SwingDoor™ – immediate mean to reduce CO_2 emissions in EAF operation and future improvement by hydrogen burners

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Currently, the main topic is the reduction of CO_2 in the steel production. A sharp transitional cut from today's CO_2 intensive towards a future net-zero CO_2 technology is hardly to achieve. Thus, the implementation of intermediate steps is of primary importance. An effective mean to immediately reduce CO_2 emissions by reducing energy and electrode consumption and simultaneously increasing the metal yield is INTECO PTI's SwingDoor. The SwingDoor allows the EAF to operate with closed slag door, thus eliminating cold spots and enhancing furnace efficiency by minimizing false air entrance. To further promote the transition to green steel making, INTECO PTI developed a hydrogen fired burner, which fits smoothly into the traditional JetBOx as well as into the SwingDoor. Running such burner with pure hydrogen may be restricted due to limited hydrogen availability and potential formation of NOx. To minimize these drawbacks the burner is designed to be operated with different air/fuel ratios. The paper reviews how achieved savings in terms of electrical energy, chemical energy and graphite electrodes can be translated into minimized CO_2 emissions based on recent results of industrial operations. Furthermore, it outlines key issues to be considered, if hydrogen fired burners are used in an EAF.

KEYWORDS: EAF, SLAG DOOR, SWINGDOOR, MELT SHOP SAFETY, CO_2-MITIGATION

INTRODUCTION

The share of crude steel produced via the Electric Arc Furnace (EAF) reached 43.7 % for the European Union in 2022 [1] and is well expected to overtake the BOF share with every EAF newly commissioned to replace blast furnaces in (still) integrated mills. This development also signals an increased competition for quality steel scrap, thereby underlining the importance of reproducible high yield from the charged scrap. The predominant focus on CO_2-mitigation and ever-increasing energy prices also affects EAF steel mills.

Meanwhile the EAF is no single piece of technology but composed of different systems like the slag door or burners, which development in detail utilizes further improvements of energy and carbon consumption and paths the way for future hydrogen utilization in preheating burners.

One break-through technology which has an immediate effect on reducing CO_2 emission is INTECO PTI's

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SwingDoor™. The EAF's key performance indicators (mainly electrical energy consumption, carbon consumption, metal yield) benefit from closed furnace operation, Simultaneously, the workplace safety of operators at the shop floor is tremendously increased as dangerous cleaning of the conventional slag tunnel becomes obsolete.

CONVENTIONAL SLAG TUNNEL – POTENTIAL DANGER FOR FURNACE PERSONAL

In furnaces with a conventional slag tunnel, scrap can fill the tunnel during charging, with portions of liquid slag accumulating in the scrap tunnel during melting and subsequently solidifying, thereby blocking the slag tunnel. This requires the steelmaker to clean the slag tunnel by various means, as oxygen lancing to cut the scrap and pushing the slag back into the furnace with a forklift. Cleaning the tunnel through the open slag door results in energy losses due to ambient air infiltration and loss of liquid slag, additionally the exposed position for the furnace personal in front of the open slag gate poses a safety hazard due to potential slag eruption. All these issues are resolved by the use of a modern slag door solution.

INTECO PTI SWINGDOOR™ – IMPROVED SLAG OPERATION AND PROCESS KEY FIGURES

General Description

The SwingDoor™ is a swiveling water-cooled slag door featuring a built-in coherent jet burner, situated directly in line with the water-cooled panels of the furnace shell, as depicted in Fig. 1. The main purpose of the burner is to preheat and eventually melt any scrap that is directly in front of the door.

Unlike a conventional slag tunnel system, the SwingDoor™ is specifically intended to allow closed slag door operation during Power-On time, minimizing the loss of liquid FeO-rich slag during melting and improving arc efficiency. This results in direct reduction of electrical energy and carbon input and an increased yield.

Fig.1 - SwingDoor™ in closed position aligning with water-cooled panels.

Fig. 2 depicts the SwingDoor™ mounted onto the EAF, the position of the SwingDoor™ replaces the slag tunnel, thus eliminates the major cold spot of the EAF and prevents the accumulation of scrap in the door area. Opening the slag door for cleaning, including its associated energy losses and potential safety hazards, is no longer needed.

Fig.2 - INTECO PTI SwingDoor™.

Fig.3 - INTECO PTI SwingDoor™.

Functionality – Deslagging Process

The deslagging process is controlled by the opening angle of the SwingDoor™, which can be adjusted according to aimed slag-off duration. The SwingDoor™ can be opened to +120° for furnace inspection and closed –15° inward to mechanically clean the door frame from slag or scrap. The furnace inspection position is depicted in Fig. 4.

Fig.4 - SwingDoor™ in furnace inspection position.

Foaming the slag is achieved by the reaction of carbon with FeO of the slag resulting in CO-Bubbles and liquid iron. By keeping the slag door sealed during the meltdown and refining period, the foaming slag is retained in the furnace, increasing the liquid steel yield by preventing any overflowing slag from carrying liquid iron out the furnace. An additional reduction of iron loss is aimed for, by only removing the top-layer of the slag, which is lower in FeO, by deslagging only the overflowing top-layer by a small opening angle of the SwingDoor™.

The integrated burner features a coherent jet oxygen injection lance. The oxygen jet achieves a supersonic speed by means of a Laval nozzle and is additionally enhanced by coherent jet technology which surrounds the oxygen jet in a shroud of flame, this allows the oxygen jet to stay coherent over a large distance. At closed door, the distance between nozzle and bath surface is in a range to guarantee penetration of the steel bath from the sidewall position of the SwingDoor™.

PTI Hybrid Hydrogen Burner – Energy Transition Ready

The INTECO Hybrid Hydrogen Burner, depicted in Fig. 5, is ready to utilize (ideally green) hydrogen fuel once it will be commercially viable, reducing natural gas consumption and directly avoiding carbon dioxide emissions. Due to its coherent design, it is directly deployable in existing SwingDoor™ and JetBOx™ water-cooled burner and injector casing.

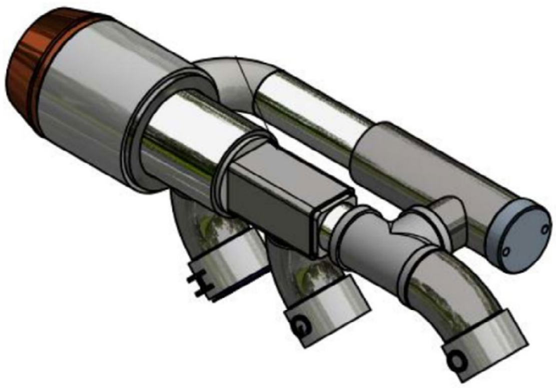

Fig.5 - INTECO PTI Hybrid Hydrogen Burner.

Potential drawbacks of the utilization of hydrogen, such as the three to four times lower heating value of hydrogen compared to natural gas, as well as hydrogen's approx. 250 °C higher adiabatic flame temperature promoting unfavorable NOx formation, can be diminished by the hybrid burners possibility to apply different H_2/NG ratios.

OPERATIONAL RESULTS AND CONSEQUENT EMISSION SAVINGS

Aside from tremendously increased operator safety on the mill floor, the application of the SwingDoor™ delivers profound and immediate improvements of key operational figures, affecting productivity as well as energy consumption and therefore valuable reductions of scope 1 and scope 2 emissions of the EAF process.

Charged coke and injected coal amount to the largest part of the direct emissions resulting from the EAF process of 60–100 kg_{CO2}/t_{LS}. [2,3,4,5]. Hence the reduction of injected coal consumption represents the largest lever in reducing scope 1 emissions in electric steelmaking. This carbon is used to achieve stable foaming slag throughout the melting and flat bath phase, insulating the arc for efficient energy transfer to the bath. Its consumption is affected by the amount of fluxes charged and subsequently lost through the open slag door during melting, as well as air infiltration through the open slag door.

Closed slag door melting practice improves both described scopes of emission, not only preventing energy losses due to outflowing foaming slag, but also enabling the reduction of necessary carbon input. Additionally, close door operation has proven to be beneficial to reduce the specific graphite electrode consumption due to minimized oxidation. To evaluate the emission reduction achieved, the key performance indicators of more than 30 SwingDoor™ installations are reported in Tab. 1.

Tab.1 - Key Performance Figures of different installation sites.

	INTECO PTI SwingDoor™ Impact
Reduced electrical energy consumption	**15 – 20 kWh/t_{LS}**
Reduced Power-On time	up to 2 min
Reduced carbon consumption	**– 20 %**
Reduced electrode consumption	up to 0.3 kg/t
Increased yield	**from 0.3 % to 1.5 %**
Payback period	Less than 12 months
FeO almost eliminated from removed slag	
Workplace safety tremendously increased	

Specific figures have been published earlier by INTECO's client Stahl- und Walzwerke Marienhütte (Austria), who has been operating a SwingDoor™ now for about 10 years. Already in the very early days of operation a significant yield increase of 0.6 %, a decrease of injected carbon by 1.3 kg/t and of charge carbon by more than 80 % were reported. Moreover, the use of the forklift to clean the slag door was almost eliminated, thus improving operator safety, and reducing maintenance costs [7].

The immediate reduction of CO_2-Emissions by the installation of the SwingDoor™ is derived from these figures, both for scope one and scope two emissions:

Scope one emissions – Direct Emissions

The reduction of carbon charge, otherwise necessary to guarantee the regeneration of the outflowing foamed slag and the reduced electrode consumption amount to substantial CO_2-Savings, shown in Tab. 2. By reducing the injection carbon consumption by 20 %, the sum of direct reductions can be lowered by a considerable 8 % – 14 % (in relation to the figures indicated above (i.e., 60–100 $kg_{CO2/tLS}$, according to [2,3,4,5]).

Tab.2 -Reduction in direct CO_2-Emissions by closed slag door melting practice.

Carbon Savings		CO_2-Savings
Electrode Consumption	– 0.2 kg/t_{LS}	– 0.7 kg_{CO2}/t_{LS}
Charged coke and injected carbon	– 2.0 kg/t_{LS}	– 7.3 kg_{CO2}/t_{LS}
Direct CO_2-Emissions		**– 8.0 kg_{CO2}/t_{LS}**

Scope two emission – The kWhs carbon intensity

By minimizing energy losses through the slag door and assisting arc shielding by increasing the foamed slag height, closed slag door operation reduces the specific electrical energy consumption. Dependent on the carbon intensity of electric energy generation, significant reductions in scope two emissions can be achieved. For the average carbon intensity of Italy in 2022 [6], scope two emission reductions can be calculated as indicated in Tab. 3. (Note EU-27 average in 2022: 0.251 kg_{CO2}/kWh [6].)

Tab.3 -Reduction in CO_2-Emissions from electric energy consumption.

Electrical Energy Savings	CO2-Savings @ 0.252 kgCO2/kWh
– 15 kWh/t_{LS}	– 3.78 kg_{CO2}/t_{LS}

CONCLUSION

With ever cleaner generation of electrical energy, the ratio of scope one to scope two emissions will increase, as will the importance and reduction of the first. A sealed slag door melting operation, enabled by the SwingDoor™ offers a turnkey solution for an immediate cut of CO_2 emissions of an EAF melt shop. Alongside these decreases of CO_2-emissions and thereby reduced energy cost will the increased liquid steel yield promote a short payback period of the initial investment, which is reported to be typically much less than one year. Even more important than environmental and economic advantages though, is the major safety improvement of removing the necessity to expose furnace personal to serious safety hazards during manual slag tunnel cleaning, replaced by the tough SwingDoor™.

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