

TATA STEEL



**Materials
Processing
Institute**



Trial with Scrap and solid iron in a 6 tonnes pilot furnace vs Model simulation

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Together we make the difference

Agenda

- Introduction
- Thermodynamics of elements
- EAF pilot Trial
- EAF – EERZ model
- Results: Trial vs model
- Conclusions



Introduction

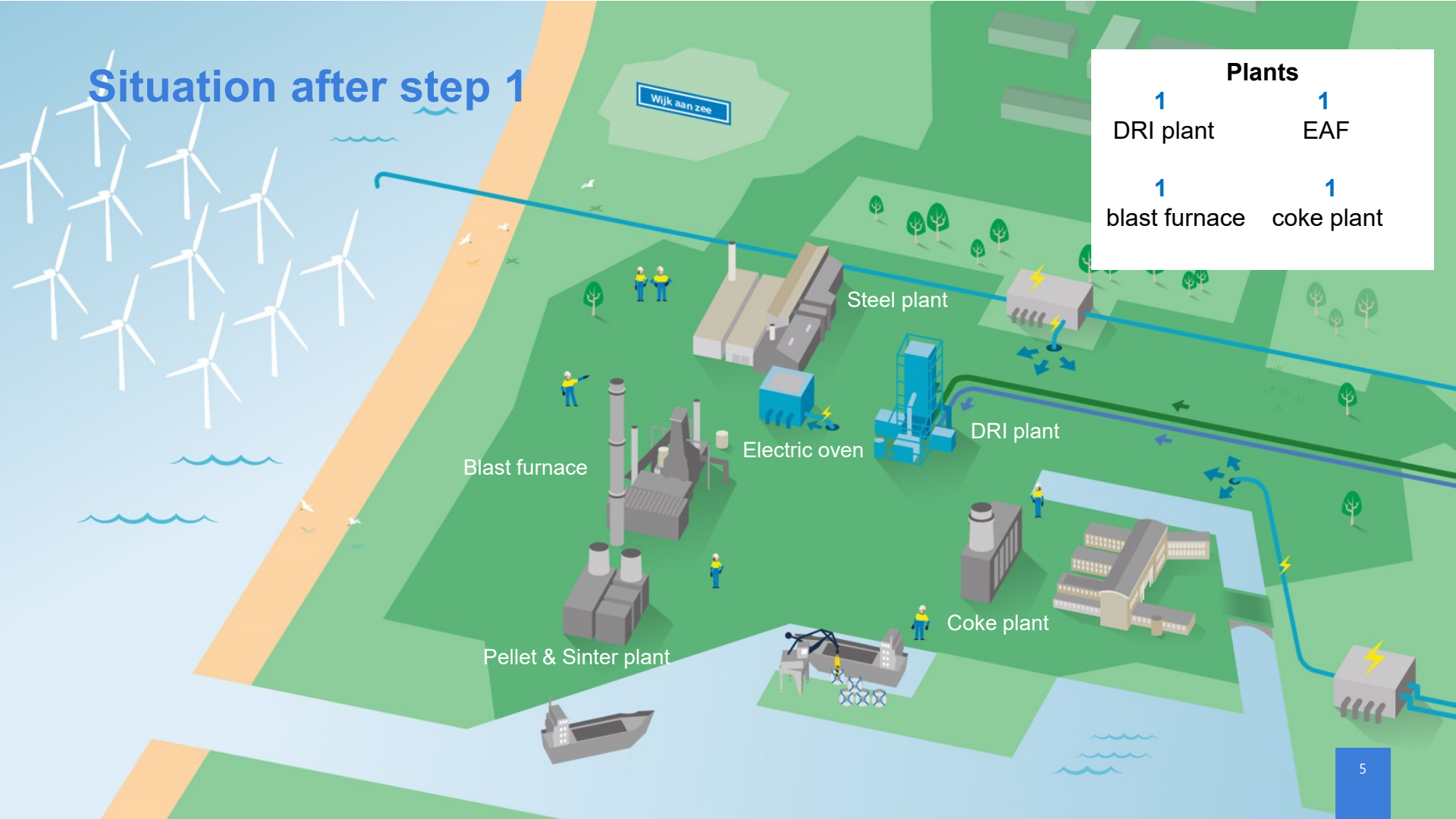
Current Situation

Wijk aan zee

Plants	
2	2
blast furnaces	coke plants



Situation after step 1



Plants	
1	1
DRI plant	EAF
1	1
blast furnace	coke plant

Introduction

Why study TRE partition distribution

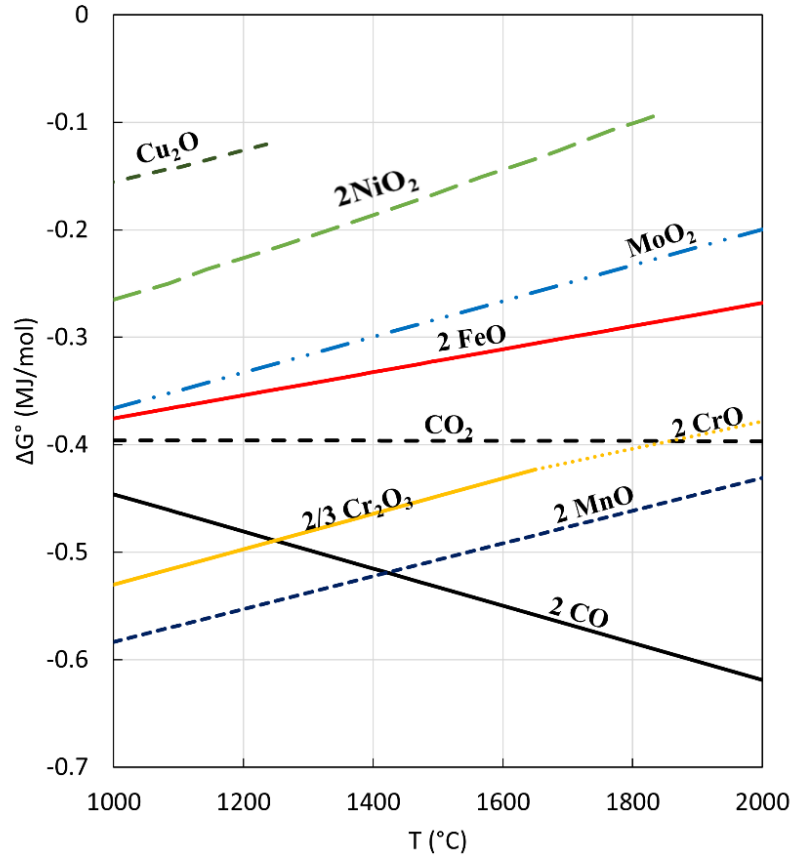
- TREs (Mn, Cr, P, Cu, Ni, S, and N) have an influence on the tapped steel quality
- TREs in the steel can impact the **mechanical properties** of the final product:
 - Enhancement of **embrittlement**
 - Increasing the **strength** and **hardness**
 - Decreasing the **toughness** of steel
 - Reducing **drawability**
 - Poor **coatability**
- Comparison of EERZ – EAF model vs trial results → model validation

TRE: tramp and residual elements

EERZ: Effective Equilibrium Reaction Zone

Thermodynamics of Elements

Thermodynamics of elements



- **Cr** and **Mn** are partially oxidized since they have more negative values for ΔG° than **Fe**.
- **Mo**, **Cu** and **Ni** will not oxidize, due to their higher ΔG° of oxidation compared to Fe
- **C** has a greater affinity with O_2 , than **Cr** and **Mn** does \rightarrow **C** content needs to be low for **Cr** and **Mn** to start oxidizing

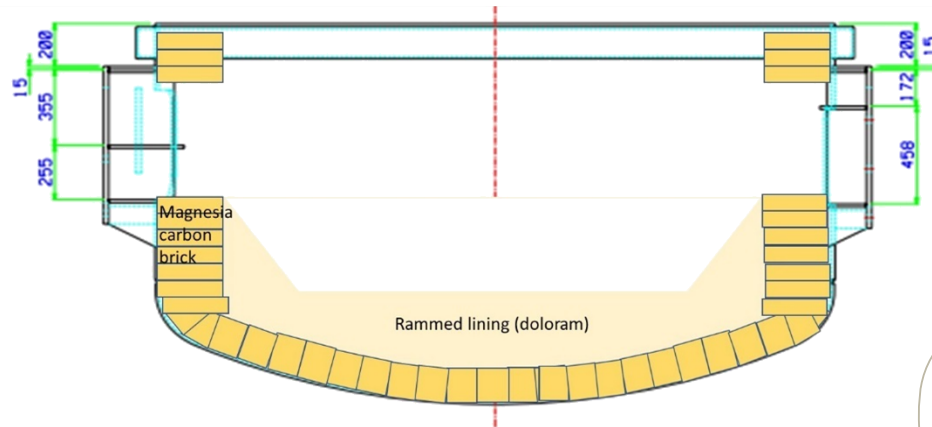
EAF pilot trial

Partition Distribution of TREs

EAF pilot Trials

General Information

- AC
- 3 electrodes
- Metallic Charge: 6t
- The charging is done from the top of the furnace, after the roof is set aside
- Carbon injection and oxygen lancing can be done through the slag door,



Scheme of the pilot EAF at MPI



Electric Arc Furnace Setup at Normanton Pilot Plant, MPI

EAF pilot trials

Objectives of the trials:

- Partition distribution of Mn, Cr, P, Cu, Ni, S, and N.
- Investigate possibilities for TREs – removal with oxygen blow in correlation to C content

Trial recipe:

Clean scrap	BF - iron	Charged Carbon (anthracite)	Injected C	Fluxes	O ₂ blow
80% (4.8t)	20% (1.2t)	120kg	55kg	Dolomite: 140kg FeSi: 15kg	Yes ~330kg

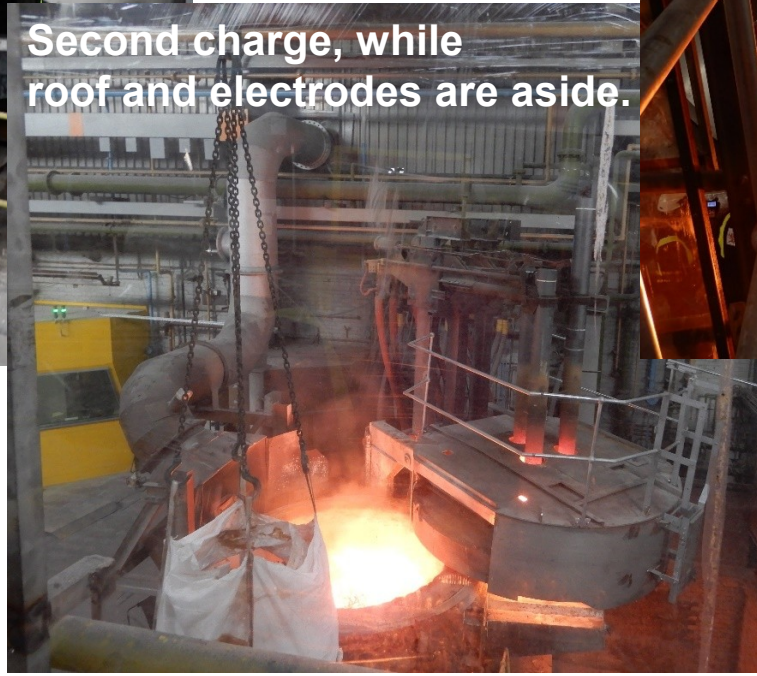
BF – iron: solidified blast furnace hot metal, which was composed of several relatively large plates of iron that had been dropped balled from larger beds of iron that had been teemed from the iron torpedo ladles.

EAF pilot trial process



First charge.

Second charge, while roof and electrodes are aside.



Tapping the furnace.

EAF pilot Trial



Oxygen being blown in the furnace, through the slag door.

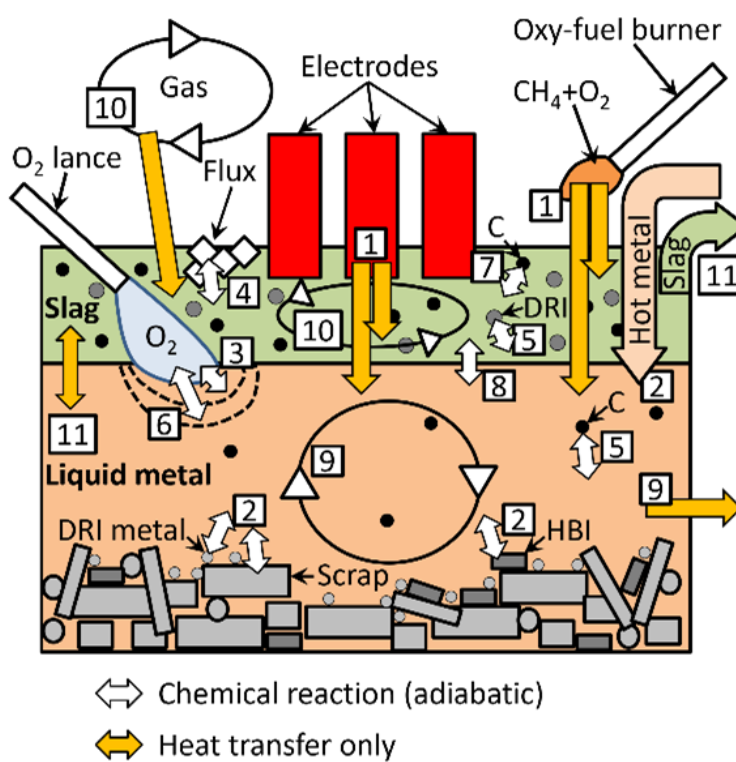
Objectives:

- TRE refining by blowing pure O_2 into the steel bath.
- Enable nitrogen removal (indirectly); oxygen blowing produces CO bubbles during decarburization
- Follow overall steel chemistry

EAF – EERZ model

EAF – EERZ model

Schematic representation of the reaction zones of EAF EERZ Model



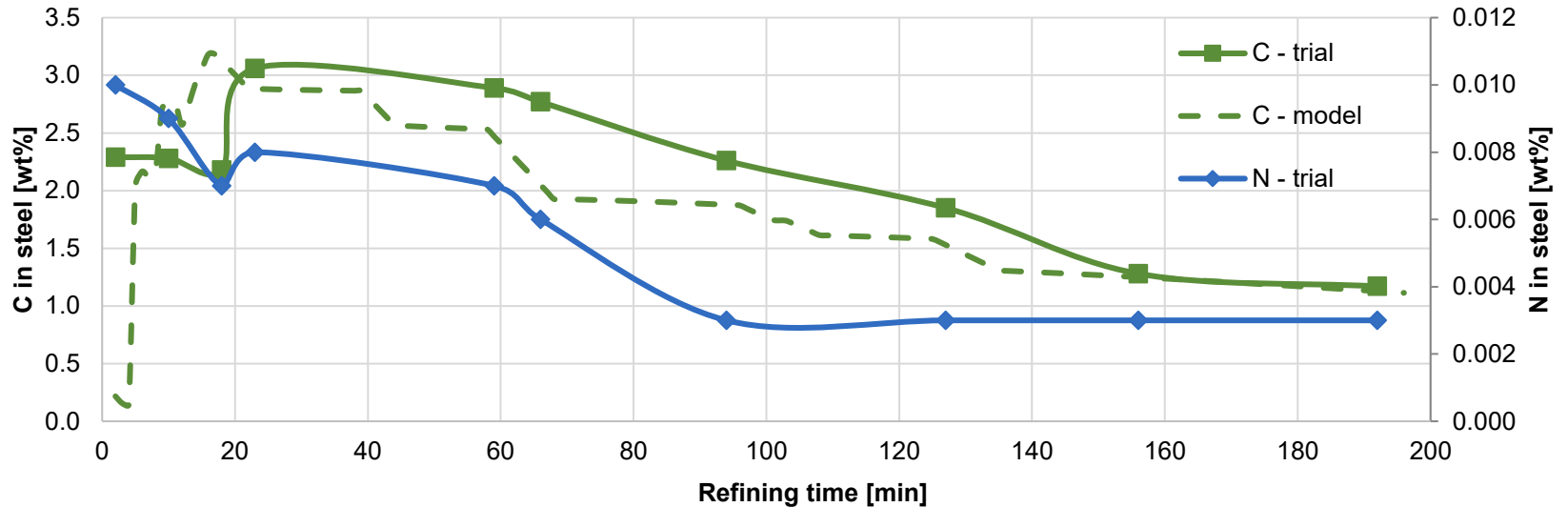
- ① Transfer of heat from arc and oxyfuel burners to charge
- ② Hot metal addition, scrap (+DRI metal) and HBI melting
- ③ FeO formation by O₂ lance
- ④ Flux and contaminants dissolution to slag
- ⑤ DRI reaction (slag + melting), C addition to liquid metal
- ⑥ Direct deC by O₂ lance
- ⑦ Carbon/slag reaction
- ⑧ Slag/metal reaction
- ⑨ Liquid metal homogenisation and heat loss
- ⑩ Post-combustion (PC) of gas, slag homog. with PC heat
- ⑪ Slag/metal heat transfer, slag discharge

Ref: M.-A. Van Ende, Development of an Electric Arc Furnace Simulation Model Using the Effective Equilibrium ReactionZone (EERZ) Approach, Journal of Metals, 2022, 74, 1610-1623.

Results: Trial vs model

Results

Model vs trial comparison



Carbon

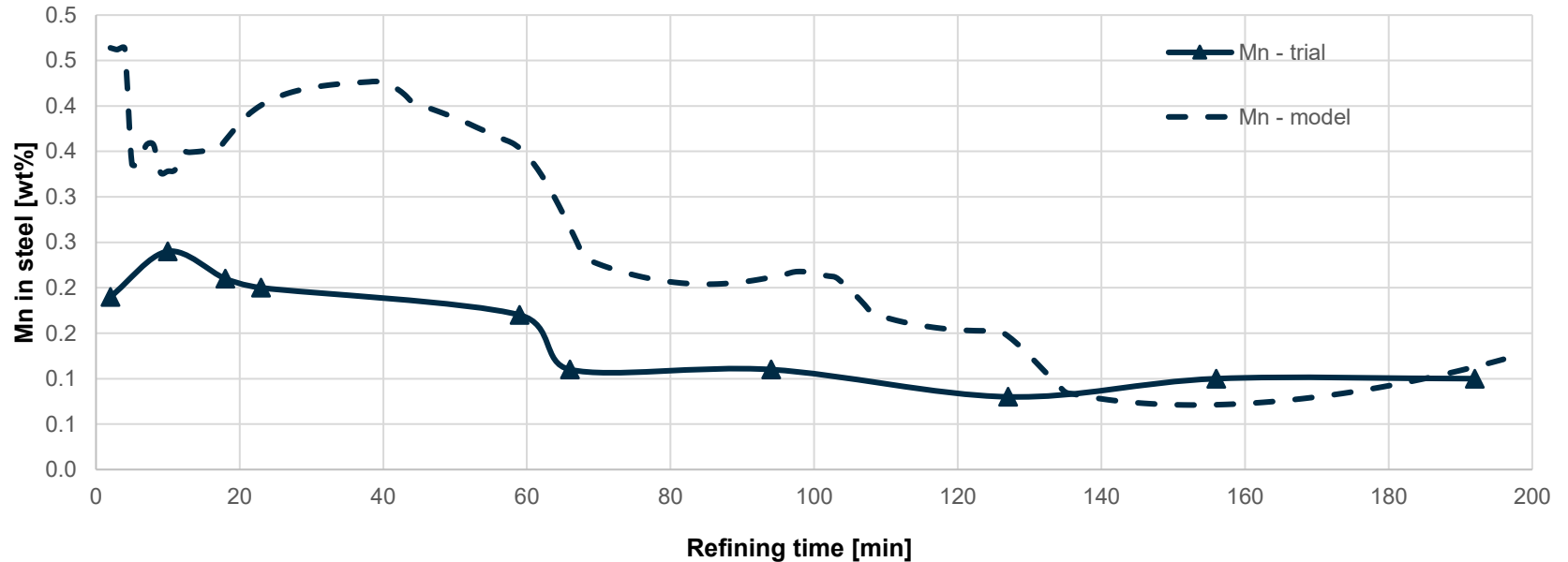
- Model and trial show very good agreement in overall trend
- End-point values are nearly identical
- Trial shows slower decarburisation rate
- Caused by delayed CO bubble formation compared to model

Nitrogen

- Sharp nitrogen removal during peak decarburization
- Removal mechanism: CO bubble flushing of dissolved N
- Direct comparison not possible
- Model limitation: no arc-induced N pickup

Results

Model vs trial comparison

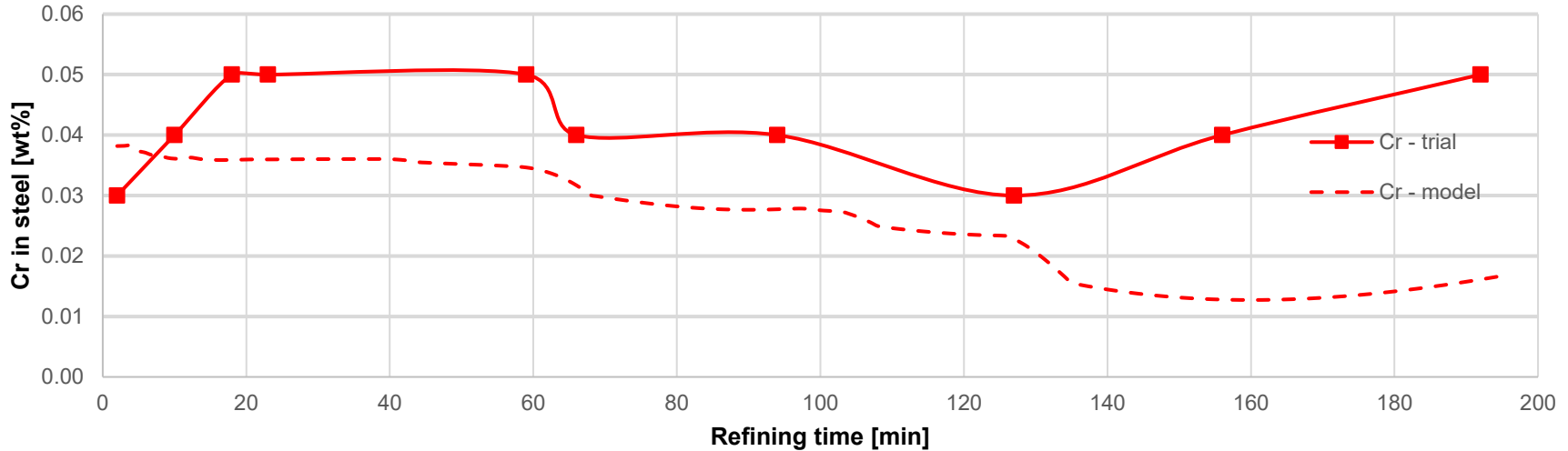


Manganese

- Good agreement in trend between model and trial
- Model captures Mn oxidation and recovery behaviour well
- Final Mn concentrations closely match
- Indicates reliable modelling of Mn partitioning

Results

Model vs trial comparison

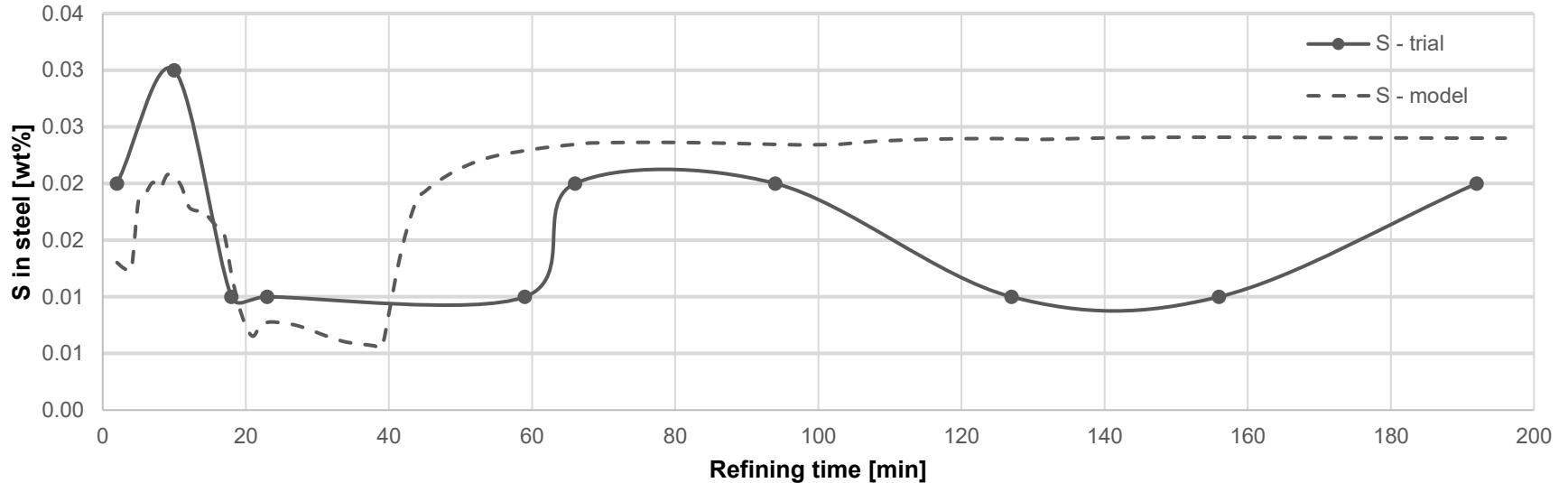


Chromium

- Similar overall trend between trial and model
- Trial shows Cr pickup not predicted by model
- Likely caused by different slag chemistry between model and trial
- Effect is not represented in model assumptions

Results

Model vs trial comparison

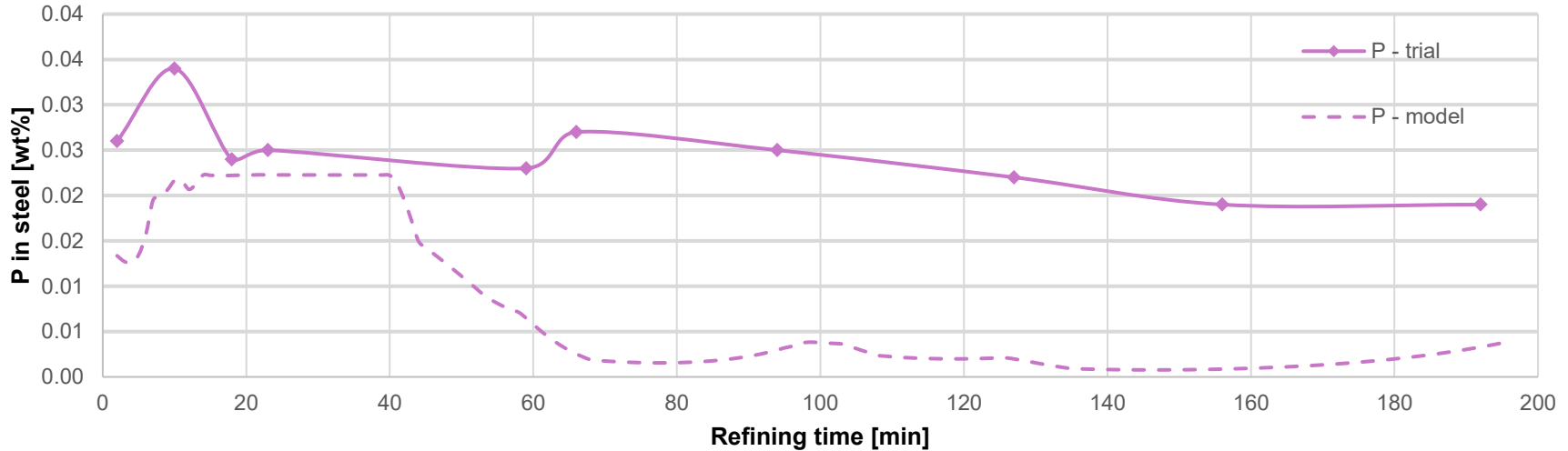


Sulphur

- Model and trial show similar qualitative trends
- Final S slightly overpredicted by model, but still close to the trial value
- Influenced by oxygen competition at high carbon levels
- Suggests limitations in modelling desulphurisation under dynamic conditions

Results

Model vs trial comparison

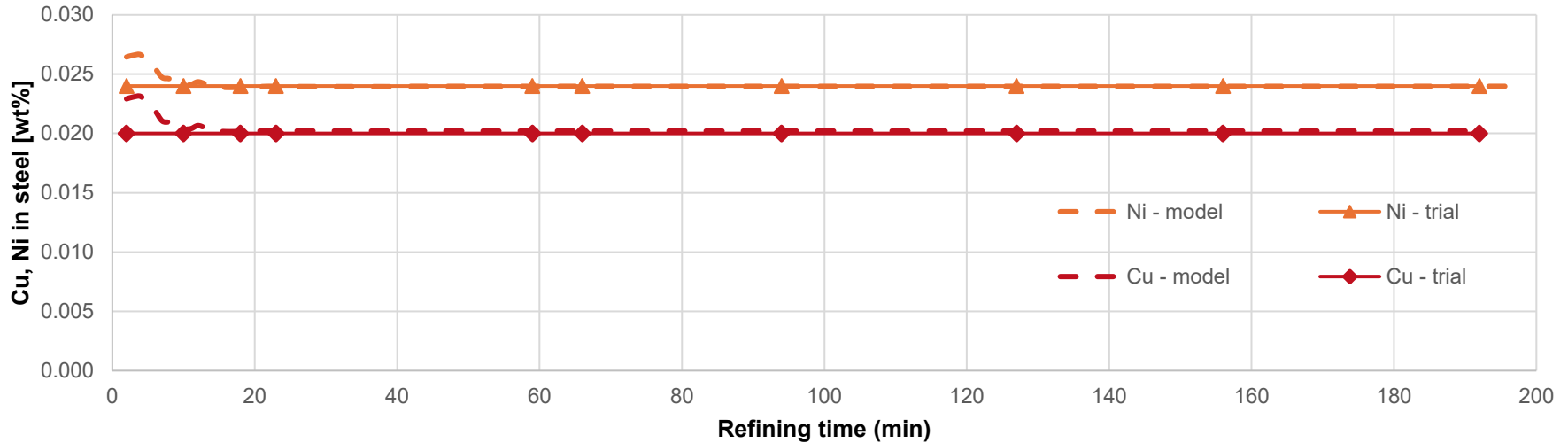


Phosphorus

- Weakest agreement among all elements
- Model overpredicts phosphorus removal
- Likely due to lower slag basicity (~1) in trial
- Possible influence of differences in slag oxide composition
- Highlights strong sensitivity to slag chemistry assumptions

Results

Model vs trial comparison



Copper

- No refining removal observed (remains in steel)
- Model correctly predicts element stays in the metal phase
- Concentrations throughout match well

Nickel

- Nickel behaviour similar to the one of copper
- Remains in the steel throughout refining
- Good agreement between model and trial

Conclusions

Conclusions

Good agreement:

- C and Mn show very good agreement, with nearly identical end-point values
- Cu and Ni behave as expected, remaining in the metal and matching the model

Moderate deviations:

- S follows a similar trend, but final values differ due to oxygen competition at high carbon
- Cr shows similar behavior, but trial data indicate pickup from refractory wear not included in the model

Largest discrepancy:

- P removal is overpredicted by the model
- Likely caused by differences in slag composition during the trial

Not comparable:

- N cannot be evaluated because the model does not include arc-induced nitrogen pickup
- Trial data clearly show the N – flushing effect, during de – C

Overall conclusion:

- The model captures the refining sequence well
- Improvements are needed to account for slag chemistry, nitrogen behaviour, and minor contamination effects