Optimizing scrap use to focus on reducing CO2 emissions

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**Emirates steel process route**

<table>
<thead>
<tr>
<th>Direct Reduction Process</th>
<th>Steel Making</th>
<th>Rolling</th>
<th>Finished Products</th>
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</thead>
<tbody>
<tr>
<td>Three Direct reduction plants with a capacity of 4.2MTPA</td>
<td>Three Steel Making plants with a capacity of 3.6 MTPA</td>
<td>Three rebar mills and a Wire rod mill</td>
<td>Rebars, wire rod, sheet piles and heavy sections</td>
</tr>
</tbody>
</table>
| Iron oxide pellets > direct reduction iron > steel making | • Steel billets  
• Beam blanks | • Heavy section mill with a capacity of 1.0 Mt  
• Three rebar mills with a capacity of 2.0 Mt  
• Wire rod mill with a capacity of 0.5 Mt | Sheet piles  
Heavy sections  
Rebars | Wire rod  
Rebar in coils |
ESA’s steel decarbonization aligned with UAE’s commitment to the Paris Agreement

Scope 1&2 CO2 intensity for steel production (tCO2/t crude steel)

Reference – world steel Sustainability Indicators report 2023, Emirates steel Arkan sustainability report, 2022
Energy balance in Electric arc furnace

Input Power 439.1 kWh/t (63.8%)

Molten steel 384.6 kWh/t (55.4%)

Exothermic oxidation 204 kWh/t (29.6%)
Fuel combustion 24.6 kWh/t (3.5%)
Slag making 15.1 kWh/t (2.1%)
Electrode oxidation 11.2 kWh/t (1.6%)

Roof heat loss 8.6 kWh/t (1.2%)
Other losses 27.9 kWh/t (4.0%)
Cooling-panel loss 37.8 kWh/t (5.5%)
Electrical loss 38.6 kWh/t (5.6%)
Slag heat loss 52.8 kWh/t (7.6%)
Exhaust gas loss 143.7 kWh/t (20.7%)

Input = Output

Technology and development

DRI
- Increase DRI Temp. by Natural gas (NG)heater
- Increase DRI Temp. by Optimizing DRI %C

EAF
- M1 injector to increase %Scrap
- EAF off-gas analyzer to Optimize EAF Process

AI/ML model
- ML models to predict Energy, Productivity, CO2 emission
- Single and Multi-objective Optimization models
M - One (all-in-one Injector)

- Advanced fixed wall-mounted injector - M-One
- Mixed swirled flame burner (MSF)
- High efficiency supersonic coherent oxygen lancing
- High momentum powdered solid injector

**Old Oxygen Injector Specification**
- Oxygen Nozzle - Laval
- Supersonic speed – Mech 2
- Oxygen Jet Length – 1.3-1.4 Meter
- Shrouding - N/A
- Burner Mode – N/A
- O2 Flow – 1500 Nm3/Hr.
- Carbon injection – Different location

**New M-One Injector Specification**
- Oxygen Nozzle - Laval
- Supersonic speed – Mech 2
- Oxygen Jet Length – 2.0 Meter
- Shrouding - Yes
- Burner Mode – Yes (4 MW)
- O2 Flow – 2200 Nm3/Hr.
- Carbon injection - Single unit
- Carbon injection - 25-65m/s
The burner tip was designed to improve the mixing of reactants and avoid the generation of a cold flame.
M-one injector performance

DRI Metallization 94%
DRI C% -2.3
DRI Temp- 430 Deg C.
Average % scrap increased from 3 to 12% after modification of M-One injector
Data Analysis and Machine learning model developed

- Operational data analysis for different charge mix (Hot DRI, Cold DRI and Scrap) for optimum energy, productivity and CO2 emission.
- AI model was developed to Predict EAF energy.
- Coefficient of co-relation between model input parameter with Specific energy.
- Optimization model was developed for optimum energy, productivity and CO2 emission at EAF.
CO2 emission reduces with increased scrap % in the charge mix.

Optimum scrap is 15-20% for high productivity, low energy, and CO2 emission.
Steps for model development

- Step 1: Data collection and data inspection
- Step 2: Data preprocessing and data conditioning
- Step 3: Selection of relevant input output variables
- Step 4: Align data
- Step 5: Model parameter selection, training and validation
- Step 6: Model acceptance and model tuning
Modelling technique

The dataset is divided into three:

i) Training dataset
ii) Testing dataset
iii) Validation dataset

- By training dataset ANN build the model by changing weights and biases.
- The built-up model is validated by validation dataset
• The results demonstrate the model's accuracy and predictive Energy, as evidenced by high $R^2$ values close to 0.9 on both the training and test sets.
Optimization Plot

Optimization Specific energy With variation of HDRI and Scarp

Optimization of productivity With variation of HDRI and Scarp
Optimization Plot

Contour Plot of Productivity vs Cold DRI, Scrap

- Optimization productivity with variation of CDRI and scrap

Contour Plot of Total CO2 ton per ton of LS inc vs Hot DRI, Scrap

- Optimization of CO2 emission with variation of HDRI and scrap
Conclusion

- Scrap% Increases after implementation of M-One injector.
- With the current setup 15 -20% Scrap uses will be optimum for energy and CO2 emission.
- ANN model having higher $R^2$ values close to 0.9 on both the training and test sets indicates accuracy of Energy predication.
- Coefficient of corelation of model input parameters with Energy gives inside relationship of EAF process.
- Optimization model was developed to optimize energy, productivity and CO2 emission with varying charge mix at EAF process.
Future works

• Increase energy efficiency in Steel making and rolling process
• Modification of Existing EAF for more scrap use
• Partial replacement of natural gas to Hydrogen in the DRI process
• Microgrid concept
• Increase the use of Clean Energy
• Energy management to save energy
• Waste energy utilization
1. world steel Sustainability Indicators report 2023
2. Emirates steel Arkan sustainability report, 2022


THANK YOU