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Numerical analysis of reasons for the CO distribution in an opposite-wall-firing furnace

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Key words: Opposite-wall-firing furnace (OWFF), Carbon monoxide (CO) distribution, Distributions of coal and air, Gas/particle flow, Corner vortex, Over-fire air (OFA)

Problem description

In practical operations of opposite-wall-firing furnaces (OWFFs), the CO distribution along the furnace width is characterized by a U-shaped profile. That is, the CO concentration is high near the side walls but low in the middle of the furnace, and the difference is large.

Distribution coefficients of coal and air, and mixing coefficient

The characteristics cross-section of the furnace was divided into 400 ($i \times j$) facets, with 16 (i) and 25 (j) segments evenly spaced in the width and depth directions, respectively. The coal distribution coefficient η_p, air distribution coefficient η_a, and mixing coefficient η were defined as follows:

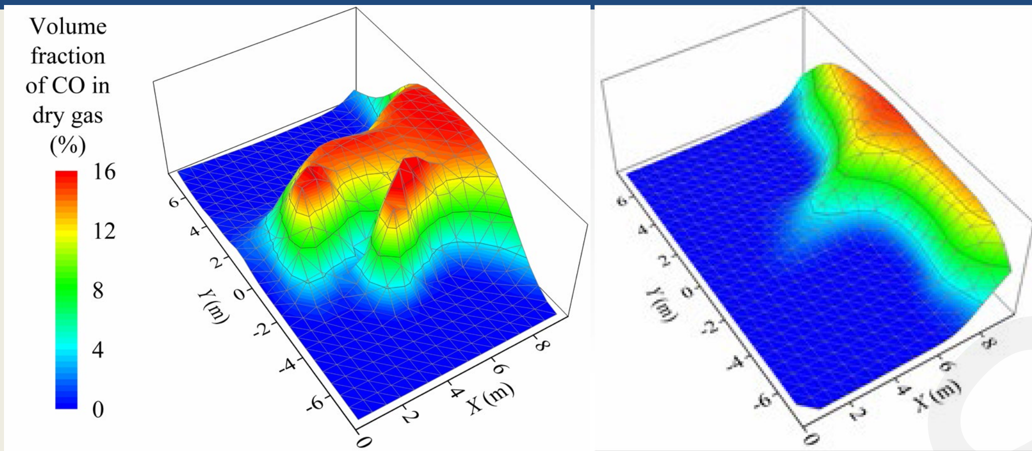
$$\eta_p = \frac{M_{p,i,j}}{M_p} \quad (1)$$

$$\eta_a = \frac{M_{n,i,j}}{M_n} \quad (2)$$

$$\eta = \frac{\eta_p}{\eta_a} \quad (3)$$

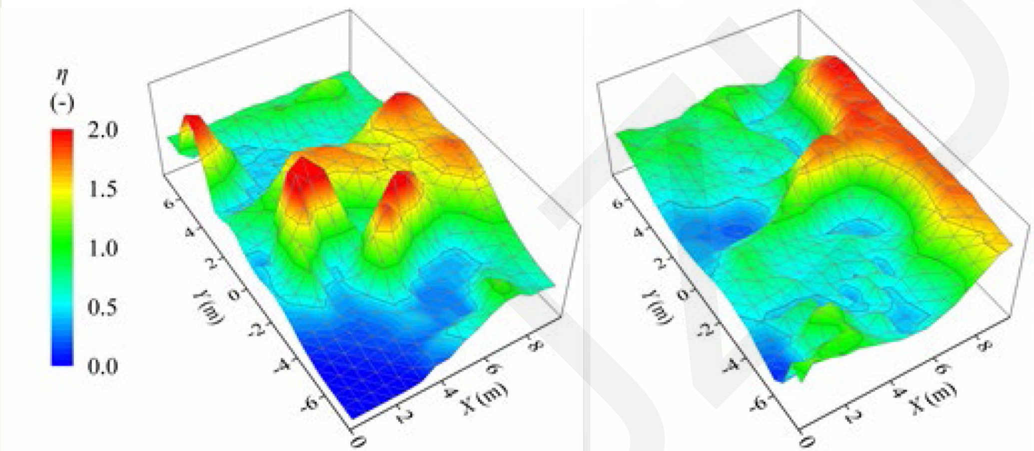
where $M_{p,i,j}$ is the initial particle mass flow rate crossing the (i, j) facet, kg/s; M_p is the initial particle mass flow rate at the whole cross-section, kg/s; and $M_{n,i,j}$ is the nitrogen mass flow rate through the (i, j) facet, kg/s; M_n is the global nitrogen mass flow rate integrated over the whole cross-section, kg/s.

Correlation analysis of mixing coefficient and CO concentration distributions



(a) (b)

Fig 1.Contours of CO concentration (%, v/v) at the characteristics planes of (a) the burner region and (b) the OFA region



(a) (b)

Fig 2.Contours of the mixing coefficient η (-) at the characteristics planes of (a) the burner region and (b) the OFA region

- The CO concentration and η varied in roughly the same manner whilst η showed large oscillation.
- The correlation coefficients between the CO concentration and η were calculated: 0.81 for the burner and 0.87 for the OFA outlet regions.
- The CO concentration and η were positively correlated.

Analysis of the aerodynamic mechanism behind the formation of the CO distribution

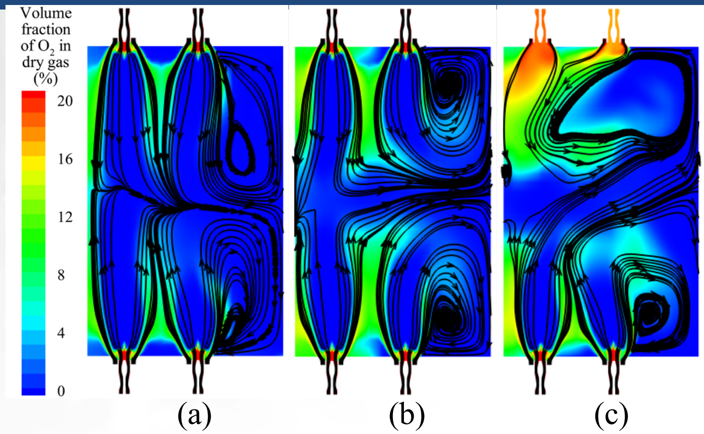


Fig 3.Streamlines of gas flow and distributions of O_2 concentration (%, v/v) over cross-sections through the centers of (a) the lower burners, (b) the middle burners, and (c) the upper burners

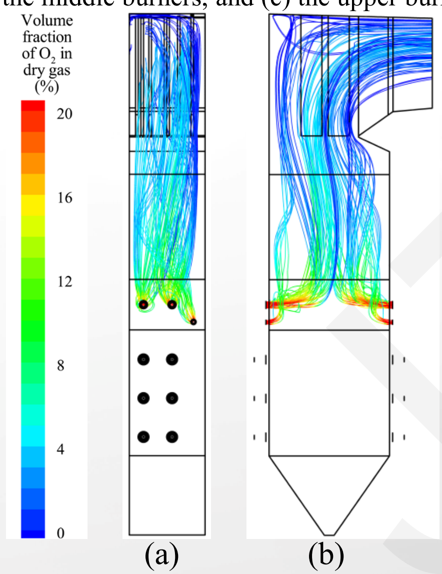


Fig 4.Streamlines of gas flow and distributions of O_2 concentration (%, v/v) over cross-sections through the centers of (a) the lower burners, (b) the middle burners, and (c) the upper burners

- In the burner region, the collision of opposite flows leads to the migration of gas and particles toward the side wall which, together with the vortexes formed at furnace corners, are responsible for unburned particles concentrated and oxygenized from the furnace center to the side wall. Thus, high CO concentrations appear in these areas.
- As the OFA jet is injected into the furnace, it occupies the central region of furnace and pushes the gas from the burner region outward to the side wall, which is disadvantageous for the mixing effect in the side wall region.
- As a result, a U-shaped distribution of CO concentration is formed.

Conclusion

(1) The CO distribution within the furnace is characterized by a high concentration near the side wall and a low concentration in the middle. Closer examination showed that, in the burner region, CO is concentrated along the furnace center to the side wall, while after the injection of OFA, most of the CO is attached to the side wall.

(2) The consistency between the distributions of CO concentration and η indicates that the mixing characteristics of coal and air are of critical importance to the formation of the CO distribution. Non-uniform mixing characteristics lead to an uneven combustion process, resulting in the observed variation in CO concentration.

(3) In the burner region, the collision between opposite flows pushed the gas and particles to the side wall. Then a moderate vortex was formed in each corner of furnace, which further trapped the particles in the side wall region. In this way, a large fraction of the char was concentrated and oxygenized along the furnace center to the side wall, which produced a great amount of CO.

(4) As the OFA jet was injected into the furnace, it preferentially filled the central part of the furnace and sent the gas from the underside of the furnace outward to the side wall. This implies that the mixing capacity of OFA was weak in the side wall region, which is disadvantageous for reducing CO. Consequently, a so-called U-shaped distribution of CO was formed.