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Optimization of Fe Feedstocks for EAF Steelmaking

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Introduction

- EAF has been identified as primary path forward to decarburization
- EAF effectiveness closely tied to raw materials
- Future EAF technology dependent on balance of OBMs+ steel scrap
- Dependence on OBMs can be mitigated by improving scrap quality
- Improved scrap quality improves EAF efficiency

Scrap Projections to 2050



- Scrap availability is good – quality will be an issue
- Rising residual levels are a concern
- Steel scrap doesn't have a zero CO2 footprint
- CO2 footprint dependent on scrap quality

Circularity/Sustainability



- Recycling can be maximized when recycle streams are pure
- Most environmental concerns in the EAF are related to extraneous material in the scrap
- Steel scrap doesn't have a zero CO2 footprint
- Better product design for EOL dismantling

Why We Need To Improve Scrap Quality?

	As-Is	Endpoint Improvement	Endpoint and Acid Load Improvement	Units
Charge Tonnes	150	150	150	tonne/ht
Average FeO%	39.3%	32.0%	32.0%	wt%
Acid Load	25	25	16	kg/tonne
Dolo Lime Usage	46	40	25	kg/tonne
HiCal Lime Usage	18	22	14	kg/tonne
Flux Consumption	64	62	39	kg/tonne
Slag Generation Rate	157	136	86	kg/tonne
Tap Tonnes	135.3	136.4	138.1	tonne/ht
Yield	90.2%	90.9%	92.0%	tap/chg
Flux and Scrap Costs per TLS	\$429	\$425	\$415	\$/tls
		(\$4)	(\$14)	\$/tls

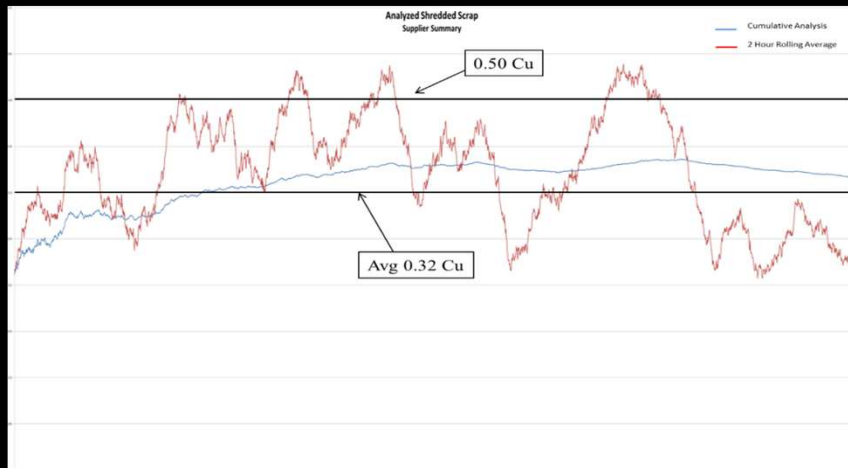
Technologies For Scrap Upgrading



The ScrapTuning[®] and HMS Cleaning Advanced tools pursue three main objectives:

- a) Concentrating the metallic Fe.
- b) Complete decontamination from inert materials, non-ferrous metals, non-metallic components, and composite materials,
- c) Isolation and separation of steel scrap particles with high inherent residual content (Cu, Ni and Cr)

Capabilities at the Shredder



- CB-RM analyzer uses prompt gamma neutron activation analysis (PGNAA)
- Continuous measurement of Cu content allows equipment configuration to be optimized for Cu removal in the shredder
- Feedstock, shredder mill grate/hammer patterns /wear characteristics, maintenance/replacement programs for wear parts, drum magnet types + settings, level of manual picking of copper contamination, all have significant influence on the final quality and chemistry.
- Level of nonmetallic and nonferrous is also reduced by 3-7% when density >85 lbs/cuft and Cu < 0.25 wt %

Results - Arvedi

- Arvedi was another client of CIX which embarked on a program to optimize raw material inputs to the EAFs.
- Over a period of approximately 7 years, CIX worked with Arvedi's plant operations team to optimize EAF operations. A significant effort was placed on slag analysis and optimization of slag foaming.
- Arvedi operates the most productive ConSteel furnace in the world and an optimum slag practice was critical to achieving this. CIX worked with Arvedi to reduce dirt input to the EAF.
- In 2022, Arvedi started up one of the largest on-site shredder operations. At the same time, pickers were implemented to separate free copper from the processed material. Official results have not been published though it is rumored that Arvedi plans to install a second shredder at site.

HMS Upgrade Results

- Trials conducted by SICON in Europe. Processed HMS
 - Cu content was reduced by 0.15 wt. %
 - Ni contents was reduced by 0.04 wt. %
 - Cr content was reduced by 0.06 wt. %
 - Pb was reduced by 0.03 wt. %
 - P was reduced by 0.02 wt. %.
- CO₂ emissions would have been increased by ~ 200 kg/ton of scrap if the scrap was unprocessed
- energy savings were projected at ~ 200 kWh/tonne of scrap

Scrap Upgrading At The Steel Plant

- Latest trend is to process scrap at the steel plant site
- Shredder and/or HMS processing
- Some facilities considering shredding of bushelling (densify)
- Dirt removal can provide significant savings
- Eventually want to push this processing back on the scrap supplier and/or reduce contamination through better design for EOL

Economics Of Scrap Upgrading

- One of the major obstacles to upgrading scrap quality is the argument that the costs will outweigh the benefits.
- CIX has resolved this conundrum through the development of a value-in-use model that allows for detailed evaluation of EAF feedstocks to track the benefits of higher quality raw materials.
- Coupled with equipment and operating costs supplied by equipment manufacturers, it is a relatively simple exercise to determine the cost benefits.
- Cost benefits greatly outweigh the costs



Database of individual commodities

Select Commodity

Bushelling (#1)

Enter Price

\$ 410.00 \$/GT

Endpoint Control Method

Adjust Oxygen Usage

Adjust Inj C Usage

SINGLE VIU

GENERATE RESULTS

MASS BALANCE on a 1 Ton Basis: melting to your custom final slag chemistry, temperature and bath carbon%.

Mass Analyzed

1000 KG

Resulting Liquid Metal

965 KG

Yield

90.5%

Electrical Consumption

377 KWH

HiCal Lime Consumption

3 KG

Dolo Lime Consumption

12 KG

dLance Oxygen

-0.3 M3

Electrode Consumption

1.2 KG

Consumption on a liquid on basis

Consumption per Liquid Tonne

Electricity

391 KWH/LIQ TONNE

HiCal Lime

3 KG/LIQ TONNE

Dolo Lime

13 KG/LIQ TONNE

dLance Oxygen

-0.3 M3/LIQ TONNE

Electrodes

1.2 KG/LIQ TONNE

Scrap

1037 KG/LIQ TONNE

COST PER LIQUID TON (VIU): Includes yield effect and conversion cost

Cost per Liquid Tonne

Electricity

17.6 \$/LIQ TONNE

HiCal Lime

0.68 \$/LIQ TONNE

Dolo Lime

2.74 \$/LIQ TONNE

dLance Oxygen

\$-0.02 \$/LIQ TONNE

Electrodes

\$9.01 \$/LIQ TONNE

Scrap

\$418.32 \$/LIQ TONNE

Total VIU

\$448.32 \$/LIQ TONNE

Original Scrap Price

\$403.52 \$/CHARGE TONNE

Relative Power On Time

35.2 MINUTES

12 Cu Jan 2018 Act

MaxCu: 0.15 % MaxPOT: 40 Status: Up to Date

Commodity	Cu %	Price	Price Unit	Min Charge %	Charge %	Max Charge %	Charge T Ton	Yield %	HiCal lb	Dolo lb	Oxygen scf	Electricity (KWh)
Merchant Pig Iron (#17)	0.000 %	\$ 386.25	\$/MT	0 %	25 %	100 %	45.38	91.49	1186.64	2667.67	62594.27	5785
VoestAlpine BRS (#57)	0.000 %	\$ 406.09	\$/MT	0 %	13 %	100 %	23.60	87.70	439.62	1144.30	5154.52	8132
Bushelling (#1)	0.080 %	\$ 420.52	\$/MT	0 %	12 %	100 %	21.78	96.46	142.29	535.89	-237.11	7455
Shredded Scrap (#2)	0.250 %	\$ 376.22	\$/MT	0 %	25 %	100 %	45.38	86.67	1416.13	3532.19	-2320.69	16304
Home Scrap Flatrolled (0.120 %	\$ 0.00	\$/MT	0 %	6 %	100 %	10.89	96.42	71.14	267.95	-118.55	3726
Plate & Structural (#5)	0.160 %	\$ 369.94	\$/MT	0 %	13 %	100 %	23.60	95.18	162.57	1112.22	884.27	7183
Railroad Wheels (#7)	0.250 %	\$ 405.10	\$/MT	0 %	3 %	100 %	5.45	96.08	22.74	172.73	1367.71	1563
Pit Scrap (#9)	0.100 %	\$ 0.00	\$/MT	0 %	3 %	100 %	5.45	86.75	182.12	463.86	-1235.73	2002
Shredded Scrap 17 Cu	0.171 %	\$ 396.22	\$/MT	0 %	0 %	100 %	0.00	87.92				
Injection Carbon	N/A	\$175.00	\$/ST	N/A	N/A	N/A	2.0	-0.08%	208.53	359.61	52916.32	-3507
Charge Carbon	N/A	\$259.00	\$/ST	N/A	N/A	N/A	0.0	0.00%	0.00	0.00	0.00	0
Total or Average					100 %		182	91.1%	3829	10248	118950	48600

ADD

CIX
VIU
Model

Optimization of recipe with Cu and power on time as constraints – finds least cost recipe

CIX CO2 Footprint Model

Linked with output of CIX VIU Model

UserForm1

NEW COMMODITY ENTRY

NAME:

from CIX VIU Model (per tonne of material)

Liquid Steel:	<input type="text" value="901"/>	kg/tonne
Electricity:	<input type="text" value="424"/>	kWh/tonne
HiCal Lime:	<input type="text" value="8"/>	kg/tonne
Dolo Lime:	<input type="text" value="15"/>	kg/tonne
O2 Consumption:	<input type="text" value="3.4"/>	Nm3/tonne
Electrodes:	<input type="text" value="1.1"/>	kg/tonne
Copper:	<input type="text" value=".28"/>	wt%
Carbon:	<input type="text" value="0.40"/>	wt%

Ore Based Metallics

Pig Iron Product kgCO2/tonne

DRI Product kgCO2/tonne

Scrap Processing Consumption

Electricity:	<input type="text" value="45"/>	kWh/tonne
Natural Gas:	<input type="text" value="0"/>	Nm3/tonne
Electricity Intensity:	<input type="text" value="300"/>	gCO2/kWh

Transportation Totals Inputs

Internal Scrap - no transportation

Short Sea: km

Barge: km

Rail: km

Road: km

Road/Rail: km

Road/Barge: km

Road/Short Sea: km

Pipeline: km


Deep Sea Container: km

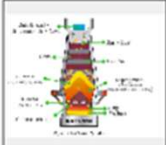
Deep Sea Tanker: km

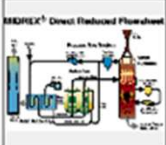
Air Freight: km

SAVE to DATABASE

CALCULATORS (click image)

 Electricity Intensity Calculator

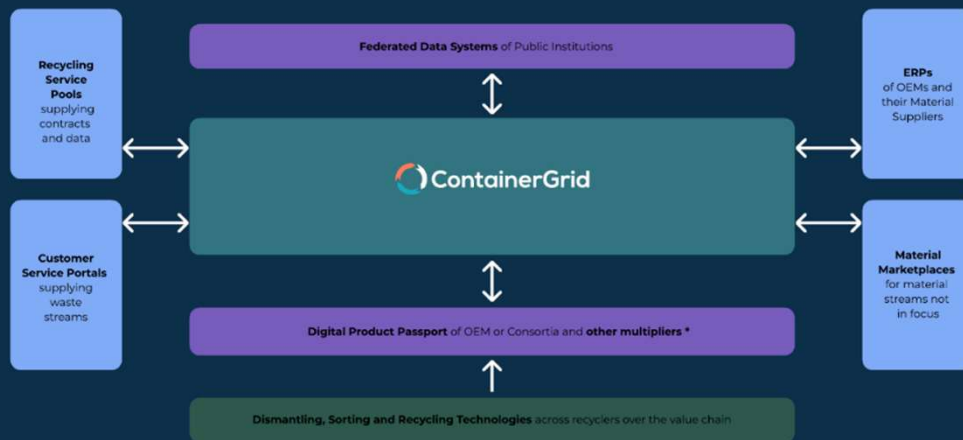
 Pig Iron Product Calculator

 HBI/DRI Calculator

Continuous Improvement – New Business Models

ContainerGrid acts as the backbone of the Circular Ecosystem

The essential application layer for the automation of digital take backs.



- In the EU, some start-up companies are proposing solutions to the EAF raw materials challenge in the future. One such company is ContainerGrid.
- They have proposed a model as shown in the figure.
- Their concept is to track scrap quality through the circular supply chain in order to certify the CO2 footprint of steel produced from this scrap and supplied to their ultimate customer, the fabricator.

Conclusions

- Must drive towards a “cleaner” raw material input to steelmaking
- Steel scrap plays critical role - Can improve scrap VIU
- Costs more than offset by reduction in CO2 footprint/EAF efficiency
- Equipment available to upgrade scrap quality
- Need more involvement from scrap processors/manufacturers
- OBMs enable greater scrap recycle and demand will remain high for the foreseeable future

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Thank You

