INFLUENCE OF CORIOLIS FORCE ON THE FLOW FIELD OF COMBINED TOP AND BOTTOM BLOWN CONVERTER

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Abstract

Based on the principle of Coriolis force and the structure of combined top and bottom blown converter, the relationship between Coriolis force and the converter was analyzed theoretically. It is concluded that Coriolis force affects converter’s flow field by the action on top and bottom blown gas. It makes top gas clockwise deflection and bottom gas counterclockwise deflection, and the deflection angle of the former smaller than the latter. According to the theoretical analysis, the water model experiments were designed to primarily test and verify the influence of Coriolis force on converter’s flow field. It is shown from the investigation that the counterclockwise trend of bottom gas caused by Coriolis force can be superimposed with the counterclockwise trend of flow field caused by the arrangement of bottom tuyeres, further to reduce the mixing time of bath.

Introduction

Coriolis force is generated by the earth’s rotation. It reflects on making those objects which are moving horizontal on the Earth’s surface deflected. An object having horizontal velocity at Northern hemisphere will deflect to the right whereas at Southern Hemisphere to the left. A case which can prove the existence of Coriolis force is the whirling effect while water running through a funnel. The hot cyclone caused by the non-uniform heat flow in the atmosphere and the erosion of right bank of the river in the Northern hemisphere can also prove the existence of Coriolis force [1]. Due to its widespread existence, its influence on construction, water conservancy, and industrial production has to be taken into consideration [2,3]. In the currently steelmaking process, the Coriolis force’s effect on gas flow created by the top and bottom blown gas in the converter has to be considered. The currents generated from the top lance to decarburize and the bottom lance to stir the bath, both of the two flows have a certain horizontal velocity, which provides the initial conditions for Coriolis force to act. If the flow field of converter can be superimposed with the action of Coriolis force, the circulation of the flow field will be strengthened, and also with the mixing time reduced, productivity increased.

Many researchers had investigated the flow field of the converter using the water modeling [4-9], however to our knowledge, no study has been done on the effect of the Coriolis force on the flow field in combined top and bottom blown converter. Although Coriolis force cannot dominate the flow field in a converter, its action can’t be ignored. In our previously experiments, the results disagreed with the expected without considering the Coriolis force. Many experimental phenomena can be rationally explained since the Coriolis force was applied in the system. In this paper, theoretical calculations and water modeling experiment were combined together to investigate the influence law of Coriolis force on the flow field of the converter.
Parameter Analysis of Coriolis force

Assuming that there is an object whose mass is $m$ on the Earth’s surface, its force is different at moving state and stationary state. When the object is stationary, it will subject to the gravity force $F$ and the centrifugal force $C$, where $C = \omega^2 R \cos \phi$. The $C$ and $F$ are decomposed into axial and tangential directions, which are expressed as $C_z$, $C_H$, and $F_z$, $F_H$, respectively.

\[ C_z = m(\omega^2 R \cos \phi) \cos \phi \]  
\[ C_H = m(\omega^2 R \cos \phi) \sin \phi \]

Where $m$ is the mass of the object, kg; $\omega = 7.292 \times 10^{-5}$ rad·s$^{-1}$ which is the angular velocity of the Earth’s rotation; $R = 6.371 \times 10^3$ km which is Earth’s average radius; $\phi$ is the latitude of the object located; $\phi'$ is the geocentric latitude. As the earth’s radius is very big, $\phi$ is quite close to $\phi'$. $C_H$ and $F_H$ are in the opposite direction, equivalent value and offset each other. $F_z$ is far more than $C_z$ and their resultant force is gravity force. For the stationary object, its centrifugal force which caused by rotation of the Earth is negligible. While an object in motion along longitude or latitude will deflect. When the object is moving along latitude, it will produce extra centrifugal force along the earth’s rotation direction. For example, if an object at Northern hemisphere is moving along latitude from west to east at speed $V$, at this moment the angular velocity of the moving object to the Earth is $V/(R \cos \phi)$ and the centrifugal force acting on the object is $C'$ which can be expressed as:

\[ C' = m(\omega + \frac{V}{R \cos \phi})^2 \cdot R \cos \phi \]

The component force at tangential direction can be expressed as:

\[ C_H = C' \sin \phi = m(\omega + \frac{V}{R \cos \phi})^2 \cdot R \cos \phi \sin \phi \]
\[ = C_H + m(2\omega + \frac{V}{R \cos \phi}) \cdot V \sin \phi \]