Current state and ongoing development of a dynamic EAF process model

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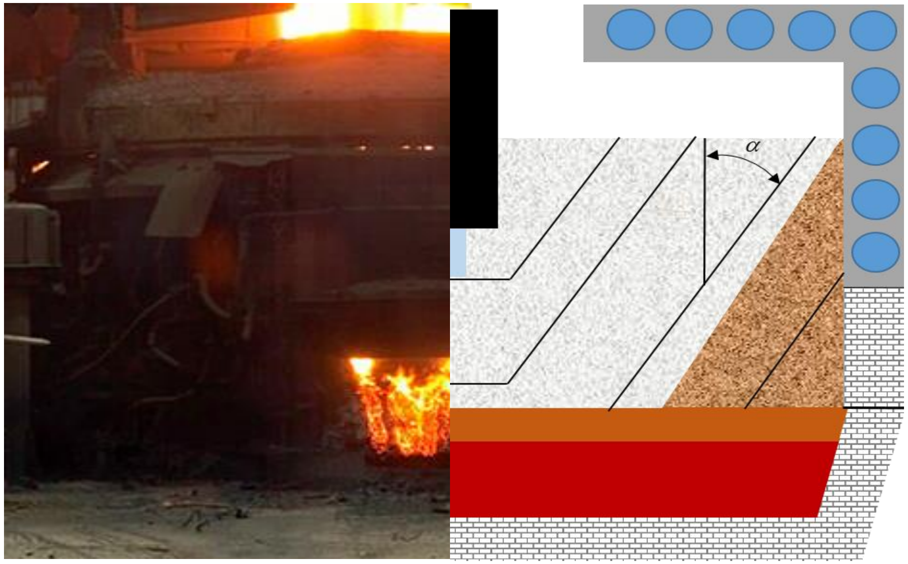
Dynamic EAF Process Model

Comprehensive, Analytical, Fast

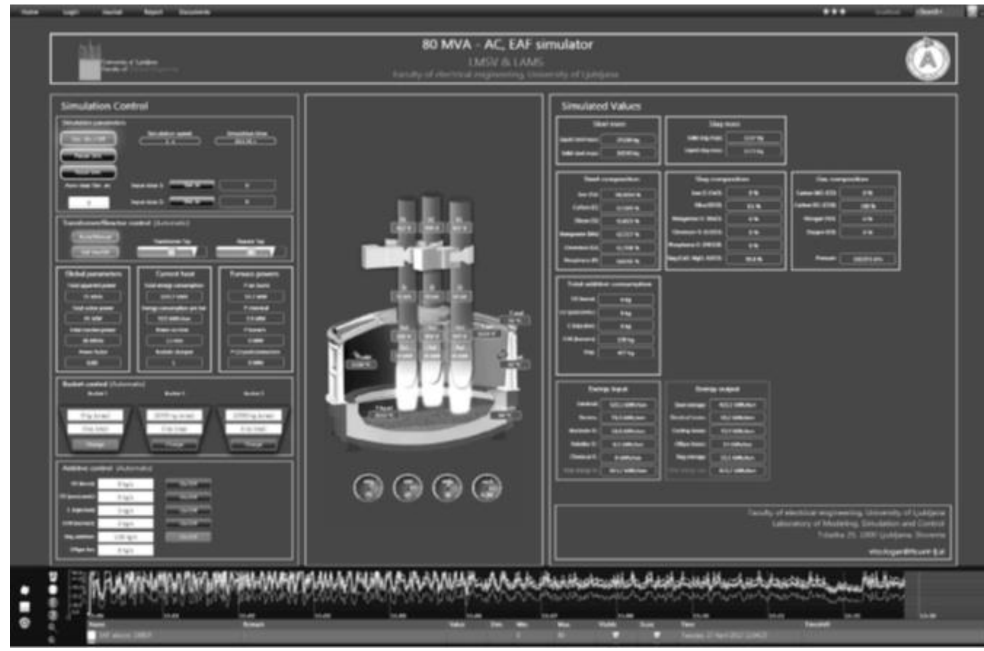
- All relevant phenomena
  - Heat and mass transfer, chemistry, phase changes etc.
- Complete process from tap to tap
- Applicable to different types of furnaces without adjustment of core model
- Extrapolation capability
- Fast enough for online applications



Model Overview - Development

Based on Logar et al. and Meier

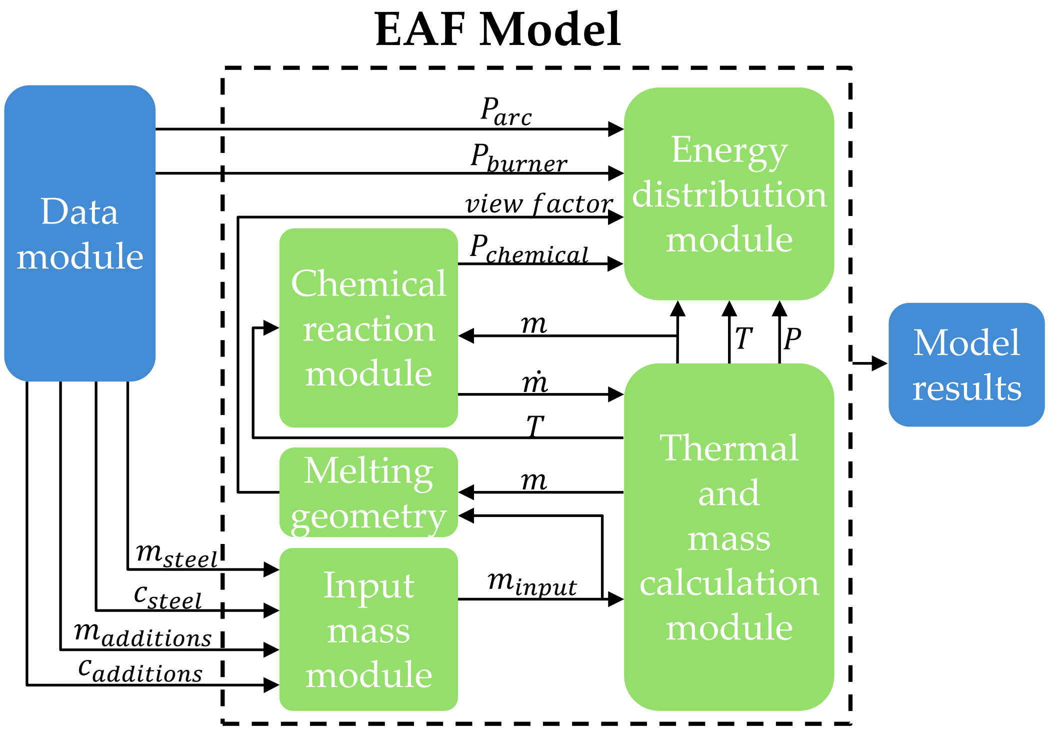
- Initial publications by Logar et al. in 2011-2012
- Validation with 80MVA industrial EAF
- Further development by Meier (2013-2017)
  - Gas phase
  - Radiative heat transfer
  - Automatic generation of operation chart
- Validation with 140t industrial EAF



Source: Logar, V.; Skrjanc, I.; Electric Arc Furnace Simulator; ISIJ 2012, Vol.52

Further Development after 2017

- Thermochemistry
- Radiative heat transfer
- Stability and speed
- Simulator with real-time in- and output
- Automatic generation of operation charts



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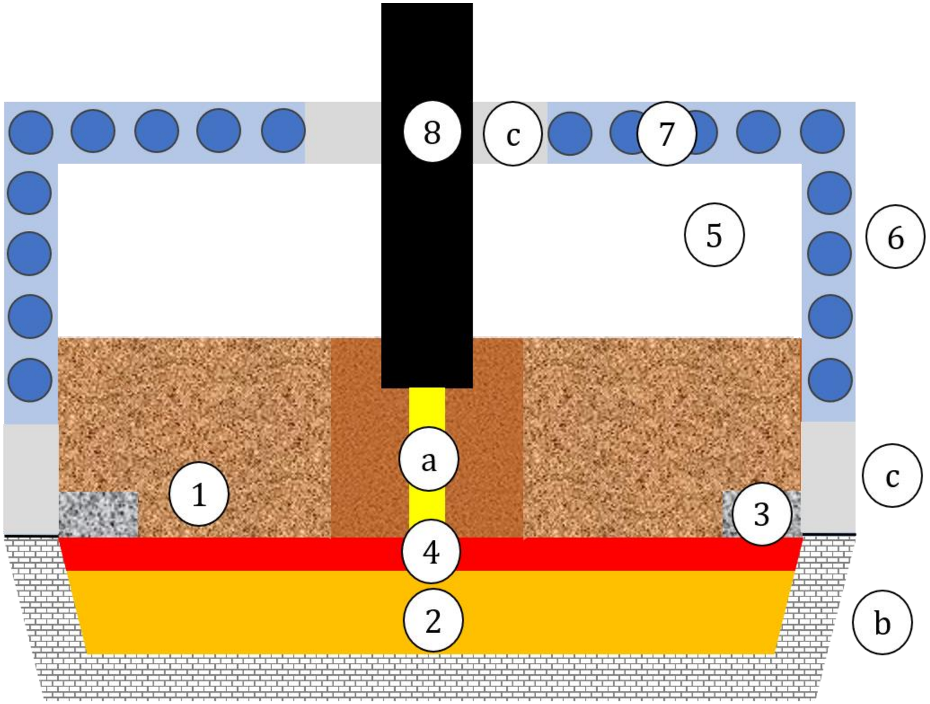
Model Overview - Structure

Zones and Heat Sinks/Sources

- Zones with homogenous temperatures and compositions
- Heat transfer
  - Between zones in direct contact
  - Through radiation
- Mass transfer
  - Melting/Solidification
  - Chemical reactions
  - Injection/charging
- Chemical reactions
  - Melt/slag
  - Injection of carbon and oxygen
  - Gas zone
  - Limited heterogeneous reactions

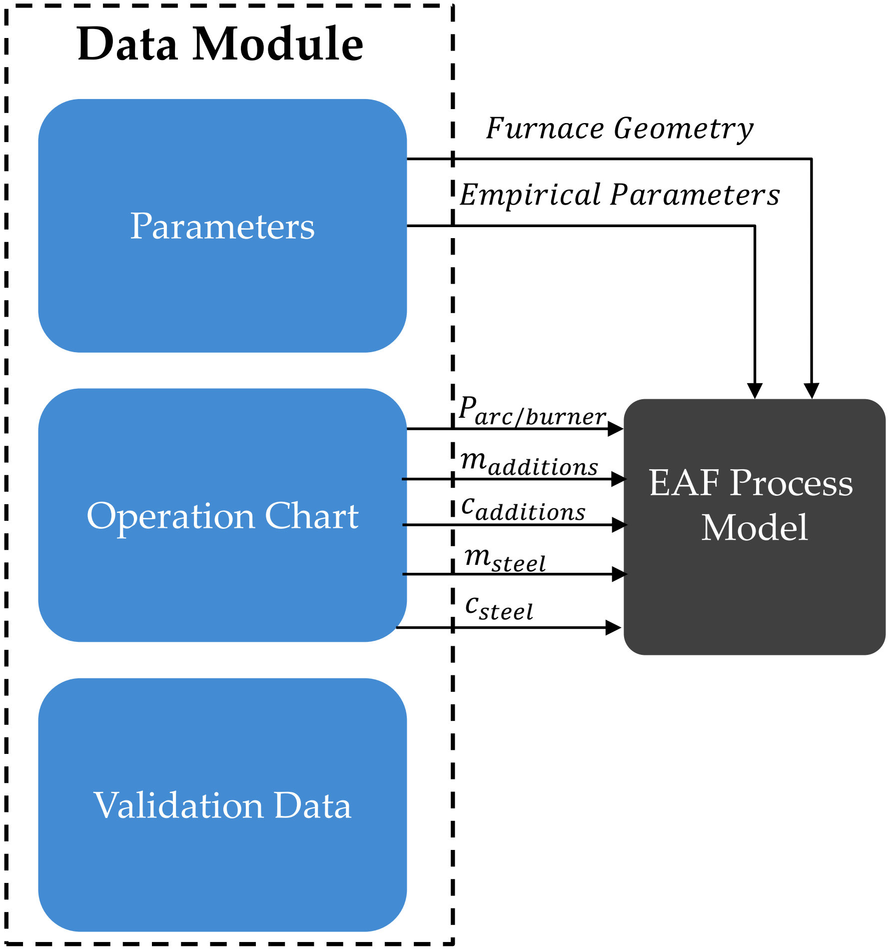


1: Scrap | 2: Melt | 3: Slag Formers
4: Slag | 5: Gas | 6: Wall (water-cooled)
7: Roof (water-cooled) | 8: Electrode | a: Arc
b: Bottom Vessel | c: uncooled roof/wall

Off-line/Validation mode

Data from industrial EAF

- Operation chart
  - Electrical power
  - Mass flows
  - …
- Charged masses, tapped mass…
- Validation
  - Continuous
    - Off-gas temperature and composition
    - Cooling water temperature
    - Electrode position
  - Spot
    - Slag and melt composition
    - Melt temperature



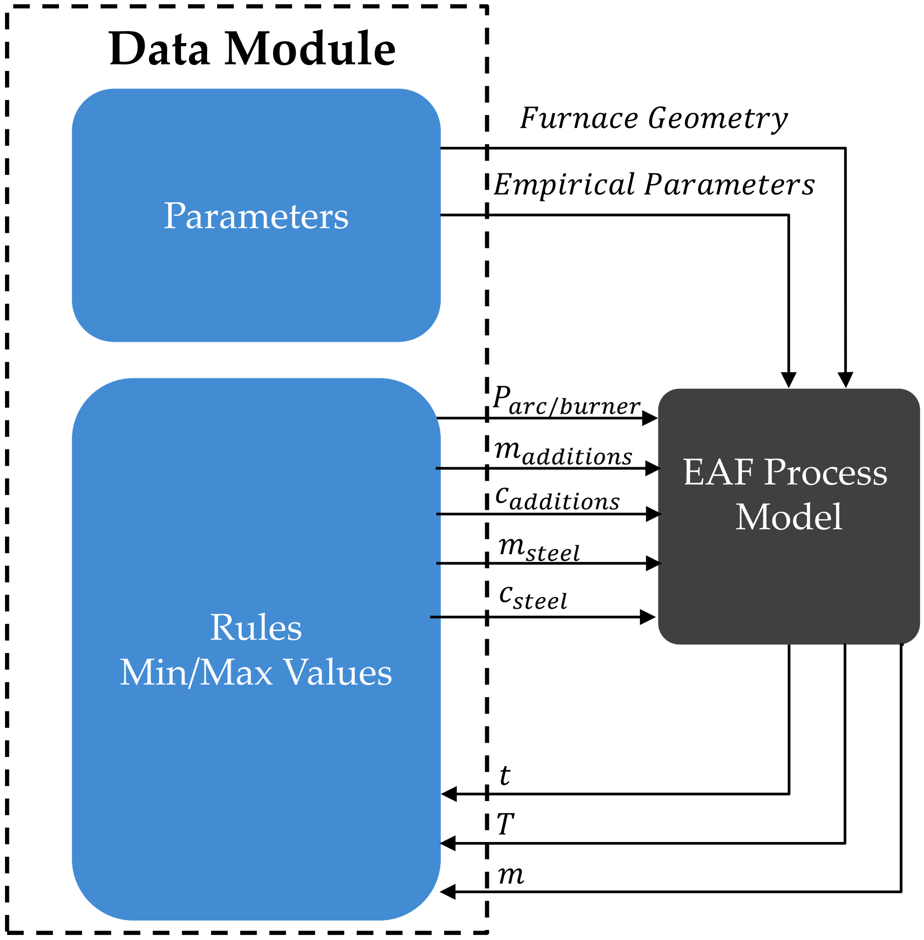
Automatic Control Mode

Evaluation of Control Strategies

- Automatic determination of operation chart based on Meier

- Based on rules and parameters
  - Steps for input values
  - Conditions for selection of steps
  - Desired steel grade and temperature

- Different possible operation charts for the same outcome
  - Different conditions
  - Optimization



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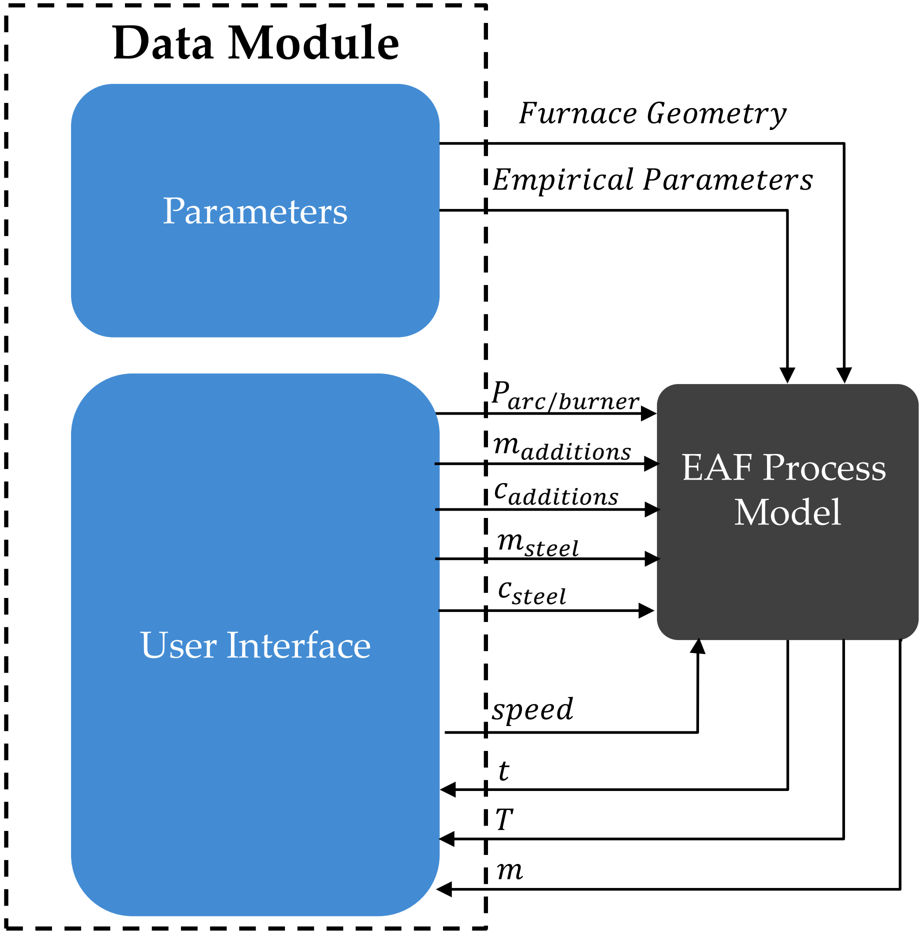
Simulator Mode

Real-Time Interaction

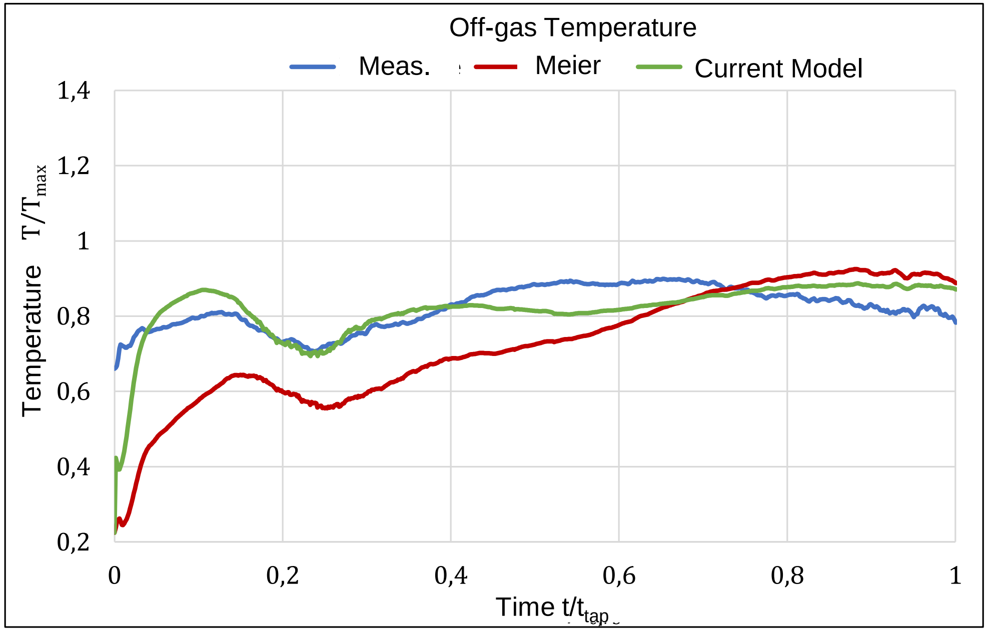
- In- and output through user interface
- Variable speed of the simulation
- Higher stability necessary due to more extreme possible inputs
- Possible applications in training and education
- Alternative use as soft sensor by using real-time measured data as input



Results: Validation

Measured Data from several EAF

- Continuous and spot measurements
- Similar levels of accuracy as Meier with significantly improved speed
- Base for parameter adjustment and model validation



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Results: Automatic Control

Case Study Results

- Case 1 to match measured profile, Case 2 to evaluated alternative oxygen source
- Same tapping temperature in all cases
- Increase in electrical and chemical energy consumption
- Increased tap-to-tap time
- Potentially compensated by cheaper oxygen

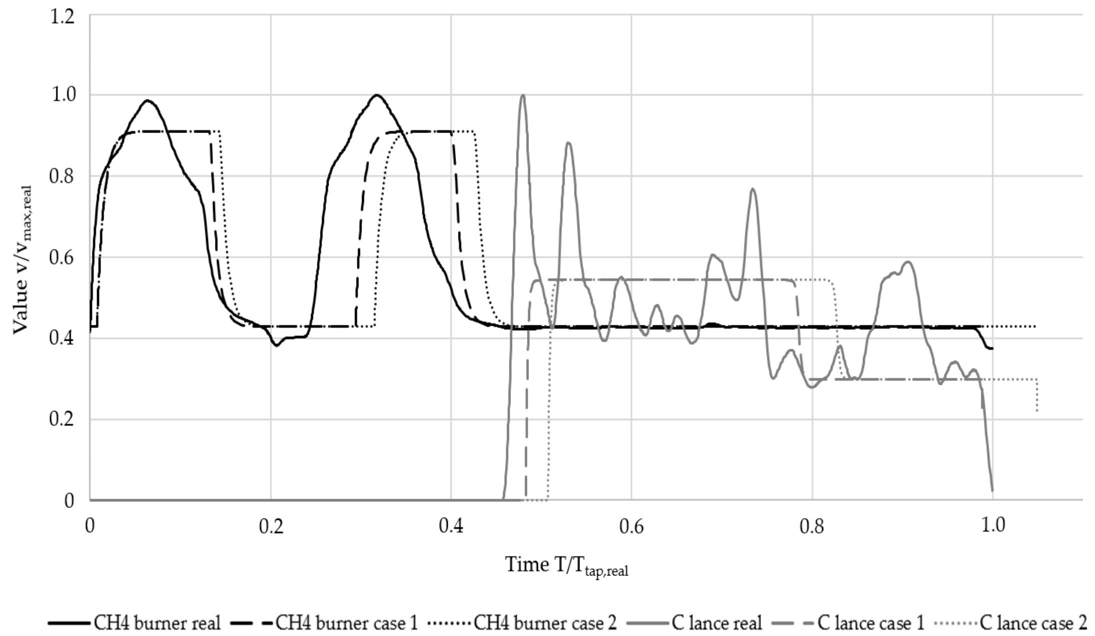
Parameter	Case 1	Case 2
Electric energy	1	1.06
Oxygen (lance)	1.1	1.17
Oxygen (post-combustion)	1	1.06
Injected carbon	0.9	0.96
Off-gas	1.06	1.13
Natural gas	0.99	1.04
Oxygen (gas burners)	1	1.07
Total oxygen	1.07	1.14
Tap-to-tap time	0.99	1.05

Calculated performance indicators for the studied cases relative to measured values

Results: Automatic Control

Control of Carbon and CH_4 Injection

- Late onset of burner operation for second basket for both cases
- Longer injection and burner operation for case 2
- Similar profile of injection and burner operation with slight delay but with similar total consumption
- Case 2 increased consumption to offset N_2 content



Conclusion

Current status and next steps

- Comprehensive and flexible model with different operating modes
- Validation based on measured data from different EAF
- Consolidation and translation into Python for more flexibility
- Application of real-time model and model based operating strategies in industrial steel mill

Thank you for you attention

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