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3-D temperature distribution of a full size BF copper stave with oblate channel

Daqiang Cang[1), *Yanbing Zong*[1), *Yixin Mao*[1), *Hao Bai*[1), *Jingpenng She*[2), *and Keshi She*[2)

1) Metallurgical Engineering School, University of Science and Technology Beijing, Beijing 100083, China
2) Shantou Huaxing Metallurgy Spare Parts Co., Shantou 515011, China
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Abstract: An experiment of a new type full size copper stave for a real blast furnace was carried out in a special-designed experimental system. The 3-D temperature distribution inside the stave including isotherm was obtained based on the experiment data. And the effects of the temperature of cooling water and the velocity of the water as well as the temperature of the furnace on the 3-D temperature distribution were obtained. The experimental and calculation results show that the highest temperature of the hot surface is lower than 90℃ which is very good for the solidified slag formation on the hot surface and protecting the stave.

Key words: blast furnace; copper stave; experiment; temperature distribution

Four generations of cooling staves for blast furnace were developed in the past decades. The update one is copper stave [1-3] which attracts more and more researchers to do much more research work on it due to its excellent performance in blast furnace like long service life and the very low temperature inside the staves as well as relatively lower water consumption. There are about 50 blast furnaces with different kind of copper staves in the world so far [4,5] and more and more blast furnaces decided to use copper staves in near future especially in China.

Many theoretic research have been carried out in China including some numerical simulation for new copper stave design and optimization [6,7]. But the results need to be verified and compared with the calculated results in order to use the mathematical model to predict the thermal process of the staves and for the optimizing design as well as to determine how to control the stave temperature during operating. The full size experiment is necessary for better copper stave design and utilization in real blast furnace [8].

1 Experimental cooper stave and facilities

1.1 Experimental cooper stave

The size of the experiment cooper stave: 3000mm×908.7 mm×125 mm, in which there were 4 oblate water channel in a rolled cooper plate.

There had more than 100 temperature measurement points which were designed on the surface and inside the cooper stave used in the experiment in order to get the 3-D temperature distribution along with the time change. The near stave gas temperature was measured as well.

1.2 Experimental facilities

There had four parts of the experimental system which included (shown as **figure 1**):

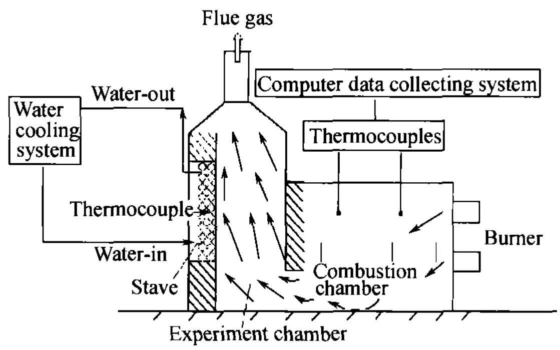

Figure 1 The experimental system.

(1) Experimental section where the tested stave was installed.

(2) Combustion section with dual-fuel (oil and pulverized coal) system which supplied hot gas with enough temperature and heat flux to simulate the different conditions of the near-wall area of a stave in BF. The combustion air was preheated to about 300℃ by the high temperature flue gas with a regenerative heat recovery system in order to save fuel consumption.

(3) Computer data collecting system which stored all the necessary temperature, pressure, flow rate information in the whole experimental process.

Corresponding author: Daqiang Cang, **E-mail:** myxcdq@public3.bta.net.cn

(4) Water cooling system supplied the given temperature of cooling water by a water spray cooling system.

This experimental system could be used to simulate the staves with highest height of the staves using in the industrial blast furnaces recently. It already finished 4 kinds of cooper staves experiment and got many valuable results in which some are not found in the previous experiments which supply very reliable evidence for the new cooper stave designing, controlling and operation [9,10].

2 Experiment and the results

The experiment lasted 14 h and the max temperature in the experiment section went up to 1100℃. The water velocity was ranged from 0.5-2.5 m/s. The inlet water temperature was in 30-40℃ and the outlet temperature was 32-46℃. The gas temperature of the experimental section was from 800-1100℃.

2.1 3-D temperature distribution of the stave

Based on the results in **figure 2**, it indicated that the maximum temperature difference between the upper part and the lower part of the stave is about 40℃ due to the temperature near the stave in the experiment section is different like that inside the real blast furnace. But the temperature in the same horizontal level are almost the same.

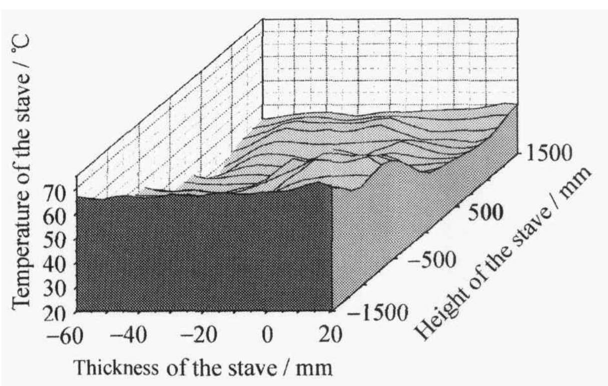

Figure 2 3-D temperature distribution in part of the experimental copper stave.

2.2 Isotherm in the stave

Figure 3 shows the isotherm of the stave under different temperature in the experiment section.

Based on the figure 3, it gives an important message that cooling ability of the cooper stave is very strong.

2.3 The effects of cooling water velocity and water temperature on the isotherm of the stave

Figure 4 shows the effects of cooling water velocity and water temperature on the isotherm of the stave.

Figure 4 shows that the higher water velocity is good for the temperature uniform and the safty water velocity is around 1.5 m/s though the 1.0 m/s water velocity still could get the maximum temperature of the stave lower than 90℃ which is much lower than the standard of European: 150℃ [2]. In lower water velocity case, just the water-out temperature increased a little (maximum outlet water temperature increased 1.0℃).

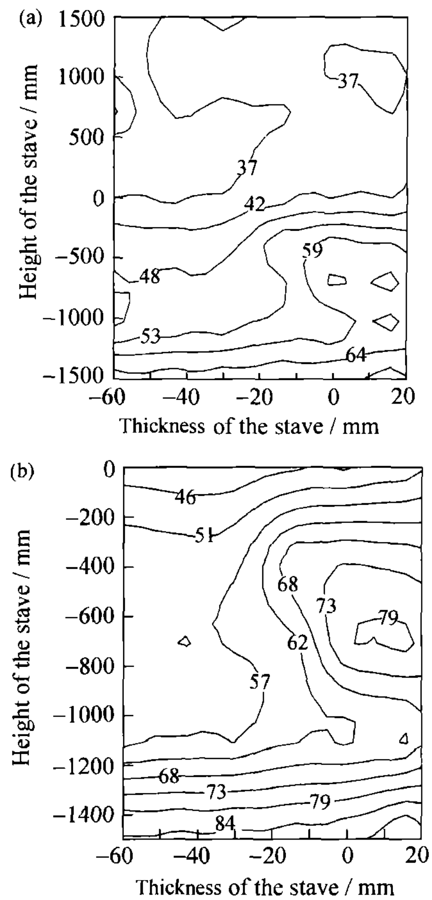

Figure 3 Isotherm of the stave under different temperature in experimental section, (a) gas temperature is 900℃, velocity of cooling water is 2.0 m/s; (b) gas temperature is 1000℃, velocity of cooling water is 2.0 m/s.

3 Conclusions

Based on the large full size cooper stave with oblate channel simulating experiment, some useful and new conclusions could be obtained based on the results:

(1) The simulating experimental facility and the computer data collection system are good to obtain the 3-D temperature distribution and many other important data for better stave designing and operating.

(2) All the temperature distribution inside the tested stave is lower than the European standard: <150℃ (lower than 90℃) which is much lower than the cast iron stave and could get a long service life for blast furnace due to the solidified slag could be formed on

the stave surface easily.

(3) The designed water pipe distribution influences the temperature distribution of the cooling stave greatly due to cooper excellent heat conduction ability.

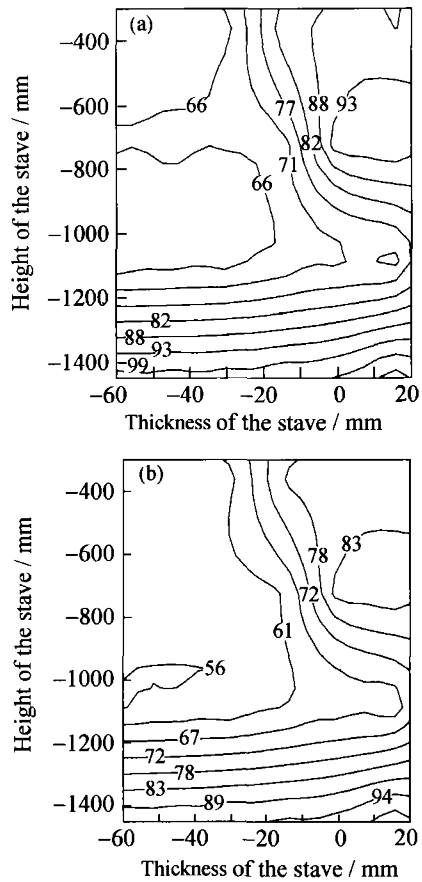

Figure 4 The effects of cooling water velocity on the isotherm of the stave, (a) gas temperature is 1100℃, velocity of cooling water is 1.5 m/s; (b) gas temperature is 1100℃, velocity of cooling water is 2.5 m/s.

(4) The temperature along the horizontal level is uniform and there is some temperature difference between the upper and lower part stave (about 40℃).

(5) The maximum stave temperature will be lower than the European standard when the velocity of cooling water is 1.0 m/s, considering some points with maximum temperature on the cooper stave in practice use, the velocity of cooling water is suggested to be 1.5 m/s or larger than it.

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