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Reduce CO2e by optimizing process parameters in EAF using combined CFD and Empirical Modeling

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Reduce CO_2e by optimizing process parameters in EAF using combined CFD and Empirical Modeling

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The CO2 Emission is the corner stone in the greenhouse gas emissions GHG that contribute to global warming. 8 % of the total CO_2e emission in the world comes from steel industry. The steel is produced by two main routes Blust Furnace (BF) with Basic Oxygen furnace BOF and Electric Arc Furnace (EAF). 30 % of the steel produced in the world is produced through the EAF production route. The study aims at the reduction of CO_2e emissions during steelmaking process by EAF. This can be achieved by reducing the electrical energy consumption, the indirect source of CO_2e, minimizing the process variation; mainly during EAF refining stage. This goal can be achieved by the establishment of an empirical model based on real measurements and compared to thermodynamic predictions. Moreover, the steel melt fluid flow fluid dynamic is simulated using computational fluid dynamic "CFD" model to avoid excess electrical energy consumption.

The last stage after complete melting in EAF before tapping is the refining process. It is for removing impurities (such as phosphorus) and adjusting carbon levels. This often done by injecting oxygen, carbon and adding flux (e.g lime) to from slag that absorbs impurities. The goal is to produce clean, consistent steel ready for further processing. So, adjusting O, C and slag conditions are effective in the process. The main controlling parameter for steel melt yield is the balance between C and O in the bath. Nevertheless, an optimum slag height ensures efficient energy distribution, stable arc behavior and effective insulation, all of which contribute to shorter refining time. Suboptimal slag height where too low or too high can disruptive energy distribution increase energy losses, and hinder refining Kinetics, extending the refining time. Optimizing refining time will reduce electrical energy consumptions and will contribute to reduce CO_2e emissions.

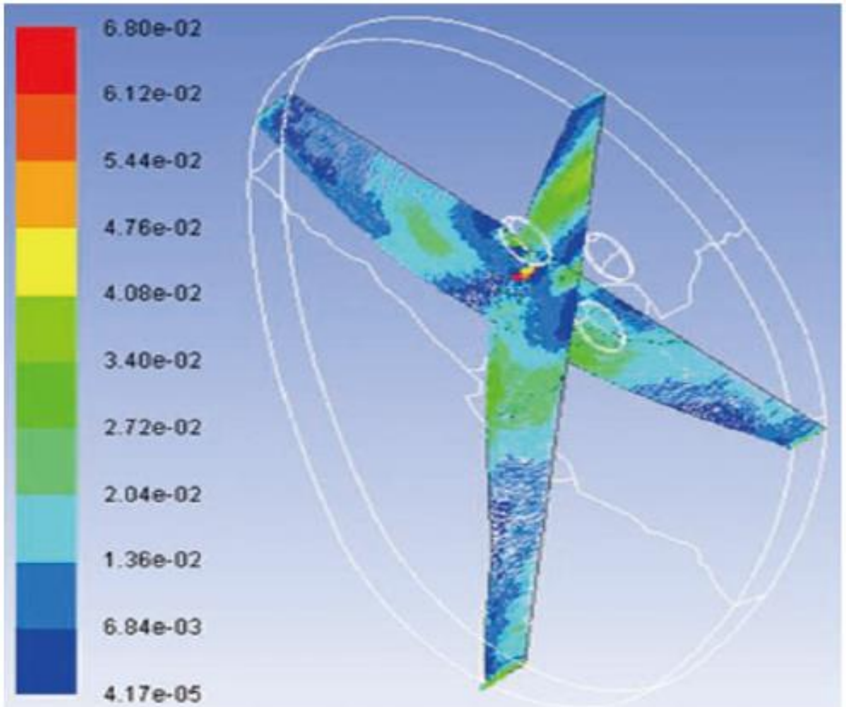
To simulate the molten steel flow in bath computational fluid dynamics were used. CFD is a numerical analysis method used to simulate and study behavior of fluids using physical equations that describe how to react to the velocity, pressure, temperature and density of the fluid.

On the other side empirical regression equations were established to study the effect of O, C on FeO in slag. 10000 heats were analyzed with different conditions, with charge mix from 0 – 100 % DRI for 185 ton EAF.

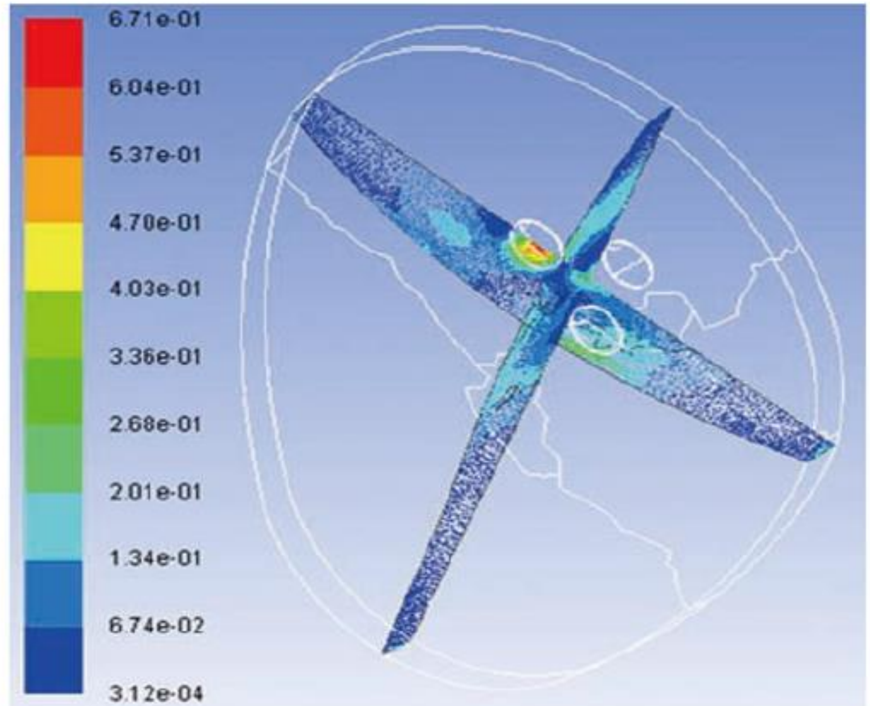
The effect of thermo-physical properties of molten steel in the refining stage from initial refining stage "0.20 -0.02 % C at 1823 – 1973 K" at constant slag height of 15 cm were simulated using CFD modelling.

- The changes in the thermo-physical steel melt properties from initial refining stage "0.20 % C and 1823 K" till end of refining stage "0.02 % C and 1973 K" result 52.6% alteration in melt fluid flow velocity; "from 0.19 m/s to 0.29 m/s" at constant slag thickness of 15 cm for both cases.

- To examine the important role of slag height in electrical energy distribution and hence refining time, the effect of slag height on the vector velocity distribution during refining time were simulated by CFD.
- Slag heights were examined from 0.05 m to 0.30 m at constant C% content and temperature.
- Increasing slag height increasing the melt flow velocity by 10 times. This effect is more significant than the effect resulting from changes in thermo-physical properties of steel melt.
- The optimum slag height to achieve the optimum energy distribution could be determined at 15 cm.
- The effect of O, C during refining stage have been investigated and its effect on the FeO in slag by regression analysis. Reducing O_2 tapping with moderate C tapping will reduce the Fe losses as FeO in slag. This will contribute by increasing yield up to 2 %. Not only but also the moderate tapping C, O_2 effect will reduce CO_{2e} by 9 – 10 kg CO_2e / Ton molten steel.
- Optimizing the process achieved 1 min P ON less which reduces the electrical energy by 9 kwh / Ton.
- The total CO_2e emission could be reduced up to 30 Kg CO_2e/ton molten steel.

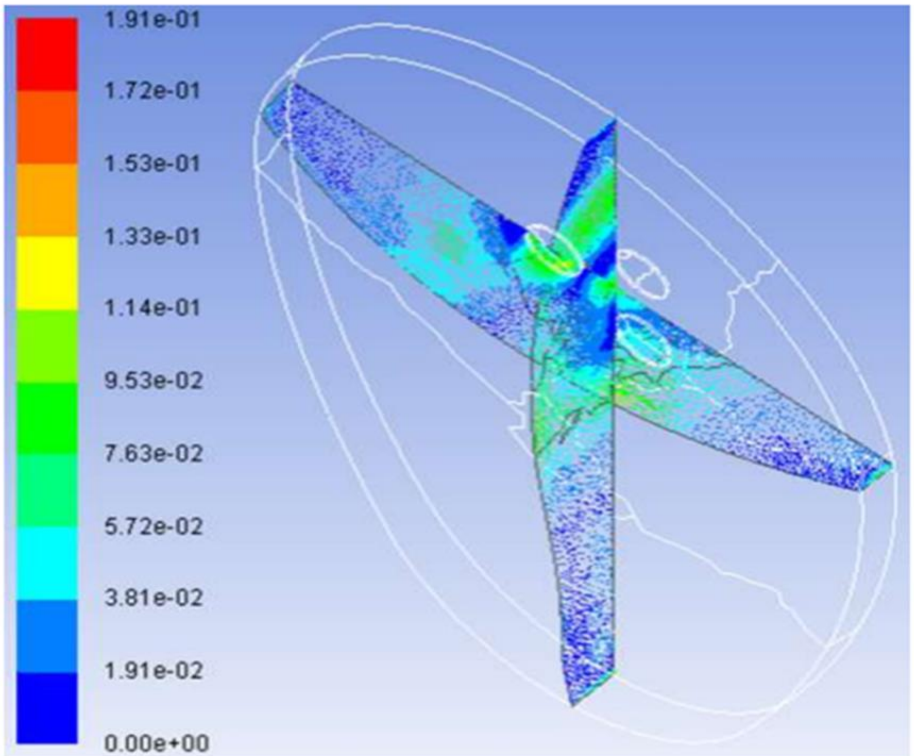
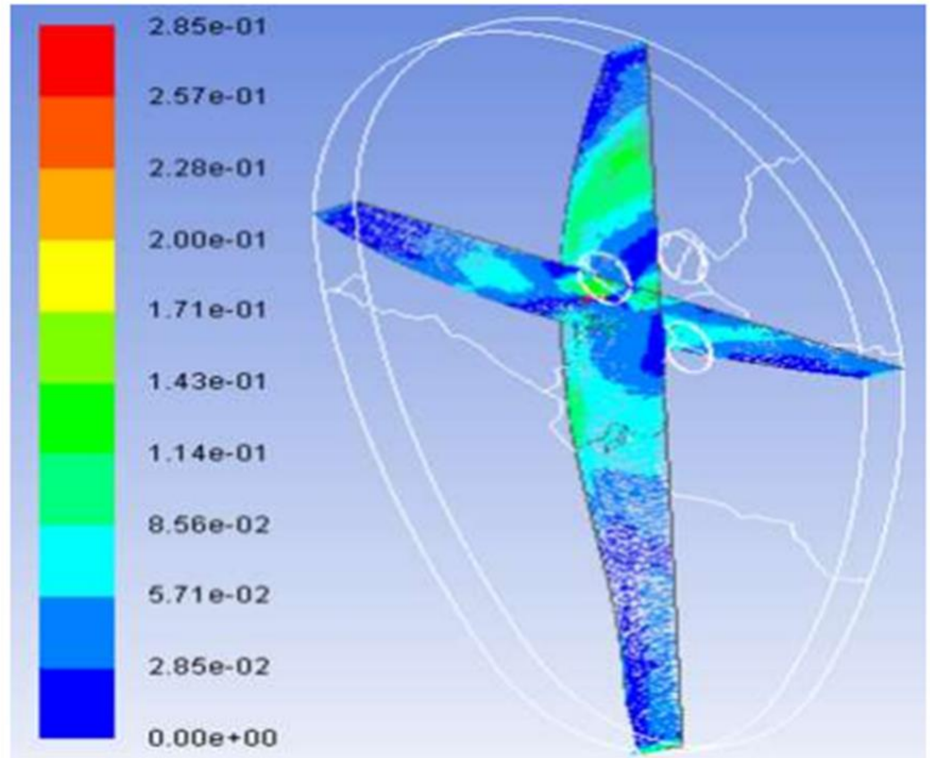


Vector velocity distribution for forced convection at 0.05% C, 1923 K and 0.05 m slag thickness

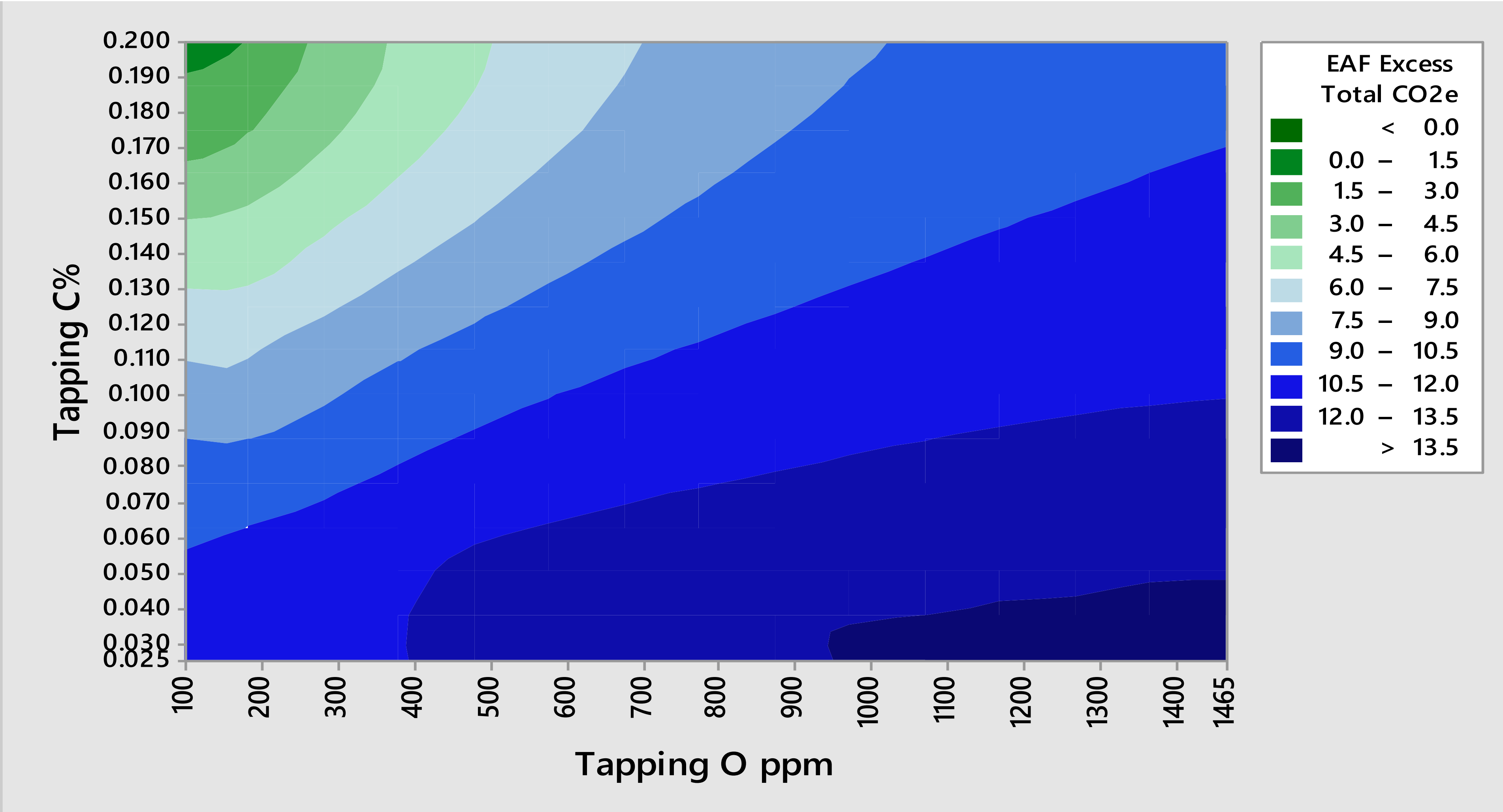


Vector velocity distribution for forced convection at 0.05% C, 1923 K and 0.30 m slag thickness

Effect of slag height on the fluid flow velocity of steel melt in bath

	
Contour of velocity distribution for forced convection at 60 sec at 0.20 % C, 1823 K and 0.15 m slag thickness	Contour of velocity distribution for forced convection at 60 sec at 0.02 % C, 1973 K and 0.15 m slag thickness

Effect of carbon content and thermophysical properties of molten steel on the fluid flow velocity of steel melt in bath



Contour plot of EAF excess total CO2e versus tapping O ppm and C% and tapping