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Thermal Performance Assessment of Reformed Gas Combustion in O_2 Injection Lance

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Extended Abstract

In HYL direct reduced iron (DRI) process, the reformed gas (composed of CO, CO_2, CH_4, H_2, and H_2O) from the steam/methane reformer with a temperature of ~1150 K is subjected to pre-heating to provide sufficient temperature for the DRI process (i.e., ~1250 K) in the shaft furnace. Such pre-heating is achieved by the O_2/reformed gas combustion. In the HYL process, the O_2 is injected through an 'L-shaped lance' penetrating the flow path of reformed gas. The combustion performance is significantly influenced by the lance configuration and O_2/reformed gas operating variables such as flow rates and temperature. For example, the formation of local ignitable gaseous composition may lead to issues related to explosion while insufficient O_2 velocity at nozzle exit leads to nozzle wear out due to flashback. Therefore, the design of the nozzle in addition to gas flow conditions governs the local mixing of O_2 and reformed gas which ultimately influences the local reaction mechanisms and flame formation.

In the present work, the fluid flow, reaction mechanisms, and flame stability in the O_2 injection lance system are investigated using computational fluid dynamics (CFD). The reformed gas enters into the horizontal cylindrical tube with diameter of 0.96 m and length of ≈ 7m. The O_2 injection lance penetrates the cylindrical tube and the O_2 exit is located at centre of the tube. The nozzle diameter at O_2 exit is 3 cm. Reynolds-averaged Navier-Stokes (RANS) coupled with the shear stress transport (SST) k-ω turbulence model is used to simulate the turbulent flow (Reynolds number at O_2 inlet ~ 10^6). The inlet mass flow rate and temperature of O_2 and reformed gas are 0.66 and 19.7 kg/s, 303 K and 1163 K respectively. The reformed gas at the inlet is composed of 4.89 vol % CO_2, 15 vol % CO, 67 vol % H_2, 1.71 vol % H_2O, 10.76 vol % CH_4, 1.11 vol % N_2. The CO, H_2, CH_4 combustion and water gas shift reactions are implemented [1]. Further details of the geometry and the model will be presented in the conference.

Due to penetration of the lance into the flow path of reformed gas, a low-pressure region is created in the latter upper part of lance region and the flow field predicted is inclined towards the upper region. The CO, H_2, CH_4 combustion reactions led to an increase in the spot temperature up to 4950 K. However, the predicted outlet temperature averaged across the pipe cross section is 1270 K. Further, due to dominant backward water-gas shift reaction the CO at the outlet increased from 15 vol % to 17.83 %. Further details of the effect of flow variables and nozzle design on the gaseous mixing, reaction rates, temperature and species distribution, flame stability (i.e., flashback and flame lifting), and outlet composition will be presented in the conference.

References

[1] Parvathaneni, S., 2022. Characterization of dynamics of binary gas solid flows and coal gasification in fluidized beds: high speed imaging measurements and CFD simulations (Doctoral dissertation, IIT Delhi). http://hdl.handle.net/10603/432562.

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