Probabilistic EAF charge-mix optimization using machine learning based scrap characterization

Dr. Christoph Kirmse
SMS digital GmbH
The world of metals becomes increasingly challenging

**PROCESS CHALLENGES**
- Ensure plant utilization
- Improve punctuality (OTIF)
- Secure profitability
- Reduce operational costs
- Employee safety

**EFFICIENCY AND SUSTAINABILITY**
- Reduce carbon footprint
- Improve efficiency
- Utilization of green energy
- Apply energy certification

**MARKET CHALLENGES**
- Global overcapacities
- Smaller lot sizes
- Product quality certification
- Resource price fluctuations

**ENABLING DIGITAL TECHNOLOGIES**
- Industry 4.0
- Artificial intelligence
- Data-driven decision making
- 5G data streaming
- AR / VR / 3d visualization
- Cloud computing / big data
- Robotics and smart devices
- ...
The SMS group approach
Merging Domain Expertise with Digitalization Knowhow

SOFTWARE SOLUTIONS
Viridis Energy & Sustainability Suite
Manufacturing Execution Suite
Product Quality Suite
Asset Optimization Suite
Infrastructure Solutions

ADVANCED SERVICES
Expert know how
Equipment | Consulting | Process
Training
Software & data model customization
Software maintenance
CapEx- based business models
Subscription models
Performance-based contracts
Global Leadership in Digitalization

Founded in April 2016 and > 300 employees

Unique combination of digital, engineering and process expertise

Presences in Germany, India, China, USA, Brazil, Italy, Russia, Luxemburg, Singapore

We develop

› Digital products & apps
› Solution development | Data analytics | AI & ML
› Platform and Cloud services
› Consulting with focus on digital transformation in the steel industry

WE COMBINE DIGITALIZATION EXPERTISE WITH 150 YEARS OF METALLURGICAL AND OPERATIONAL KNOW-HOW
Autonomous Plant Operation
Four Dimensions to Boost Efficiency and Sustainability

- Predictive Energy Management
- Predictive Product Quality
- Predictive Production Planning
- Predictive Asset Optimization

Actionable items
Maintenance tasks

TECHNICAL SERVICE
Maintenance schedules

X-Pact® Electric and automation solutions
SMS Digital Solution Suites
Boosting efficiency and sustainability

Predictive Asset Optimization
- 10-25% lower maintenance cost
- 15-35% lower unplanned downtime
- 2-5% Process Optimization

Predictive Product Quality
- 6-8% lower cost of quality
- Reduction of downgradings
- Maximum prime rating

Predictive Production Planning
- 1-2% increased EBIT
- 10% improved OTIF (on time in full)
- 15% less transition

Predictive Energy Management
- Process energy reduction
- Lower carbon exhaust
- Up to 7% reduction of energy & utilities costs

100+ REFERENCES
43 REFERENCES
35 REFERENCES
14 REFERENCES
SMS digital Solution Suites
Partners who trust us

SMS DataFactory
10 references

Asset Optimization
Suite – 100+ references

Product Quality
Suite – 43 references

Manufacturing Execution
Suite – 35 references

Viridis Energy & Sustainability
Suite – 14 references
EAF steelmaking process

Electric Arc Furnace → Ladle Furnace → Caster
Maximize the amount of low-cost Scrap in Electric Steel Making

**Challenge**

Low-cost scrap with unwanted tramp elements puts product quality at risk (e.g. copper)

**Lack of Knowledge**

Limited information about the chemical composition of each scrap type

**Fill the Gap**

Machine Learning provides information on scrap chemistry

**Save Money**

Calculation of the cheapest scrap mix by an optimization algorithm
The Concept

Machine learning algorithm predicts tramp element concentrations in scrap.

Mass and energy balances to calculate chemistry, yield and energy consumption of the heat.

Optimizer calculates the lowest cost charge mix considering different constraints.

First Step | Better Tramp Element Prediction

Second Step | Optimization to Tramp Element max

Cheapest charge mix which meets the analysis requirements.
Historical approach

Scrap Type 1
Copper Content <= 0.3

Scrap Type 2
Copper Content <= 0.1

Virgin Material
Copper content = 0.002

35%

Electric Arc Furnace

35%

Ladle Furnace

30%

Caster

Probe Analysis
Heat copper content = 0.1 %

△ = 0.05%

Maximum allowed copper content for steel grade < 0.15 %

Theoretical copper content <= 0.14 %

\[ \text{Scrap Type 2 } \quad \text{Copper Content } \leq 0.1 \]

\[ \text{Scrap Type 1 } \quad \text{Copper Content } \leq 0.3 \]

\[ \text{Virgin Material } \quad \text{Copper content } = 0.002 \]
Machine learning training with historical data

Scrap Type 1
Copper Content <= 0.3

Scrap Type 2
Copper Content <= 0.1

Virgin Material
Copper content = 0.002

Historical Heat Analyses

Machine Learning

Historical Charge Mixes

Electric Arc Furnace

Ladle Furnace

Caster
Machine learning model in production

Scrap Type 1
Copper content ~ 0.23

Dynamic copper prediction

Scrap Type 2
Copper content ~ 0.07

Machine Learning

Δ = 0.01%

Probe Analysis Heat Copper Content = 0.14 %

Maximum allowed copper content for steel grade < 0.15 %

Virgin Material
Copper content = 0.002

40%
50%
40%

10%

Electric Arc Furnace

Ladle Furnace

Caster

Virgin Material
Copper content = 0.002

Scrap Type 2
Copper content ~ 0.07

Dynamic copper prediction

Machine Learning

Δ = 0.01%

Probe Analysis Heat Copper Content = 0.14 %

Maximum allowed copper content for steel grade < 0.15 %
Copper predictions
Copper efficiency

![Graph showing copper efficiency over number of heats with different lines representing Metallics Optimizer, Copper target, and Produced charge mix.](image-url)
Charge mix comparison

- Restricted scrap types
- No virgin material used by Metallics Optimizer

Bar chart showing the weight comparison between Metallics Optimizer (orange) and Produced charge mix (blue) for different scrap types.
Metallics Optimizer Benchmark - benefits

• Demonstrate the EAF’s charge mix savings potential by using the Metallics Optimizer
• Gain better understanding of tramp elements in the scrap
• Charge more scrap and less virgin materials and simultaneously have less downgrades
• Lower CO₂ emissions
• Find out how to produce closer to analysis targets
• Identify discrepancies in your data
Benchmark data requirements – raw materials

Raw materials data
• Definition of ids and names of raw materials
• Chemical analysis of raw materials
• Historic prices
Benchmark data requirements – heats

• Heats data
  • Definition of ids, steel grades, tap weights
  • Chemical analysis of steel grades
Benchmark data requirements – analysis data

• Analysis data
  • Measured chemical concentration for each heat after melting in EAF
  • Heat charge mix weights
• Provide data in csv files
• Data format requirements available upon request
Benchmark optional data

• Scrap yard inventory
  • Historical inventory data
  • Availability of scrap over time

• Commodity constraints
  • Minimum and maximum allowed scrap usage by copper target
Benchmark results

• Optimize recipes over historic time span
• Compare historic costs incurred with optimized recipe costs
• Use different technical/business constraints for scenario analysis
• Show potential of charge-mix optimization
Conclusion and outlook

- Low-cost scrap has high uncertainty of tramp elements which poses risk to steel quality
- Materials Identifier reduces uncertainty by providing more accurate scrap analysis
- Charge-mix optimization finds cheapest recipe for any given steel grade
- Copper target is not exceeded
- Significant savings can be achieved by using less amounts of virgin materials
- Extend Materials Identifier to more elements
- Provide savings estimation for potential customers via Benchmark analysis
Contact details

• Dr. Christoph Kirmse
• Senior Data Scientist

• Center of Competence Product Quality
• SMS digital GmbH
• Düsseldorf, Germany
• christoph.kirmse@sms-digital.com