still considered a “waste” by some actors
  ▪ Global study on the socio-economic value of Mn alloy slags
Aims and approach

➢ The Mn industry generates significant social and economic benefits – but these may not be well understood by governments, regulators and other key stakeholders

➢ Socio-economic analysis (SEA) provides methods to quantify the social and economic benefits that a product, company or industry sector generates for an economy or community

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Consultation and literature review to identify uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>Estimating value of potential uses of Mn alloy slags</td>
</tr>
<tr>
<td>Step 3</td>
<td>Regulatory status of Mn alloy slags (focus on EU and China)</td>
</tr>
</tbody>
</table>
Estimated Mn Alloy Slag Production (2015)

World:
SiMn alloy slag: 11.4 million MT
FeMn alloy slag: 4.2 million MT

China:
57% of global SiMn slag production
41% of global FeMn slag production
Mn Slag - Use

➢ A 2016 life cycle assessment of global Mn alloy production by Westfall et al. shows that:
   ➢ Most HC FeMn slag is internally recycled (SiMn alloy production)
   ➢ Most SiMn slag is used as a construction material

<table>
<thead>
<tr>
<th></th>
<th>HC FeMn</th>
<th>SiMn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internally recycled</td>
<td>54%</td>
<td>12%</td>
</tr>
<tr>
<td>Construction material</td>
<td>36%</td>
<td>70%</td>
</tr>
<tr>
<td>Waste stockpile</td>
<td>10%</td>
<td>18%</td>
</tr>
<tr>
<td>% by weight</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Mn Slag - Use

- Identified uses:
  - Electrolytic manganese metal (EMM) and electrolytic manganese dioxide (EMD)
  - Fertiliser
  - Foundry
  - Fire-resistant coatings/ geopolymers
  - Glass ceramics
  - Wastewater treatment
  - Shot blast media
  - Jewellery
  - Construction

Mn Slag - Direct market value

- Worldwide – estimated 2.46 million MT of Mn alloy slag sent to stockpile per year
- Price of Mn slag dependent on various factors: e.g. type of slag (FeMn/SiMn) and its Mn content, form of slag (lumpy or fine), market price for alternative materials, location
- Assumed price of Mn alloy slag if sold: US$ 2 to US$ 5 per tonne
- Total value of “wasted” slag: US$ 5 million to US$ 12 million per year

- Globally, 9.4 million MT of Mn alloy slag is already put to use in construction applications each year - total revenue generated ~US$ 19 million to US$ 47 million per year
Construction - Cement

- For decades industrial by-products (e.g. blast furnace slag and fly ash) have been successfully recycled as artificial pozzolans in cement.
- Chemical composition of SiMn slag is similar to blast furnace slag – consultation indicates that SiMn slag is already being used to produce cement in parts of South America, Europe and Asia.
- The market for supplementary cementitious materials is growing.

<table>
<thead>
<tr>
<th></th>
<th>Global supplementary cementitious materials market</th>
<th>Global supplementary cementitious materials market – slag cement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value in 2015</td>
<td>US$ 79.2 billion</td>
<td>US$ 4.0 billion</td>
</tr>
<tr>
<td>CAGR 2015-2020</td>
<td>+5.4%</td>
<td>+4.1%</td>
</tr>
<tr>
<td>Value in 2020</td>
<td>US$ 103.2 billion</td>
<td>US$ 5.0 billion</td>
</tr>
</tbody>
</table>

_BCC Research (2016)_
Construction - Cement

➢ Cement production accounts for ~5% of global man-made CO₂ emissions
➢ Production of cement releases CO₂ both directly and indirectly:
  ▪ heating of limestone releases CO₂ directly
  ▪ burning of fossil fuels (to heat kiln) releases CO₂ indirectly
➢ If some limestone is replaced with SiMn slag, less CO₂ is released directly and less fuel needs to be burned => reduced (indirect) emissions of CO2
➢ A kiln producing 850,000 tonnes of clinker per year with 5% SiMn slag would save around **13,500 tonnes of CO₂ per year in direct emissions**
➢ Fuel savings would vary depending on the fuel type used, but could be substantial
➢ Total value of CO₂ savings over a 10 year period: **US$ 1.55 – 7.83 million**
Construction - Aggregate

➢ Iron and steel slags have been used as aggregates for thousands of years: e.g. road bases, railway ballast, construction fill

➢ Current uses for Mn slag aggregate:
  ▪ SiMn – asphalt, roadbed material/landfilling for roads, hardstand
  ▪ FeMn – ground completion and shaping, pipe packaging

➢ Potential uses for SiMn slag aggregate
  ▪ Railway ballast
  ▪ Mortar, as a replacement for sand

Image: TasPorts (2016)
Construction – Aggregate for concrete

- FeMn alloy slag and SiMn alloy slag have both been used as a substitute for aggregates in concrete
- SiMn alloy slag is cheaper than some alternatives:
  - Granulated blast furnace slag ₹ 400-500 per m³ (US$ 6 to US$ 7.5)
  - Copper slag ₹ 1700-1800 per m³ (US$ 25 to US$ 27)
  - SiMn slag ₹ 250-300 per m³ (US$ 3.5 to US$ 5.5)
- The properties (e.g. density, adsorption) of Mn slag may be different to conventional aggregates and must be taken into account in the mix design
- In some cases, these properties may be advantageous:
  - Mn alloy slag may be lightweight compared to some other aggregates: granulated SiMn slag ~15% lighter than river sand
  - May enable production of lighter and smaller precast elements, reducing cost of handling and transportation
Construction – Bricks and Mineral Wool

Bricks
- Mn alloy slag has been used to produce bricks in China and South Africa
- World brick production is concentrated in South East Asia
  - South East Asia is also the world’s largest producer of Mn alloy slag → Potential for co-location of production activities?

Mineral Wool
- SiMn alloy slag used to produce mineral wool in the US and China
- Global mineral wool market - expected to reach > US$ 14.65 billion by 2022
For the Mn industry, an important consideration is the cost of having to stockpile and/or dispose of Mn alloy slag.

Disposal costs vary by country, but are assumed to be ~US$ 30 to US$ 50 per tonne based on data from Europe and the USA.

Globally, ~2.5 million MT of Mn alloy slag is sent to waste stockpile each year.
- ~ US$ 74 million to US$ 123 million per year in costs could be avoided if this slag used instead.
- Reduces transport cost (and associated emissions) when used in locations near to production.

Employment

- **Potential for double counting workers!**
  - It is not possible to produce Mn alloy without Mn alloy slag
  - Furthermore, Mn alloy slag is used as an input to Mn alloy production

- Our 2014 study estimated that, worldwide, between 67,000 and 86,000 people are employed **directly** in the production of Mn alloys:
  - 87% of direct employment can be found in China
  - 75% of direct employment related to production of SiMn

- A further 217,000 to 278,000 people are employed through indirect and induced employment effects
Employment

- Workers employed in the **processing and/or transportation of barren slag** ready for use in other downstream applications can be considered **additional** to those employed in the production of Mn alloy

- On the basis that 9.4 million MT of Mn slag is used in construction applications each year:
  - **Processing**: Consultation indicates that a single worker may be able to process between 75,000 to 140,000 tonnes of Mn alloy slag per year → **67 to 126 jobs**
  - **Transportation**: Consultation indicates that a single truck driver may be able to transport between 10,000 and 30,000 MT of Mn slag per year → **315 to 944 jobs**

- Workers employed in **downstream uses** for Mn alloy slag (e.g. cement production) can also be counted as additional, but could not be calculated
Regulatory Status of Mn alloy slag

---

Europe & China
Circular Economy

- Recognising the benefits of using resources more efficiently, Governments around the world are beginning to create policies and regulations to promote the development of more circular economic systems.
The circular economy concept can be applied to Mn slag.
Regulatory Status - European Union

➢ The status of waste in the EU is determined by the Waste Framework Directive (2008/98/EC)

➢ Under the WFD there is a possibility for substances/objects to have their status changed from “waste” to “by-product” where certain conditions are met
  ▪ Substances/objects classified as waste are subject to restrictions on how they must be contained, handled or moved
  ▪ Article 5(1) of the WFD defines when a substance/object can be considered a by-product

➢ Various cases before the European Court of Justice (ECJ) have discussed aspects of the definition of waste
  ▪ But still largely decided at the national level
Regulatory Status – European Union

➢ A prerequisite for the use of Mn alloy slag is that it meets the requirements of harmonised European or national standards

➢ Cement must comply with European Standard EN 197-1
  ▪ SiMn alloy slag cement (5% and 15% additions) fulfils the chemical, physical and mechanical requirements
  ▪ Specific approval may still be required before Mn alloy slag can be used for cement (e.g. from national Environment Agencies)

➢ SiMn slag complies with European standards for aggregate in asphalt (EN 13043) and has been used to produce asphalt for the Vinjani Donji – Vinjani Gorji road in Croatia
Regulatory status - China

- China has laws on solid waste – with provisions on import, use and disposal of Mn alloy slag:
  - Solid Waste Pollution Prevention and Control Law
  - Circular Economy Promotion Law
  - Clean Production Promotion Law

- In addition there are import restrictions:
  - HCFeMn slag containing >25% Mn - Catalogue of Restricted Imports of Solid Wastes which can be Used as Raw Materials
  - Mn alloy slags containing <25% Mn – Catalogue of Prohibited Imports of Solid Wastes – cannot be imported

- There are also two product standards for manganese-rich slag and ground silico-manganese slag and use in cement and concrete
Slag Webinar

• In-depth information regarding current and future uses of Mn alloy slag
• Current EU and Chinese Policy
• Help engaging policy makers regarding slag classifications
• Free for IMnI Members, open to all
• Webinar details coming soon - enquire at hse@manganese.org
Thank you for listening!

-------------

Email:

meg.postle@rpaltd.co.uk