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Use of model and pilot scale plasma furnace to assess the next-gen DRI-EAF slags

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11/04/2025

9th International Slag Valorisation Symposium

From residues to resources and resilience

European Commission

The research leading to these results has received funding from the European Union's Research Fund for Coal and Steel research programme under grant agreement number: 101112665

Context

InSGeP project

Investigations of Slags from Next Generation Steel Making Processes

- Content :
  - Data gathering about slag produced from next generation steelmaking processes and EU regulations
  - DRI-EAF slag production and characterizations
  - Impact of granulation technologies
    - Dry and wet slag granulation
  - Definition of possible applications
    - Test of applications
    - Economic evaluation
    - Environmental evaluation
- CRM contributions :
  - Future slag features estimation — EAF model
  - DRI melting → EAF slag production — Pilot plasma furnace
  - DRY slag granulation — Dry granulator

Partner	RTO / industrial	Country
FEhS	RTO	Germany
CRM	RTO	Belgium
Rina-CSM	RTO	Italy
K1-Met	RTO	Austria
BFI	RTO	Germany
SSSA	RTO	Italy
AMMR	Industrial	France
Voestalpine	Industrial	Austria
O.R.I. Martin	Industrial	Italy
Sidenor	Industrial	Spain
Saarstahl	Industrial	Germany
Tenova	Tech Supplier	Italy
Primetals	Tech supplier	Austria

Model description

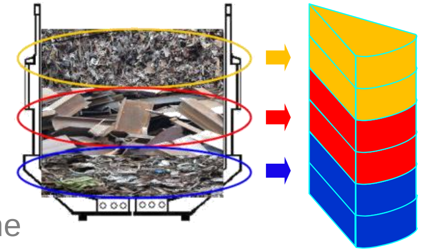
DESCRIPTION

- Dynamic metallurgical model
- Continuously solves mass and thermal balances for scrap, DRI, liquid steel, slag, gases and furnace vessel
- Calculates scrap and/or DRI melting evolution
- Based on dynamic process information

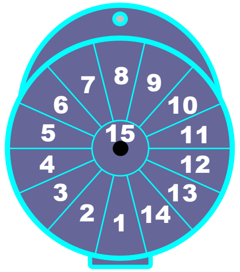
OBJECTIVES

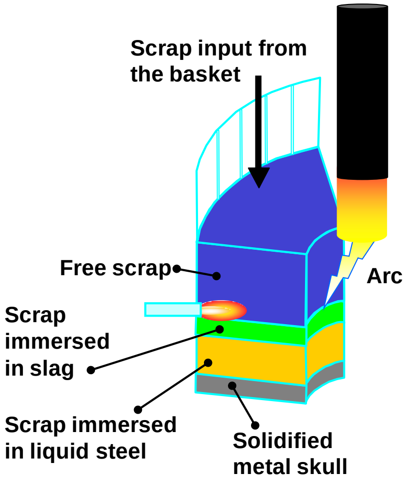
- Assessment of the end of heating and refining point
- Scrap/DRI melting evolution (best moment to charge second basket, …)
- Operating pattern optimisation, liquid heel height control
- Furnace geometry (lances, etc.)

Scrap layers
Homogeneous distribution across furnace surface,
In case of scraps, each layer follows the order inside the baskets.

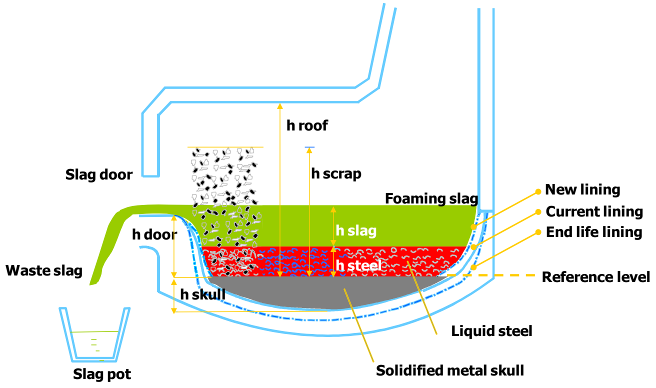


EAF discretization
Scrap melting rates vary by sectors





Mass and thermal balance
(for each phase: Temperatures, composition, weight)



De-slagging, refractory wearing, scrap height…

CRM EAF model

In/output data

Scrap txt file

Metallic part with a fixed composition
Inert part with a fixed composition
Oil
Dust

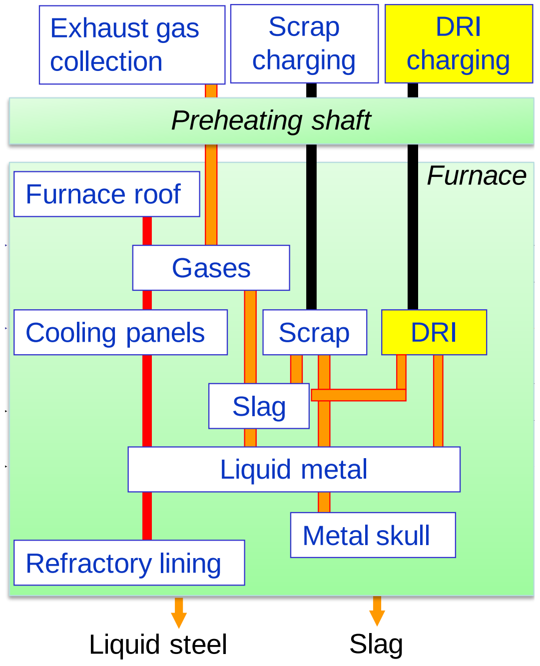
Constants txt file

Geometry of the furnace
Arc distribution, lances and burners influence zones
Lining wearing profiles
Physical and chemical constants

Cyclic data file

Scrap charging
DRI features
Electrical power and Energy
Burner
PC Oxygen lancing
Coal addition & injection
Lime/Dolomite addition
Panels & Roof cooling
Exhaust fumes: T°outlet

Model dll



Short output file

Weights of scrap, steel, slag, waste slag and skull
Temperature of steel, slag, skull
Chemical composition of steel and slag

Long output file

All variables calculated by the model

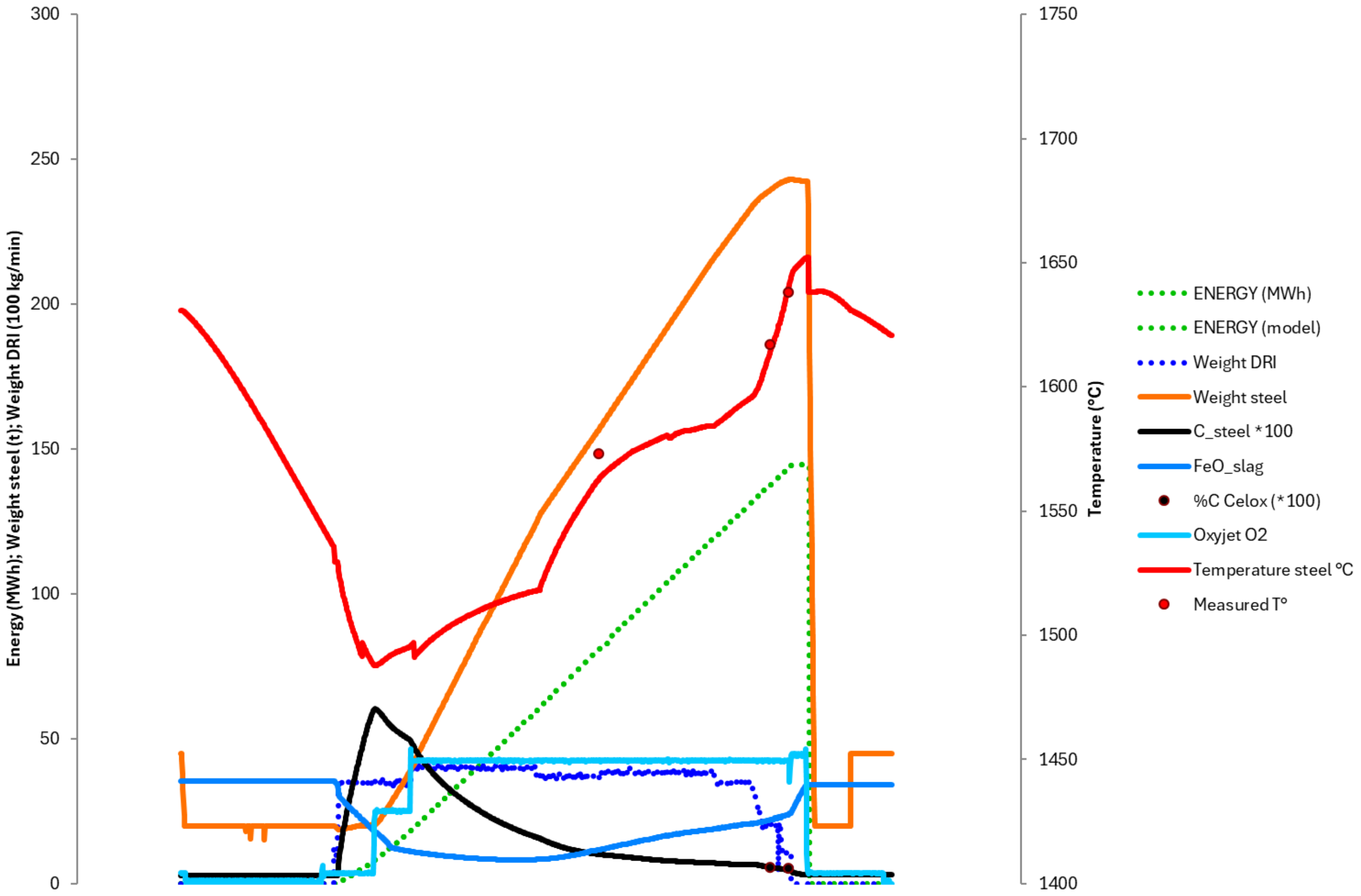
Summary

Total consumptions
Total weights of scrap, steel, slag
Final temperatures and composition

CRM EAF model

First Base Case

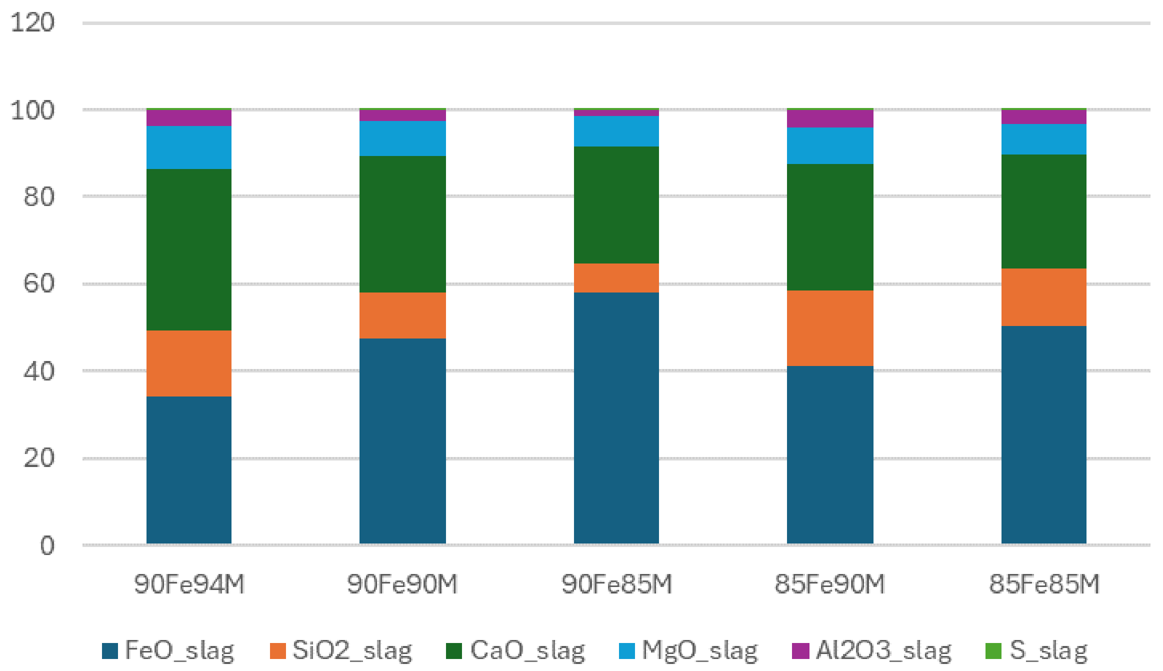
- Data from actual 100% DRI fed EAF
- ~200 tons crude steel tapped at 1640°C
- ~60 min tap to tap
- No burner
- 1 O_2 lance
- DRI:
  - 90% Fe
  - 94% metallization
  - ~2% C
- Slag compo:
  - 34% FeO
  - 15% SiO_2
  - 37% CaO
  - 10% MgO
  - 3.5% Al_2O_3
  - B2 : 2.5



CRM EAF model

Lower quality DRI impact

- Data from actual 100% DRI fed EAF
- ~200 tons crude steel tapped at 1640°C
- ~60 min tap to tap
- No burner
- 1 O_2 lance
- DRI:
  - **90% - 85% Fe**
  - **94% - 90% - 85% metallization**
  - 2% C



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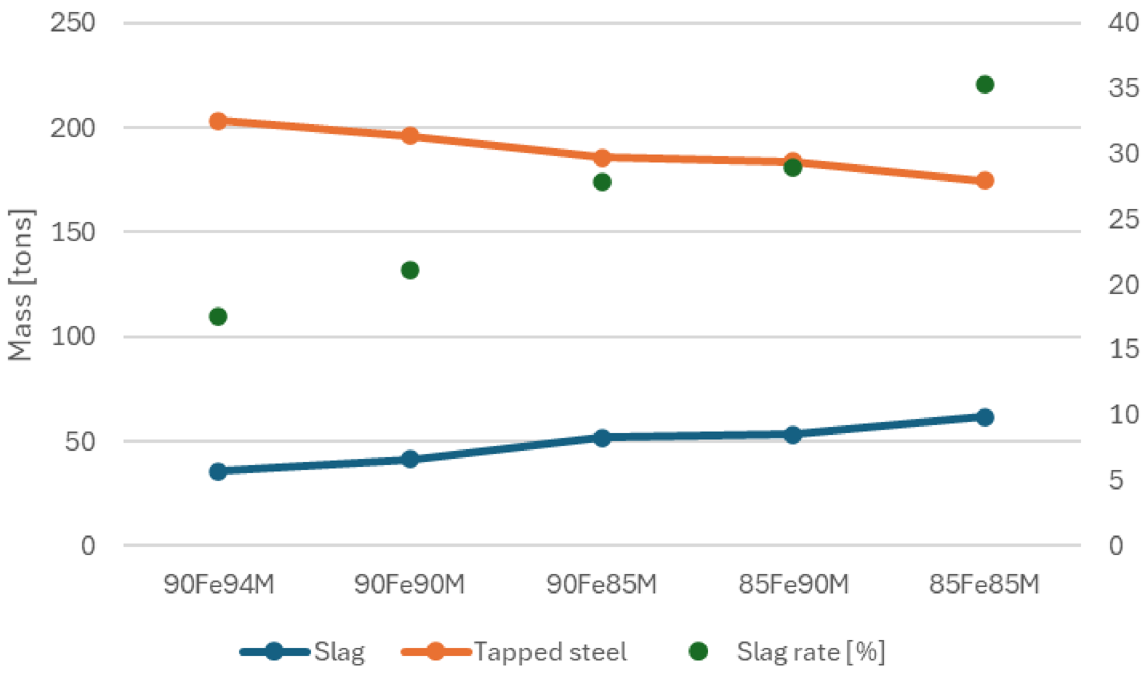

CRM EAF model

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- ~200 tons crude steel tapped at 1640°C
- ~60 min tap to tap
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- 1 O_2 lance
- DRI:
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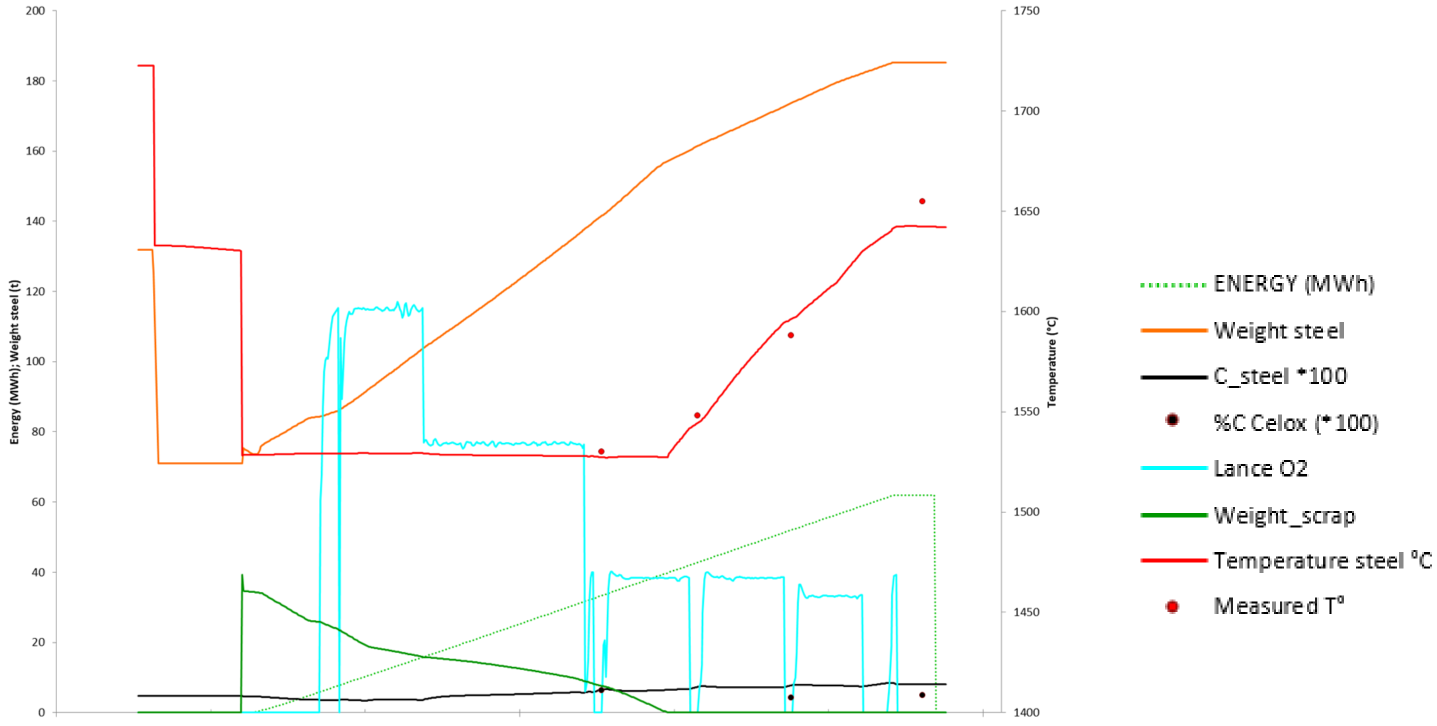
  - **94% - 90% - 85% metallization**
  - 2% C
- Process adaptation

	C addition	Iron yield	Energy
	[kg/t]	[%]	[kWh/t]
90Fe94M		91	
90Fe90M	5.3	89	13
90Fe85M	12.1	88	25
85Fe90M	3.7	83	56
85Fe85M	10.0	82	68

CRM EAF model

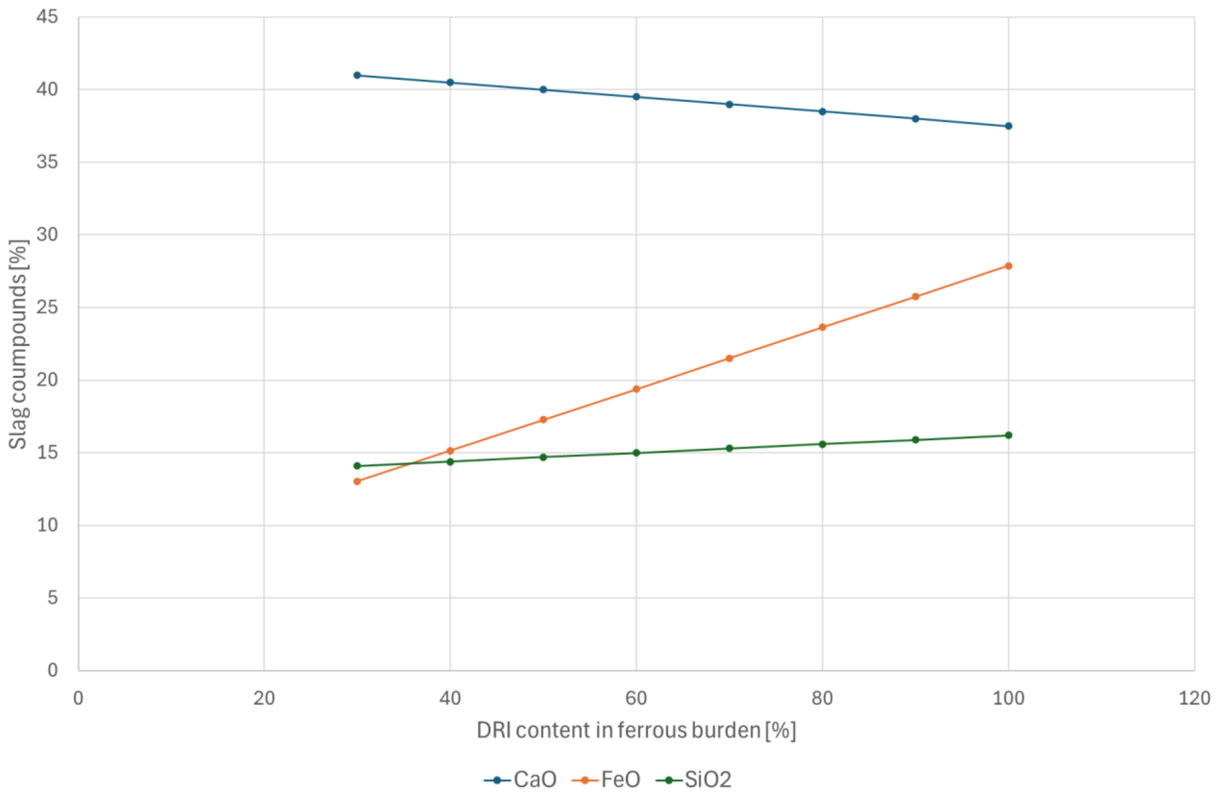
Second Base Case

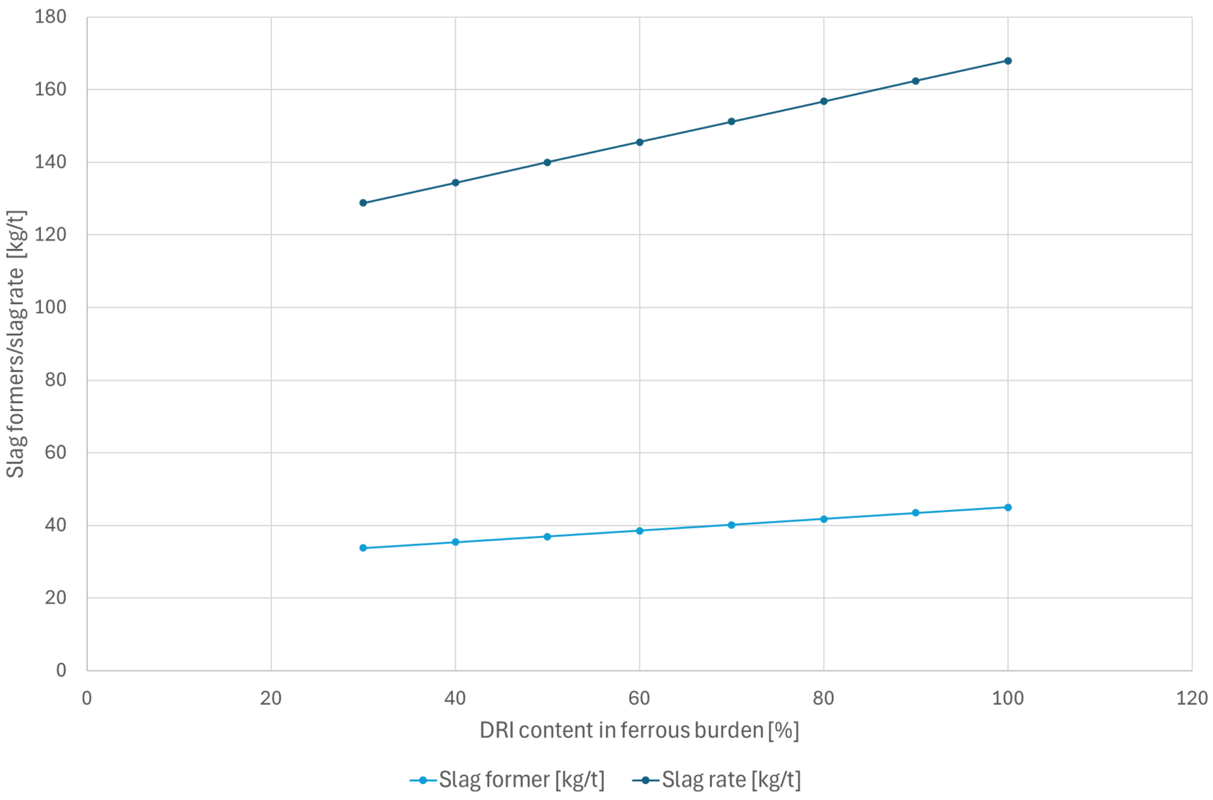
- Data from actual mixed burden fed EAF : DRI rate [50 – 100 %] – extrapolated down to 30%
- Reference case : 67% DRI (1 scrap basket)
- ~130 tons crude steel tapped at 1650°C
- ~60 min tap to tap
- 3 burner
- 3 O_2 lance (supersonic)
- 3 coal injectors



CRM EAF model

DRI share in the burden





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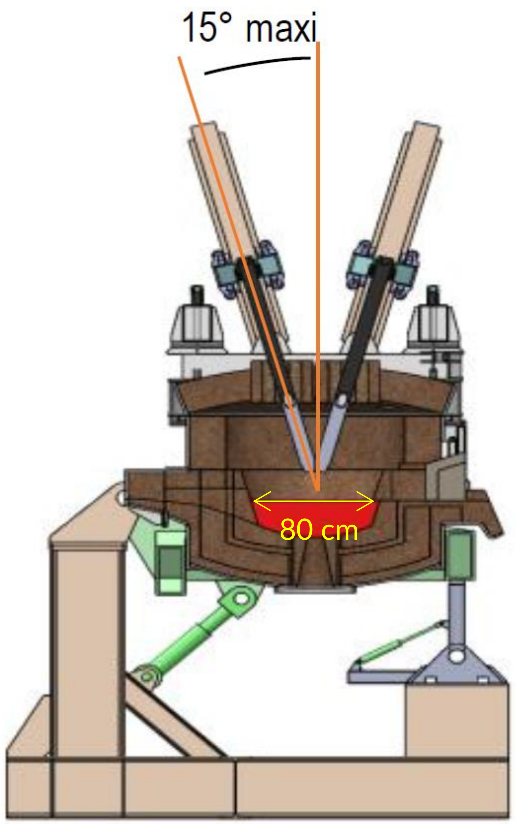
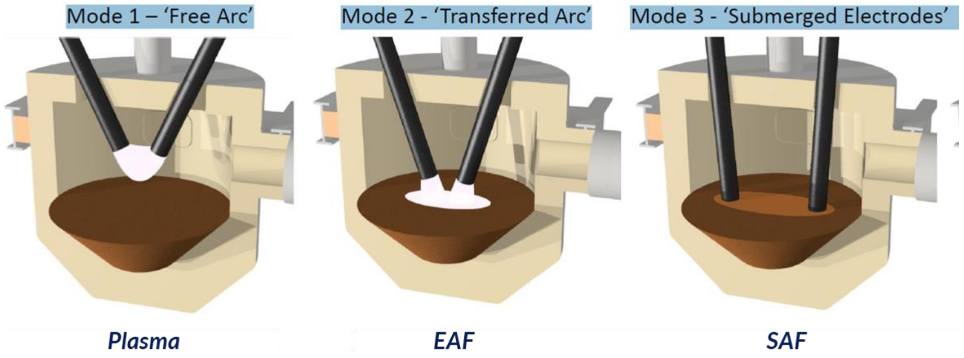
Plasma furnace for DRI-EAF melting and slag remelting





Max. temp.c	1800 ºC
Capacity	125 L / 1 ton
Heating mode	Plasma / EAF / (SAF/ESR)
Max power	DC 700 kW
Atmosphere	Air, N_2, Ar
Loading	Automatic, batch
Fully integrated off-gas system (designed for material fuming) Thermal oxidizer, bag-house & absolute filters, sorbent dosing system, sampling system	

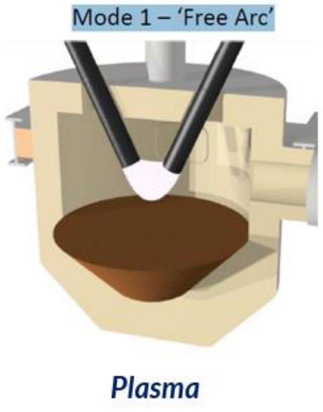
InSGeP

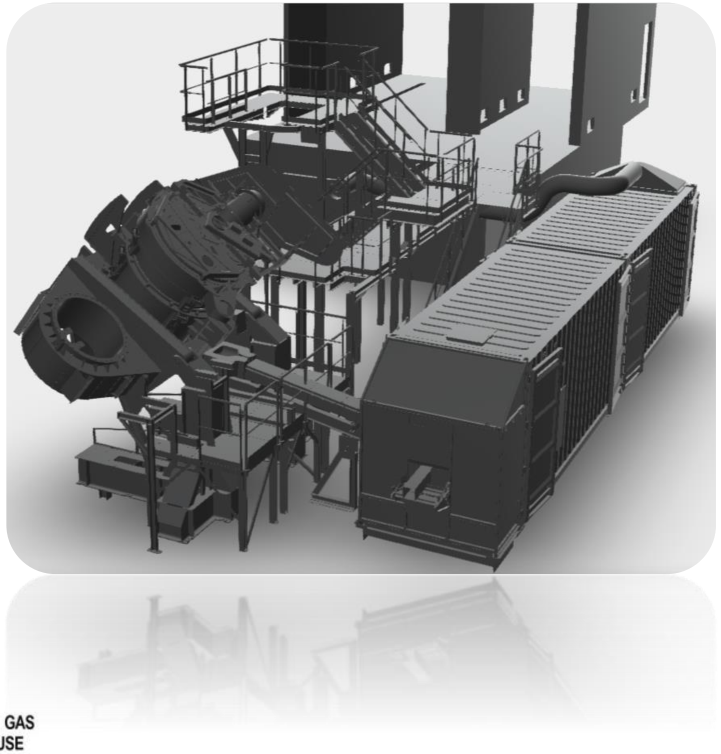
Dry slag granulator

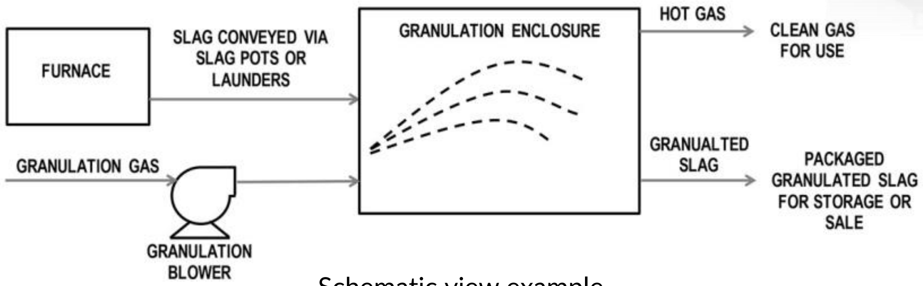
Promote valorisation of slags thanks to dry granulation & increased amorphous grade

✓ Homemade Design

- Synthetic slags OR remelting of industrial slag
- Selected technology = dry granulation
  - reduced water consumption
  - possible heat recovery
  - Up-scalable



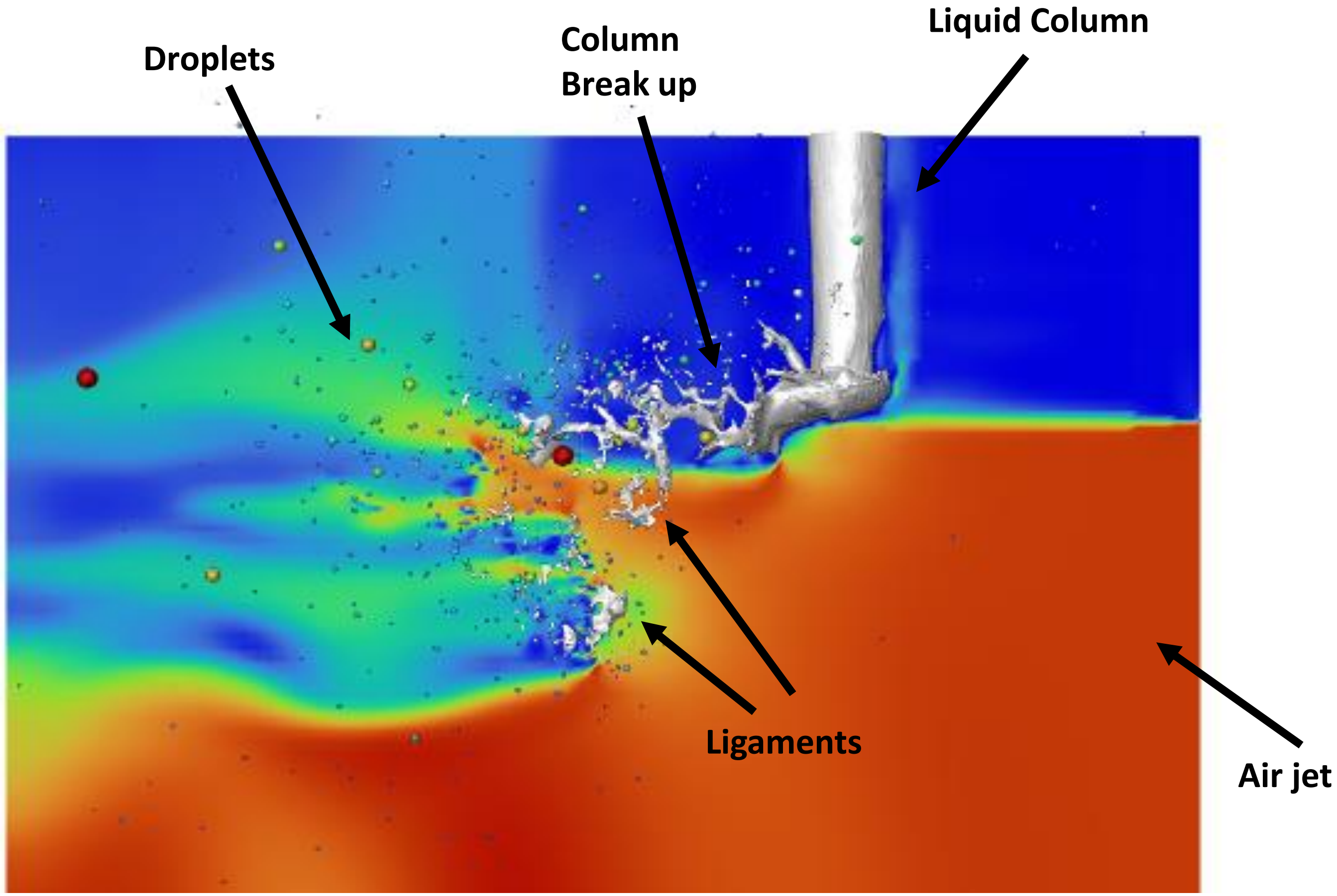




Schematic view example
[source : Lindvall et al. (2019), Stabilization of stainless steel slag via air granulation. Journal of Sustainable Metallurgy]

CFD modelling of the granulation process

The design of the CRM granulator was developed based on Computational Fluid Dynamics (CFD). This has been used to obtain detailed visuals and break up sequences with high accuracy.

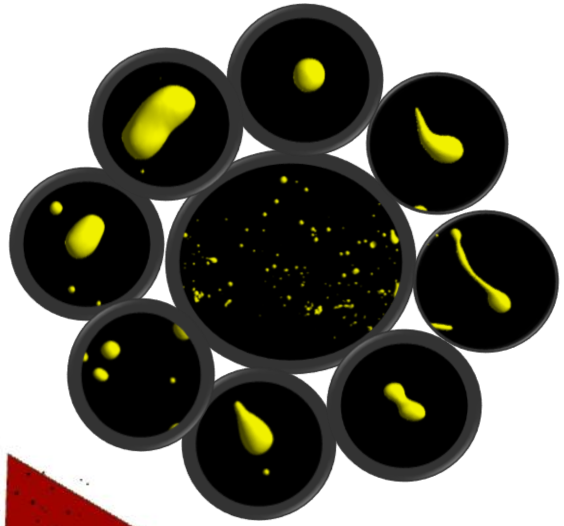


CFD modelling of the granulation process

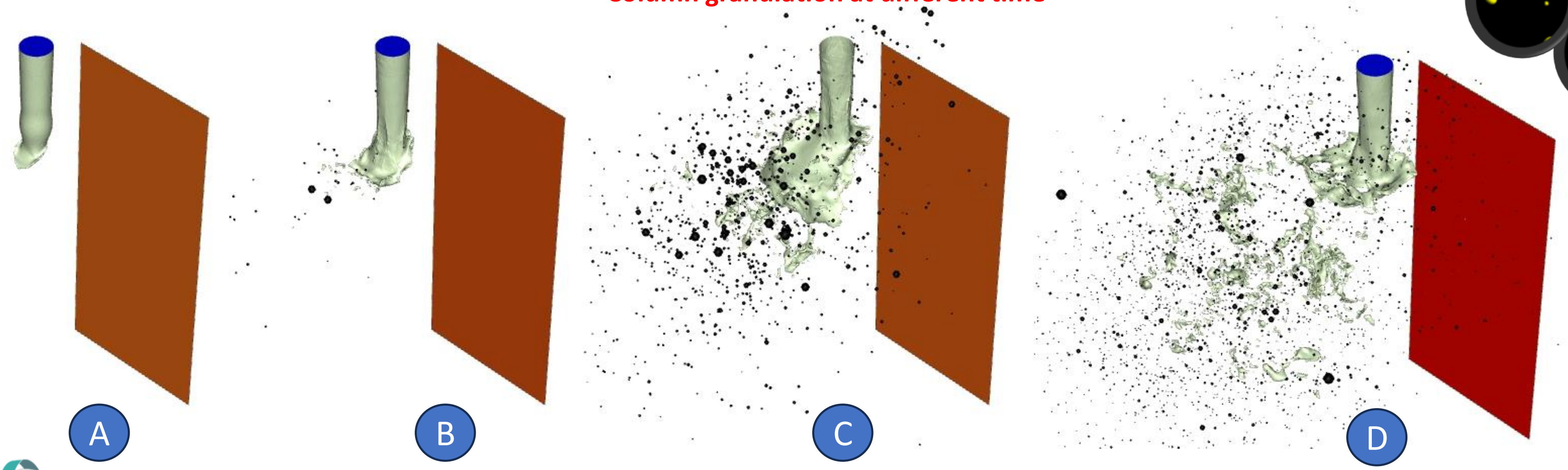
CFD analysis is performed to obtain the following parameters for an optimized granulation process :

- Air jet speed and slag flow rate (proper momentum ratio)
- Air jet inlet geometry and shapes
- Slag column shape
- Slag port position and distance from the air jet (vertical and horizontal)
- Final droplet shape and sphericity
- Generated particle size distribution (PSD)

Predicted granulated shapes



Column granulation at different time



Granulation facilities

First granulation trials

Conclusions

- DRI quality (%Fe, %metallization) strongly impacts the DRI-EAF slag/metal ratio.

- Carbon addition to keep the iron yield high has a limited range of use due to extra electric consumption of the EAF.

- Increase the ratio of DRI/scrap leads to a lower iB2, more iron loss (FeO in slag), more slag former addition and bigger slag rate.

- Next step : The plasma facility is now operational to melt DRI and granulates slags to support partners for the assessments on these slags regarding to their valorization potential.

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