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Performance Evaluation of Thermo Chemical Behavior of PCI Under Optimal Conditions

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Abstract: **In this study, a three-dimensional mathematical model is used to simulate the flow and thermo chemical behavior of the enhanced operation of PCI Victorian lignite under optimal FC conditions. The geometry of the model includes a lance, a blowtorch, a nozzle, a track and a coke bed at the bottom of a BF. Under the same operating conditions, the highest temperature in the main coal pavilion is observed in the brindled lignite container due to its higher volatile matter content. Injecting lignite into briquettes can achieve a higher overall combustion value than the semi-coke container and the carbon container in the ducting. The comparison confirms the possibility of replacing the replacement coal with PCI coal with an improved lignite, as it shows a very similar evolution of the combustion characteristics under the same operating conditions.**

I. INTRODUCTION

The majority of liquid raw iron is created via the blast furnace route, traditionally utilizing metallurgical coke as the main reducing agent. Aiming at a reduction of primary resources, using alternative reducing agents such as liquid hydrocarbons, natural gas and waste plastics contributes to the reduction of coke rates. In the blast furnace these agents also deliver the heat necessary for melting processes as well as endothermic reduction reactions.

In this work, models are developed to study the process that takes place on multiple scales and aspects, e.g. in terms of

- **length scales**: wide range from microscopic length scales where heterogeneous chemical reactions take place on defects in the atomic structure towards global flow phenomena in the blast furnace shaft
- **Time scales**: variation from very fast processes and high velocities in the zone of hot blast injection to comparatively low velocities of coke bed movement
- **Multiple phases**: appearance of solid, liquid and gas phases and intense interactions.

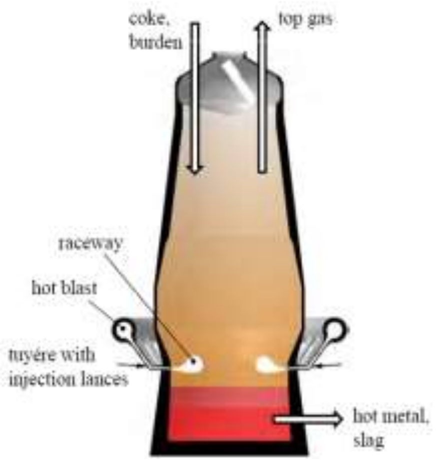

Figure 1: Blast furnace scheme

1.2 Furnace

The oven is a term used to identify a closed space. The heat is applied to a body to increase its temperature. The heat source can be fuel or electricity. Usually, metals and alloys and sometimes non-metals are heated in furnaces. The heating function sets the heating temperature and the heating rate.

The increase in temperature softens the metals. They become accessible to deformation. This softening occurs with or without alteration of the metal structure. Heating at lower temperatures (below the critical temperature) of the metal softens it by releasing internal stresses.

13 Furnaces are classified as follows:

1. Ovens
2. Metal heating furnaces
3. Heat treatment furnaces
4. Sintering furnaces
5. Coke ovens
6. Kilns
7. Melting furnaces
8. Extraction furnaces

Heat treatment furnaces are classified according to the type of heat treatment to be performed.
Standardization, hardening, annealing, grinding, etc.

1.5 Flow and Heat Transfer

A) Continuum Modeling: One of the main efforts of the focus is to model the flow of hot metal with or without conjugate heat transfer between a liquid and a solid wall during the casting operation. This was done mainly on the basis of continuous models. [19,21,23,26,27,83-90] In general, these models consider a single-phase flow, treat the coke bed as a porous support and neglect the coca and liquid interface movements, and consider flow and heat transfer as stationary.

B) Discrete Modeling: In contrast to the modeling of the continuum of the hot metal flux, the flow of solids into the fire was modeled using discrete approaches. Firstly, the main behaviors of the particles associated with the formation of a coke bed and a crocoite zone have been reproduced with respect to the experimental observations.

1.7 Cooling Process of Blast Furnace-

Because of gravity, water flows from the abnormal tank of the plant to the high-speed dome radiator. These moat cooling devices are arranged in a closed circle unlike the usual open frames. This allows you to synthetically clean up the work of the chain. By controlling the search for water during the crusade, this clean surface can be maintained, ensuring optimal heat exchange. The main capacity of the radiator heater cooling system is to cool the heat sink hull and protect it from overheating and burns. To do this, the cooling frame must have the capacity to absorb excessively the heat generated by the heater and stacked on the hull.

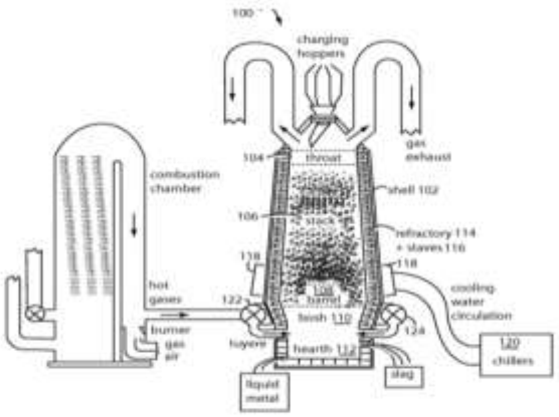

Figure 2 : Stave cooler with lining

II. LITERATURE REVIEW

Y. KO et al. [1] they analyzed the thermal behavior in the area of the taps. They found that the thermal properties of the mud core, the jet and the brick, as well as the convective heat transfer coefficient of the coil had a significant impact on the distribution of the temperature of the hearth they had developed. , which allows to predict the evolution of thermal behavior by adapting the thermal properties of the material and in a clickable area of the hole.

Akash Shrivastava and R.L. Himte [2] – studied a highperformance furnace excitation using heat transfer analysis. that they had used 2 differing types of skulls within the coating material of the furnace cooling plate and 2 differing types of bricks were thought of, the first having an impalpable thickness and therefore the alternative a definite thickness. the heat transfer analysis of those 2 totally {different| completely different} skulls at different gas temperatures between 773,000 and 1573,000 discovered that the coating for heat extraction is healthier than others.

Anil Kumar et al. [3] modeled a three-dimensional furnace plant and this analysis took 2 differing types of coating material, i. h. Brick with a high content of aluminum oxide and carbide bricks. These coating materials are used at different gas temperatures from 773 K to 1573 K and, at this gas temperature, personnel with the bone ar used. They selected the water temperature of 303 K. They found that the heat load and therefore the maximum temperature of the recent surface were the lowest between the Al plates and therefore the highest within the carbide bricks. Thus, he obtained a carbide brick that best suited the coating.

W.Lijun et al. [4] ANSYS analyzed a three-dimensional furnace model. They found that lowering water temperature and increasing water speed wouldn't be profitable. They adjusted the heat load and therefore the most temperature within the range by appropriately adjusting the operative conditions of the furnace. The operative conditions are the coating layer, the gas flow, the coating material and therefore the cooling channel spacing, additionally because the gas gap and diameter.

W. Zhou et al. [5]examined on the hot side of the furnace furnace. They used two equivalent convection coefficients between the gas flow and therefore the covered brick, similarly because the flow of gas and therefore the shaft body. They found that the equivalent convection constant inflated the precision of the numerical calculation of heat transfer.

W.Lijun et al.[6] based on the mathematical model of furnace dust, they studied AN intelligent monitoring methodology and developed an intelligent simulation technique. This intelligent simulation model of a forged steel excitement is based on the correction factor of the parameters obtained by forming the samples of cast-iron cooling dust check knowledge. They found that the info from the intelligent simulation model is sort of identical to that of the experiment.

III. OBJECTIVE

In this study, a three-dimensional mathematical model is used to simulate the flow and thermochemical behavior of the enhanced operation of PCI Victorian lignite under optimal FC conditions. The geometry of the model includes a lance, a blowtorch, a nozzle, a track and a coke bed at the bottom of a BF. Typical aerodynamic phenomena in the furnace and the physico-chemical behavior related to the injection of Victoria's lignite are simulated in terms of flow, temperature, gas composition and coal combustion properties. It should be noted that the model can predict the burning phenomena of lignite from the Victorian era under BF conditions. The performances between a typical PCI coal and two lignites treated with briquetting or pyrolysis are compared.

IV. METHODOLOGY

4.1 Mathematical Model

1. Heat transfer of external wall

To simplify the analysis, the two-plate space model is used and this model has already been validated for the creation of internal simulations (Jiang et al., 2012, Wang et al., 2014). Figure 1 shows the process of transferring heat from external walls. The equations of transient heat transfer for the external wall are as follows

$$\rho_w c_{P,w} \frac{\partial T_w}{\partial \tau} = k_w \frac{\partial^2 T_w}{\partial x^2}$$

Boundary conditions

$$h_{out}\left(T_{out} - T_{w,out}\right) + q_{r,out} = -k_w \frac{\partial T_w}{\partial x} | x = 0$$

$$h_{in}\left(T_{in} - T_{w,in}\right) + q_{r,in} = -k_w \frac{\partial T_w}{\partial x} | x = L$$

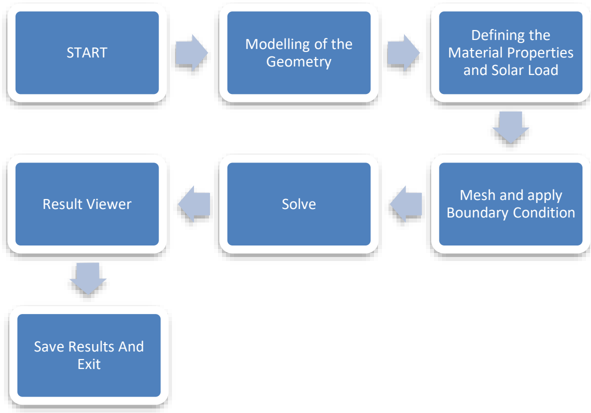

Figure 3: Setup of working

(1) Calculation of a variety of convection heat gain at τ moment

$$Q_1(\tau) = \sum_{j=1}^{N_i} A_j \alpha_j^n \left[t_j(\tau) - t_a(\tau)\right]$$

Here, Aj is the inner surface area of the j surface of the envelope, m2; $\alpha^n_j$the inner surface convection heat transfer coefficientof the j surface of the envelope, W/m2.8C; tj(t) theinner surface temperature of the j surface of the envelope at τ moment, 8C; ta(t) denotes the indoor air temperature at τ moment, 8C.

(2) Heat gain by all kinds of convection

$$Q_2(\tau) = q_1^c(\tau) - q_2^c(\tau)$$

Where q1 c (t) denotes the convection heat loss from lighting,sensible heat of the human body and equipment at τ moment etc., W; q2 c (t) denotes the water evaporation sensible heatcaused by the absorption of the room heat,W.

(3) Heat gain by air infiltration

$$Q_3(\tau) = L_w(\tau)(c\rho)_w[t_w(\tau) - t_a(\tau)]$$

Where Lw(t) denotes the air permeability at τ moment, m3/h; (cr)w denotes the outdoor air heat capacity per unit volume, KJ/m3.8C; tw(t) is the outdoor air temperature at τ moment, 8C; ta(t) the indoor air temperature at τ moment, 8C.

(4) Added value of indoor air sensible heat in unit interval at τ moment

$$Q_4(\tau) = V(c\rho)_a \frac{t_a(\tau) - t_a(\tau-1)}{\Delta n}$$

4.2 Boundary Condition & Operating Conditions

2.4 tHM/m³ day		
Tuyere numberofBF	28	
Reference pressure	461.0kPa	
Boundary conditions		
O_2 enrichmentinblast	60,000 N m³/h Blast (22.9% O_2,humidity	
22 g/N m³)		
300,000 N m³/h	1200 °C	
Cooling gas (100% O_2)	5000 N m³/h	327 °C
Conveying gas (100% N_2)	1317 N m³/h	45 °C
Coal	35 t/h	45 °C

V. RESULTS

To verify if lignite can replace the PCI charcoal, the results of the simulation of the relative furnace phenomena for the injection of a typical PCI carbon carbon with two lignites and lignites treated by pyrolysis are compared under the same conditions. It should be noted that the properties of the three fuels are different by comparing the flow behavior and the thermochemical behavior of the three fuels under the same operating conditions.

To verify if lignite can replace the PCI charcoal, the results of simulating the relative furnace phenomena for the injection of a typical PCI coal with two improved briquettes with briquetting And pyrolysis are compared under the same conditions.

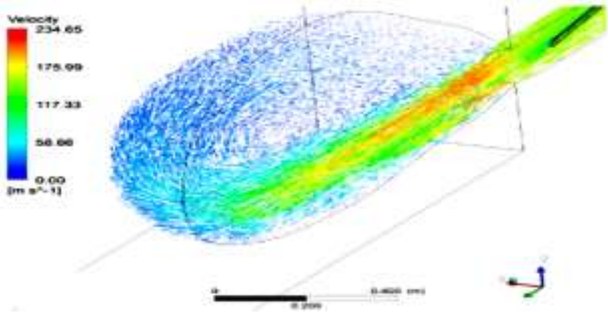

Figure 4:Vectorplot of case 1 (black coal)

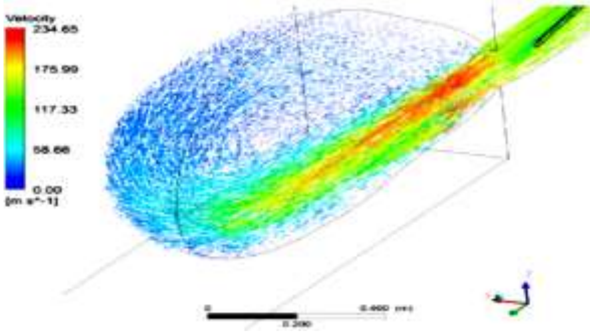

Figure 5: Vector plot of case 2 (briquetted brown coal)

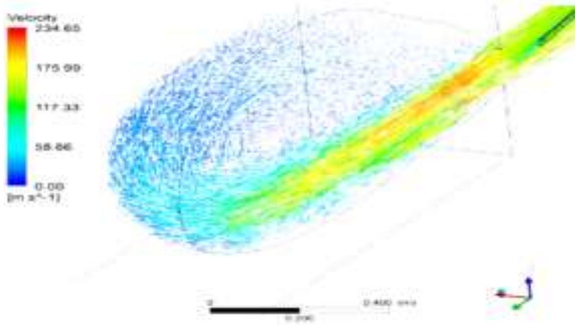

Figure 6 : Vector plot of case 3 (semicoke)

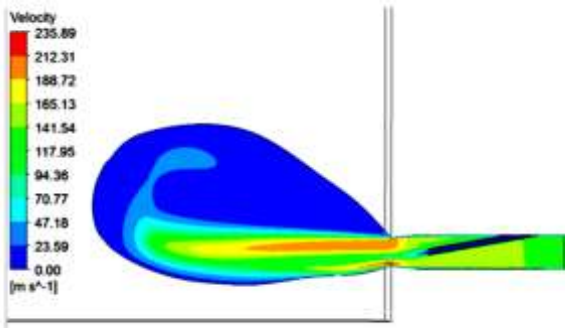

Figure 7: Velocity distribution of case 1 (black coal)

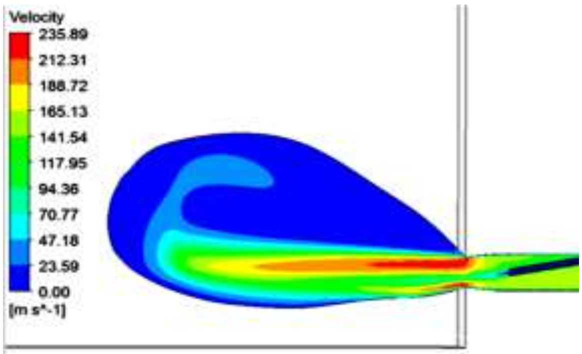

Figure 8: Velocity distribution of case 2 (briquetted brown coal)

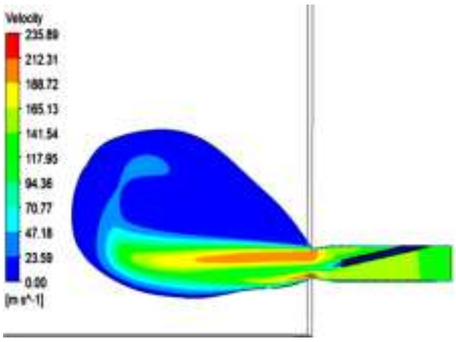

Figure 9 : Velocity distribution of case 3(semicoke)

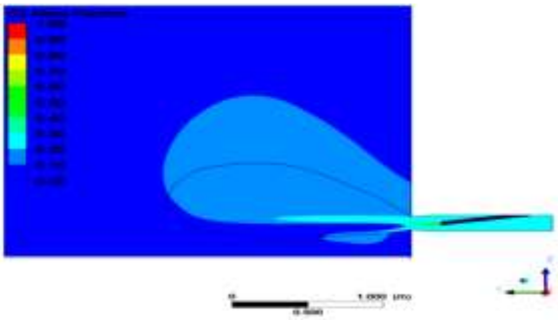

Figure 10: Mass fraction of O_2forblack coal

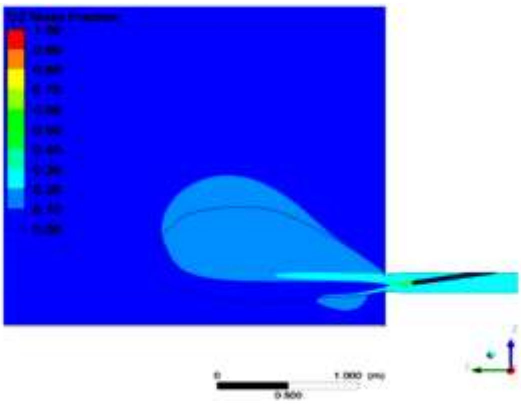

Figure 11: Mass fraction of O_2forbriquetted brown coal

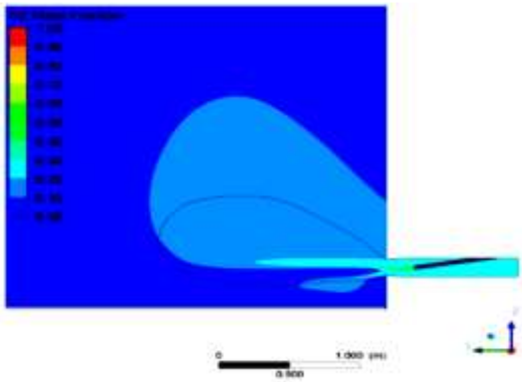

Figure 12: Mass fraction of O_2forsemi-coke

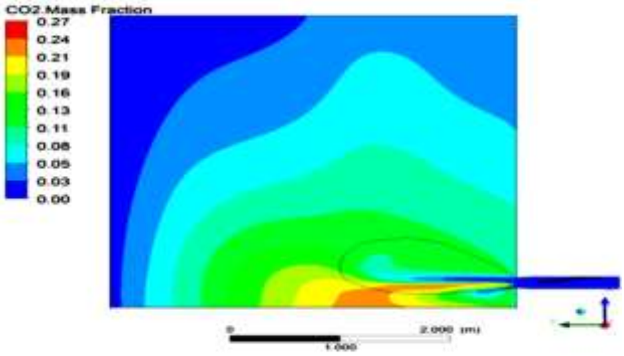

Figure 13: Mass fraction of CO_2forblack coal

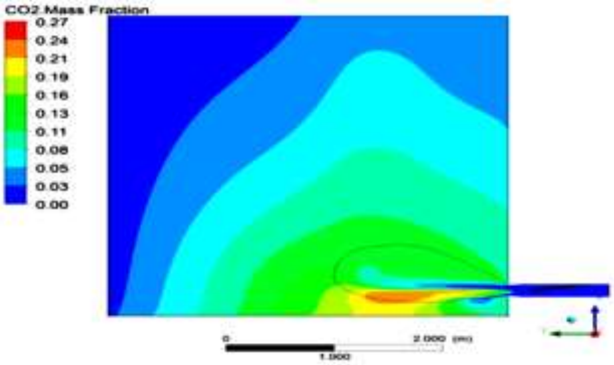

Figure 14: Mass fraction of CO_2forbriquetted brown coal

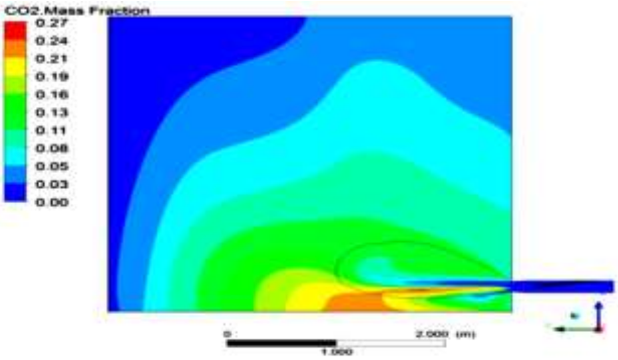

Figure 15: Mass fraction of CO_2forsemi-coke

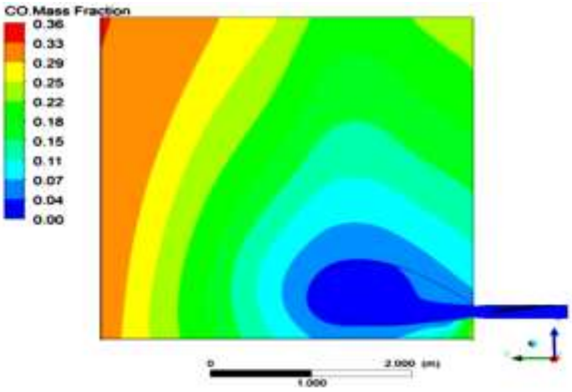

Figure 16: Mass fraction of CO for black coal

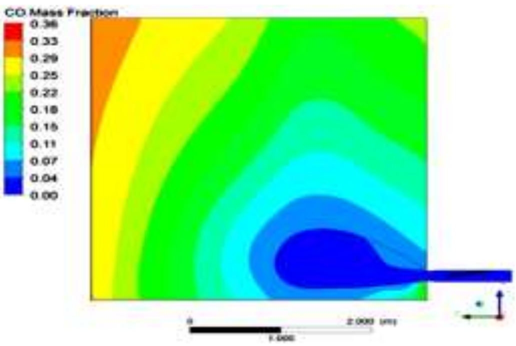

Figure 17: Mass fraction of COforbriquetted brown coal

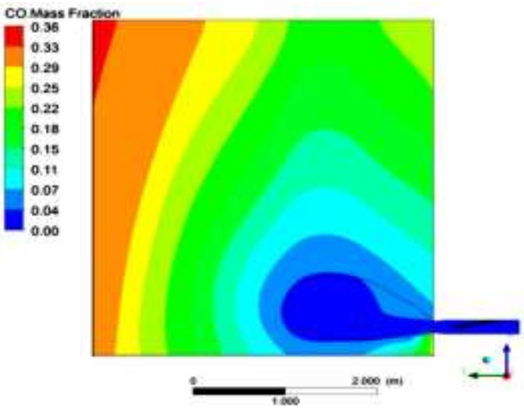

Figure 18: Mass fraction of CO for semi-coke

5.4 Validation

The entire area of the coke bed is divided into four areas based on the porosity differences: porosity assumed in the trace, the dead man, the drop zone and the cohesive zone are respectively 1.0, 0.25, 0.5 and 0.4.

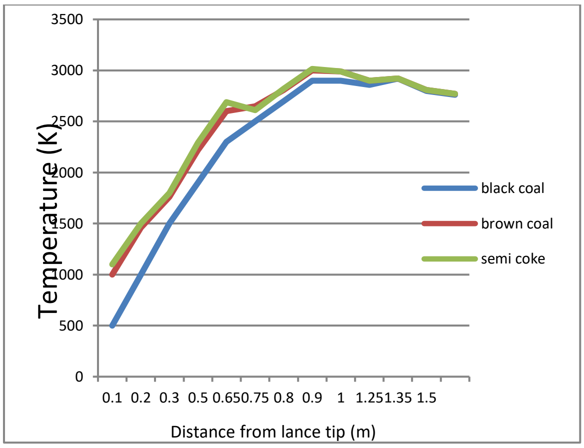

Fig. 19. Temperature along the tuyere axis.

The model is validated by measurements of combustion and gas composition in previous studies. They are destined for a certain number of coals, but not yet for lignite, no measures have been carried out under BF conditions. The quantitative temperature profile is compared along the nozzle axis.

On the other hand, the temperature along the nozzle axis, where oxygen is insufficient, is sufficient. This can lead to a different temperature and even to a different oxygen distribution in the three cases: lignite briquettes in the case 2 along the main carbon indicator plus oxygen compared to other cases and releases more of the combustible gas reaches a higher temperature and therefore a greater depletion due to the content of the MV is greater. As a consequence, the concentration of O2 in the recirculation zones for case 1 (black coal) and 3 (Semi coke) are higher because they consume less energy along the carbon and O2 flag in the recirculation region.

VI. CONCLUSION

An industrial-scale 3D CFD model simulates complex combustion phenomena in kilns in connection with the injection of lignite from Victoria, and verifies whether traditional PCI charcoal can be replaced by lignite-based products. The main conclusions of this model study are as follows.

1. Under the same operating conditions, the highest temperature in the main coal pavilion is observed in the brindled lignite container due to its higher volatile matter content. Injecting lignite into briquettes can achieve a higher overall combustion value than the semi-coke container and the carbon container in the ducting. The comparison confirms the possibility of replacing the replacement coal with

PCI coal with an improved lignite, as it shows a very similar evolution of the combustion characteristics under the same operating conditions.

2. This mathematical modeling provides an economical way to optimize and control the injection of lignite in the future in a variety of conditions.

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