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Analysis of Effect of Gas Temperature on Cooling Stave of Blast Furnace

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Abstract: In order to study the effect of gas temperature variation on cooling stave, temperature, stress and displacement distributions of cooling stave were analyzed respectively when gas temperature inside blast furnace increases from 1 000 to 1 600 ℃. The results show that the temperature field on cold side is under control of cooling pipes and hardly changes when gas temperature increases. The temperature gradient and change rate with time near hot sides are greater than those in other regions and the later can reach 100 ℃/s. The stress intensity near middle area of hot surface is up to 400 MPa and that's why there are lots of cracks at this place. The edge of stave is bent to cold side and middle regions between fixed bolts and pin moves to hot side. The displacement around fixed pin is smaller but larger on the edge and the maximum is located on hot side of top surface. The maximum displacement in z direction is about 4 mm and 3 mm in y direction. If the expansion coefficient of packing layer is 1/4, the thickness of packing layer between the cooling staves is 32 mm and 24 mm between sides up and down.

Key words: temperature variation; displacement; temperature change rate; stress intensity; packing layer

The design and operation of cooling staves (CS) are the key factors related to the long campaign-ship of blast furnace (BF). For further study of CS working mechanism, CHENG Shu-sen did many researches on CS characteristics from thermal conduction, installation, materials properties and so on[1-9]. SHI Lin analyzed the destruction of CS from the thermal and stress concentration[10-13]. It is obvious that gas flow field inside BF changes with time when iron producing process is unsteady such as hang-ups and fall of skull, then the temperature distribution of gas changes and so does the state of CS. It is necessary and realistic to study the temperature, stress and displacement distribution of CS when the gas temperature changes.

For further study on effect of gas temperature variation on cooling stave and guide of installation and maintenance of cooling stave, temperature, stress and displacement distributions of cooling stave were analyzed, respectively, when gas temperature inside blast furnace increased 200 ℃ every 300 seconds from 1 000 to 1 600 ℃, as shown in Fig. 1.

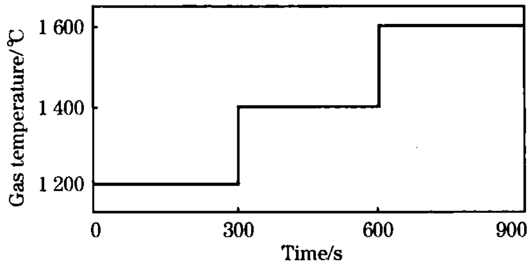

Fig. 1 Gas temperature change curve

1 Model Description

A three dimensional model of cooling stave is shown in Fig. 2. The CS is composed of furnace shell, packing layer, stave and inlaid bricks. The size of the model is 2 560 mm×840 mm×200 mm and the thickness of inlaid bricks is 70 mm and the diameter of water pipes is 65 mm. The material of furnace shell is 45 steel, cast steel for main body, SiC with SiN for inlaid bricks and slurry for packing layer. The origin of rectangular coordinate is located on the middle point of bottom line of cold side. The coordi-

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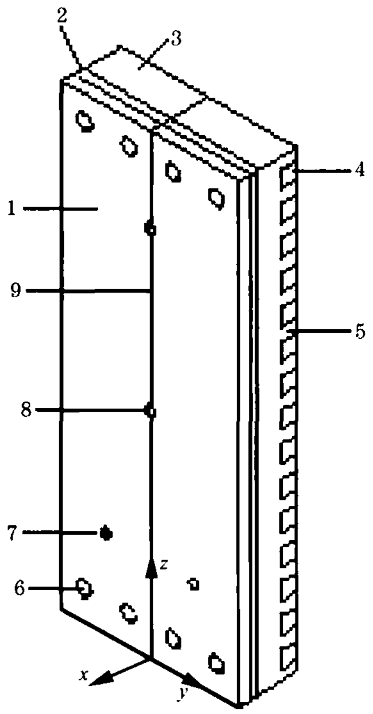

1—Furnace shell; 2—Packing layer; 3—Stave; 4—Inlaid brick; 5—Rib; 6—Water pipe; 7—Fixed bolt; 8—Fixed pin; 9—Symmetrical surface.

Fig. 2 Physical model

nates of lines and nodes on rectangular coordinate system for analysis of cooling stave are shown in Table 1.

2 Analysis of Temperature Field

The boundary conditions for calculation of cooling stave temperature distribution are as follows: the air temperature is 50 ℃ and the heat convectional coefficient between the furnace shell and environment is 12 W/(m^2 • K) as calculated with equation $\alpha = 9.3 + 0.058t$[2]; the heat convectional coefficients between gas and hot side of cooling stave are 232, 240, 250 and 260 W/(m^2 • K) respectively when the gas temperatures inside blast furnace are 1 000, 1 200, 1 400 and 1 600 ℃; the heat convectional coefficient between water and inner sides of water pipes is 8 000 W/(m^2 • K)[3] and the water temperature is 30 ℃; other sides are adiabatic boundaries.

2.1 Temperature field

The temperature of CS rises with time when gas temperature increases but the distribution is similar. As shown in Fig. 3, on hot side of ribs, the temperature is 477, 536, 632 and 740 ℃ respectively when time is 0, 300, 600 and 900 s, so it is obvious that the temperature increases greatly as gas temperature rises. The temperature differences between different positions of cooling stave are great because of the variation of material properties between different sections. The temperature on hot side of CS increases greatly because of its contact with high temperature gas. On thickness direction of inlaid bricks, the temperature gradient is higher than that of ribs at the same thickness and the difference increases as the gas temperature rises. At 900 s, the changing rate of temperature reaches to 100 ℃/s. The larger temperature difference is, the greater thermal stress gets. If thermal stress is high enough, the CS could be destroyed, so it is necessary to make sure that the gas temperature is below a certain value (that is 1 350 ℃) to avoid the serious case.

Table 1 Coordinates of lines and nodes

Position	Name	Coordinates		
		x	y	z
In Fig. 3 and Fig. 7	Midline of top surface	$-280 \leqslant x \leqslant -80$	0	2 560
	Line near fixed bolt	$-280 \leqslant x \leqslant -80$	0	2 179
In Fig. 4	Node on third of line	−210	0	1 566
	Midpoint	−170	0	1 566
	Node on cold side	−80	0	1 566

2.2 Temperature on nodes

The temperature and TCR curves on thickness direction are shown in Fig. 4. The temperature and temperature-changing-rate (TCR) curves go upward but is higher and more complicated for the nodes near hot side. The temperature field near cold side is steady and hardly affected by gas temperature. This distribution of temperature and TCR is favor of protection of furnace shell and equipments near it.