Ore-Based Metallics: adding value to the EAF

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Presentation overview

- What is IIMA and what does it do?
- The benefits of using Ore-Based Metallics (OBM’s)
- Value-in-use of OBM’s
- Prevention of value leakage in transport, handling & storage

What is IIMA?

IIMA is the trade association for the ore-based metallics industry…..

merchant pig iron, hot briquetted iron, direct reduced iron, granulated iron

What does IIMA do?

As the unified voice of the ore-based metallics industry:

- furthers the interests of members and the industry
- promotes ore-based metallics as value-adding feedstock for the steel and ferrous casting industries
- identifies and addresses threats to and opportunities for the industry
- communicates with stakeholders at industry level
- provides regulatory support
- provides a forum for exchange of ideas at the scientific and technical levels

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IIMA International Iron Metallics Association

Benefits of OBM's in EAF

- Consistent quality and low residual content
- Dilutes impurities in scrap
- Better slag foaming
- Controlled C content, consistent C recovery
- N scavenger = low N content in steel
- Easier on hearth refractory & electrodes
- High density feedstock (pig iron & HBI), less charging time
- DRI/HBI can be continuously charged to EAF

= added value relative to scrap

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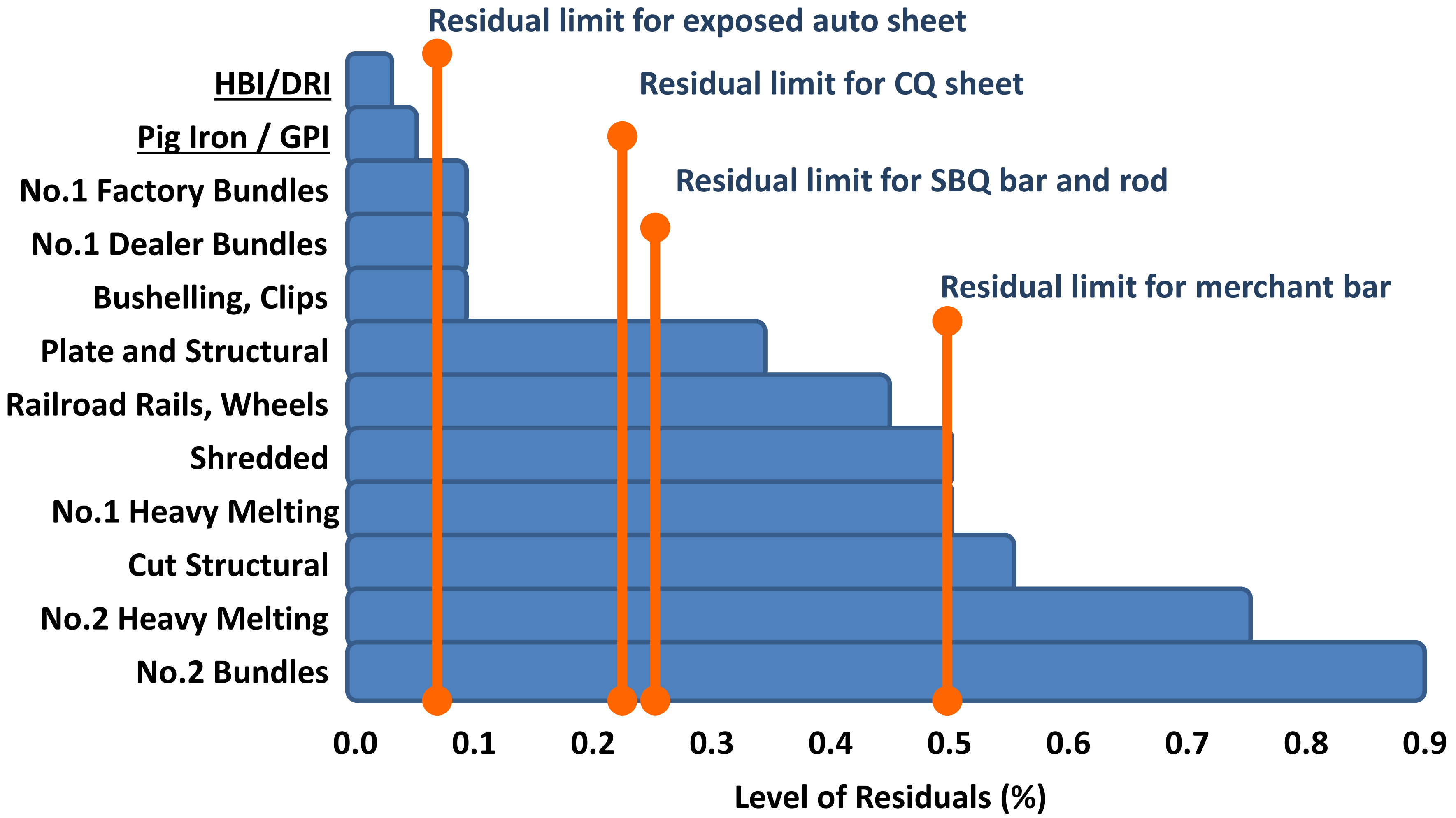
Comparison of residuals

Typical residual contents in scrap and OBM's

EU steel scrap specifications				
Category	Grade	Cu %	Sn %	Cr, Ni, Mo %
Old scrap	E3	≤ 0.250	≤ 0.010	Σ ≤ 0.250
	E1	≤ 0.400	≤ 0.020	Σ ≤ 0.300
New scrap, low residuals, uncoated	E2	Σ ≤ 0.300		
	E8	Σ ≤ 0.300		
	E6	Σ ≤ 0.300		
Shredded	E40	Σ ≤ 0.250	Σ ≤ 0.020	
Steel turnings	E5M	≤ 0.400	Σ ≤ 0.030	Σ ≤1.0
High residual scrap	EHRB	≤ 0.450	Σ ≤ 0.030	Σ ≤ 0.350
	EHRM	≤ 0.400	Σ ≤ 0.030	Σ ≤1.0
Fragmented scrap from incineration	E46	≤ 0.500	≤ 0.070	
Ore-based metallics *	pig iron, DRI, HBI	0.002	trace	Σ ≤ 0.015
* Dependent on source iron ore				

Source: EuRIC - EFR

Residuals in ferrous metallics



IIMA Fact Sheets

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What are Ore Based Metallics (OBM's)

- Direct Reduced Iron (DRI), Hot Briquetted Iron (HBI) and Pig Iron are Ore Based Metallics (OBM's), manufactured from iron ore or titanium-bearing mineral sands (High Purity Pig Iron HPPI, also known as Nodular or Spheroidal Graphite Pig Iron, is produced from smelting of ilmenite)
- OBM's are best used as scrap supplements to dilute impurities in ferrous scrap in EAF steelmaking and iron casting
- OBM's can be used as productivity enhancers in blast furnace (BF) or as trim coolant in the basic oxygen furnace (BOF) steelmaking

Direct Reduced Iron

Hot Briquetted Iron

Pig Iron

Typical Benefits of OBMs in Steelmaking, Ironmaking and Iron Foundries

- **Consistent quality and low residual content**, e.g. copper, allows dilution of impurities in scrap
- **Controlled carbon content**, consistent carbon recovery
- **Predictable** mass and heat balances
- Can be **continuously charged** to the furnace (DRI and HBI)
- **High density** can reduce the number of bucket charges, allows for increased use of lower cost, less dense feedstock and reduces storage space requirements
- Better slag foaming
- Easier on hearth refractory & electrodes
- **Higher value-in-use** for many steel products in comparison to scrap
- **Increased flexibility** is feedstock supply

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Use of Hot Briquetted Iron (HBI) in the Electric Arc Furnace (EAF) for Steelmaking

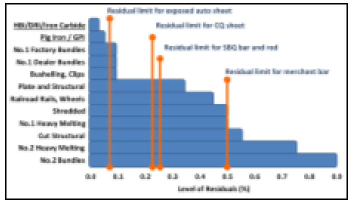
- Steel production in the EAF continues to grow both in North America and worldwide. The past 5 years have seen increases in the supply and use of Pig Iron, Direct Reduced Iron (DRI), and Hot Briquetted Iron (HBI) in the EAF.
- HBI should not be considered as a scrap substitute but rather as a source of clean iron units that can be used to supplement and enhance the scrap charge
- HBI is a high Fe, low residual metallic material for producing high quality iron and steel products in a wide variety of furnaces

The value-in-use of HBI is different for each melt shop and will depend on local scrap supply, production facilities, metallurgical practice and steel product mix.

Benefits of Using HBI in the EAF

- **Very low residual element content** enables production of high quality steel products or use of higher percentage of lower cost scrap in the charge mix
- **Known and consistent chemistry**, certified by analysis, assists melt consistency
- **Consistent shape and form** enable efficient material handling and storage
- **High density** can reduce the number of bucket charges, allows for increased use of lower cost, less dense feedstock and reduces storage space requirements
- Can be **continuously charged** to the furnace
- **Acts as N scavenger** = low N content in steel

Hot Briquetted Iron (HBI)



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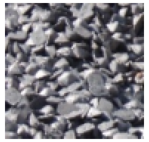
Use of Basic Pig Iron in the Electric Arc Furnace (EAF) for Steelmaking

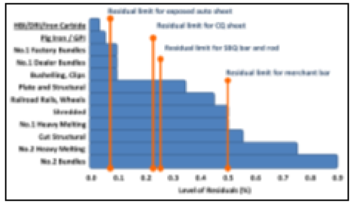
- Steel production in the EAF continues to grow both in North America and worldwide. The past 5 years have seen increases in the supply and use of Pig Iron, Direct Reduced Iron (DRI), and Hot Briquetted Iron (HBI) in the EAF.
- Pig Iron is a high Fe, low residual metallic material for producing high quality iron and steel products in a wide variety of furnaces. It should not be considered as a scrap substitute but rather as a source of clean iron units that can be used to supplement and enhance the scrap charge. Many EAF operators prefer to use Pig Iron to blend with scrap and other feedstock materials due to its high Fe content, low gangue, and chemical purity.
- On average, Pig Iron makes up between 5-10 percent of the global EAF metallics charge. In some parts of the world where scrap is scarce, Pig Iron can be used at up to 60 percent of the charge.
- The value-in-use of Pig Iron is different for each melt shop and will depend on local scrap supply, production facilities, metallurgical practice and steel product mix.

The Benefits of Using Basic Pig Iron in the EAF

- **High purity, low gangue** allows for the production of steel products requiring low residual content or for the use of higher percentages of lower cost scrap in the charge mix
- **Known and consistent chemistry** certified by analysis
- **Chemical energy** delivered efficiently by contained carbon, which promotes faster melting and increased productivity
- **High density** can reduce the number of bucket charges, allows for increased use of lower cost, less dense materials, and reduces storage space requirements
- **Consistent shape and form** provide efficient material handling characteristics
- **Easy to store** with no special requirements (silos, covered space, etc.) and a very low rate of degradation (oxidation) even when stored outdoors and uncovered



Pig Iron



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What is value-in-use?

- **Value-in-use as applied to steelmaking raw materials is a methodology that attempts to capture the true contribution and penalties associated with the use of a particular feed materials in the steelmaking process**
- **In the past:**
  - conventional scrap models used to provide least cost scrap charge to meet specified residual levels
  - these do not take into account process parameters, environmental considerations and other important scrap characteristics
  - not set up for feedback from process data - “real time” slag analysis
  - past scrap models, do not capture true “value in use”

Value-in-use calculations

- $ per Fe unit is the simplest representation of value-in-use
- Relative value-in-use of EAF feedstock materials relates to how they impact steel manufacturing costs
  - Slag Generation Rate
  - Flux Consumption
  - Yield
  - Electricity and Energy Consumption
  - Alloy costs
  - Productivity
  - Electrode consumption
  - Requirements for scrap dilution
  - Environmental issues
- These costs are real and can overtake price differences!

The value-in-use model

- Developed by Jeremy Jones of CIX LLC in co-operation with IIMA
- Based on Excel and Visual Basic, easy to operate and should give quickly principle judgements
- The model determines the value of OBM’s relative to scrap
- More complex models may optimize the whole scrap charge and take into account additional factors

Value-in-use model: the technical part

- Compares differences in % metallic Fe
- Considers C content and effect on charge C
- Considers gangue content and effect on flux requirements to maintain a desired slag basicity – could also consider effect of higher slag volume on Fe yield losses
- Applies a recovery factor for FeO and will need to consider additional energy required as well as reductant (probably C)
- Considers fines losses (DRI, HBI, Pig Iron)
- Considers moisture content and affect on energy requirements
- Applies value to lack of Cu
- Future plan: to consider additional lime required to deal with higher S and P

Value-in-use model: the economics part

- The VIU Model totals up all of the costs and benefits for each material and determines the equivalent cost of a ton of steel based on the price of each commodity and the various cost benefits/penalties associated with each scrap type.
- Can compare equivalent cost head-to-head or calculate the break-even price of one commodity against the other.
- As feedstock material costs and compositions are constantly changing, run the model at each decision point.
- Feedstock material composition database will be updated regularly.

Value-in-use model: data input

Material Analysis - Data Input

Material Name	Prime Scrap	DRI 1	HBI 1	Pig Iron
$/tonne	$ 314.50	$ 235.00	$ 255.00	$ 365.00
Fe Tot	97.200%	91.113%	89.700%	94.300%
Fe Met	95.500%	85.646%	83.900%	94.300%
Metallization	98.25%	94.00%	93.53%	100.00%
C	0.080%	2.500%	1.500%	4.100%
SiO2	0.500%	1.755%	4.210%	0.200%
Al2O3	0.500%	0.810%	0.800%	0.100%
MgO	0.000%	0.135%	0.325%	
CaO	0.000%	0.945%	0.890%	
S		0.040%	0.008%	0.020%
P		0.020%	0.009%	0.060%
Si	0.010%			0.500%
Al	0.020%			
Mn	0.700%			0.700%
Fines < 4 mm	0.000%	3.000%	2.000%	0.500%
Fines < 8 mm			2.000%	0.000%
FeO	2.19%	7.03%	7.46%	0.00%
Metallic Fe	95.50%	85.65%	83.90%	94.30%
H20	0.500%	0.500%	0.500%	0.000%
Cu wt%	0.080%	0.002%	0.002%	0.000%
Other	0.503%	1.116%	0.896%	0.02%
C req'd to reduce 100 % FeO	0.37%	1.17%	1.25%	0.00%

Value-in-use model: base assumptions

Base Productivity Conditions		
P-On time	34	minutes
Power	380	KwH/tonne
Slag FeO	28.0%	
Slag CaO	34.0%	
MgO Target	9.0%	
Productivity cost	1.00	$/%
% of OBM in Charge	10.0%	

Cost Data	$/unit	
Cu cost	$ 1.75	per pt.
Lime	$ 110.00	tonne
Dolo-lime	$ 110.00	tonne
Carbon	$ 255.00	tonne
Power	$ 0.05	kWh
T-T-T		min

Operating Data		Range
C recovery	50%	30 to 80%
Energy Efficieny	50%	40 to 60 %
Fines losses < 4 mm	100%	30 to 100%
Fines losses 4 - 8 mn	30%	30 to 100%
FeO recovery	50%	30 to 100%

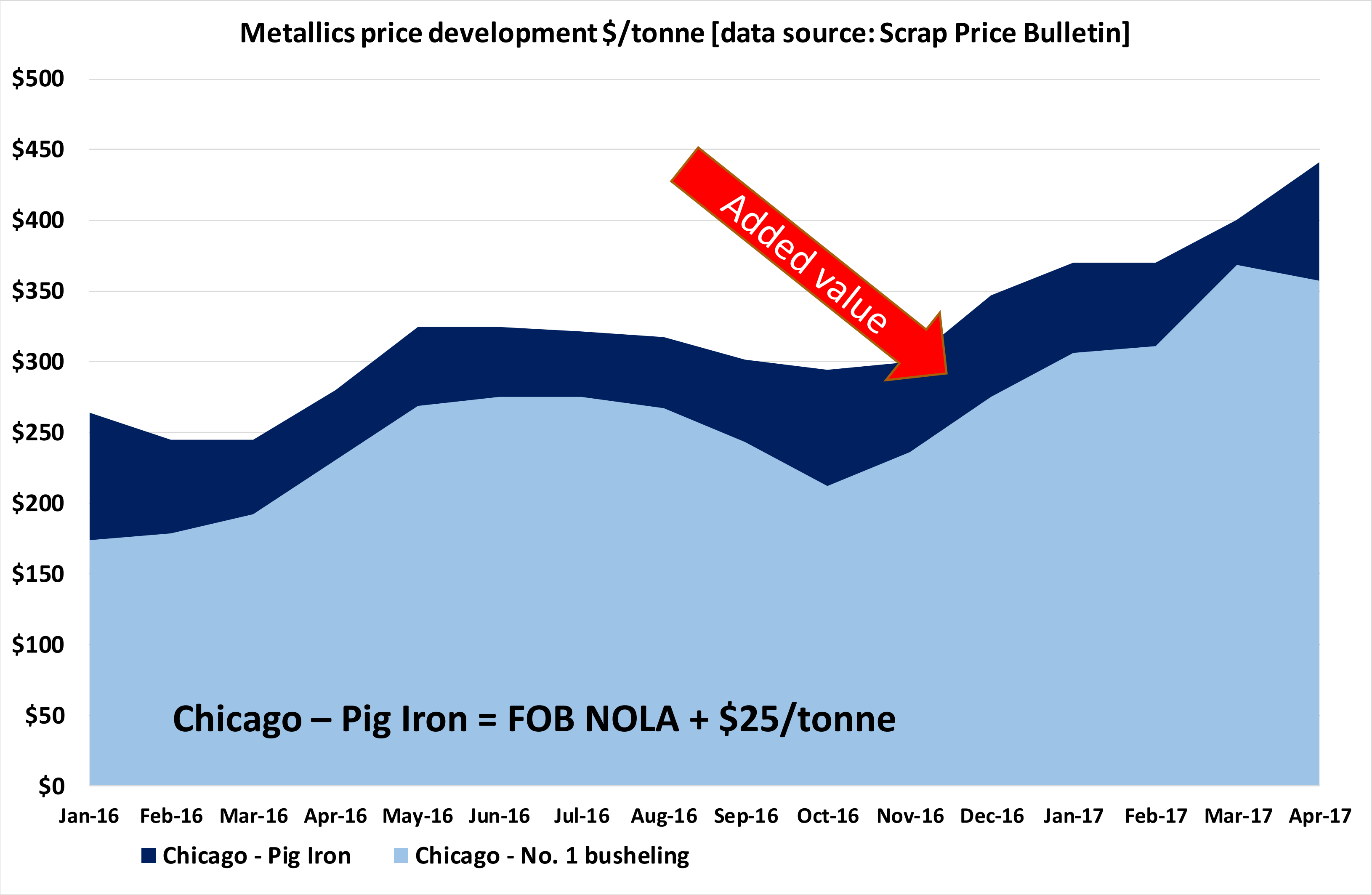
Flux Data	CaO	MgO
Lime	92.3%	1.1%
Dolo-lime	60.1%	30.1%
Slag Basicity - B3	1.80	

Run Calculation

Value-in-use model: results

Material	Prime Scrap	DRI 1	HBI 1	Pig Iron
$/tonne	$ 314.50	$ 235.00	$ 255.00	$ 365.00
$/t Fines loss		$ 7.05	$ 6.63	$ 1.83
$/t H2O loss		$ -	$ -	$ (1.83)
$ Chg C		$ (9.99)	$ (4.88)	$ (21.33)
$ Dolo Lime		$ 2.01	$ 5.49	$ 0.53
$ Lime		$ 0.66	$ 3.58	$ 0.31
$ Cu		$ (13.65)	$ (13.65)	$ (14.00)
$ Kwh		$ 1.34	$ 3.44	$ (2.27)
$ Productivity		$ 0.73	$ 1.89	$ (1.25)
Yield kg Fe	963.5	840.8	801.4	934.8
Total$/T Fe	$ 326.41	$ 264.53	$ 318.96	$ 351.14
Incl productivity		$ 265.40	$ 321.32	$ 349.81
Price of Primary Material at Break Even				
Without Productivity Effect		**$ 254.87**	**$ 307.32**	**$ 338.32**
With Productivity Effect		**$ 255.71**	**$ 309.59**	**$ 337.04**

Metallics price development



Value leakage with OBM's

Chips and Fines generation – all OBM's

- Influenced by materials handling and storage – 3-5% can be generated during shipping
- Excess chips and fines impact EAF yield and productivity
- Fines and chips are more susceptible to oxidation

Oxidation and corrosion – especially DRI

- Driven by reactivity, exposure to moisture, storage conditions, particle size
- Oxidised material will increase demand for carbon and affect C/O/Fe balance
- Oxidation represents yield loss, energy loss and increased steelmaking costs

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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
- **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.

Oxidation and corrosion

- **Not a significant issue for pig iron – surface rusting only**
  - will start to rust in days and take weeks to cover surface of ingots
- **Rusting of HBI**
  - <1% per month loss of metallisation, even in salt-laden, humid atmosphere and in heavy rain
  - re-oxidation rate for HBI is 30% of that for DRI
- **DRI is susceptible to re-oxidation due to its porous, sponge-like structure and its consequently large surface area**
  - exposure to water will lead to loss of metallisation
  - oxidation reaction is exothermic with consequent risk of self-heating and fires

Minimise oxidation and corrosion

- **Main risks are with cold DRI**
  - DRI re-oxidises exothermically in contact with air (oxygen)
  - when stored on the ground DRI can absorb 10-15% moisture (HBI about 3%)
  - aqueous corrosion of DRI evolves hydrogen
- **Precautions**
  - minimise fines in DRI piles
  - keep DRI dry, avoid contact with excessive moisture, especially sea water
  - store material to be batch charged on firm, well-drained surface and cover DRI piles
  - store material to be continuously charged in silos
  - avoid moving DRI before usage
  - monitor temperature and atmosphere in silos

Ocean transportation of OBM's: IMSBC Code*

- **Direct Reduced Iron (A) - briquettes, hot-moulded = HBI**
  - MHB, Group B (self-heating, evolution of H2 when in contact with water)
  - Surface ventilation, natural or mechanical, as necessary during voyage
- **Direct Reduced Iron (B) - lumps, pellets, cold-moulded briquettes = DRI**
  - MHB, Group B (self-heating, evolution of H**2 when in contact with water)**
  - **Shipped under inert atmosphere**
- **Pig Iron**
  - Group C - neither liable to liquefy nor possess chemical hazards
- **Iron Smelting By-products (includes granulated iron)**
  - Group C - neither liable to liquefy nor possess chemical hazards

*International Maritime Solid Bulk Cargoes Code

Contact Information

Secretary General:
Chris Barrington
cbarrington@metallics.org.uk

Administration Manager:
Abi Hart
ahart@metallics.org.uk

Website:
www.metallics.org.uk