Sensors & Transducers, Vol. 21, Special Issue, May 2013, pp. 95-99

Sensors & Transducers

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Research on Temperature Distribution Model of Electric Furnace Roof

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Received: 30 March 2013 /Accepted: 14 May 2013 /Published: 30 May 2013

Abstract: Electric furnace roof is an important device for electric steel making, whose heat preservation performance and life-span have a direct impact on the economic benefits of iron and steel enterprise. Considered contact behavior between prefabricate block, this paper establishes the complete CAD/CAE model of the electric furnace roof with finite element software based on the theory of transferring heating subject, and respectively calculates the stable temperature and stress field of the firebrick roof and the prefabricate block roof in last melting stage, as is advantageous to analyze the level and the distribution of temperature and stress of electric furnace roof. *Copyright © 2013 IFSA.*

Keywords: Electric furnace roof, Temperature field, Finite element method, Distribution model.

1. Introduction

Electric furnace roof is an important component of the electric furnace lining, whose heat preservation performance and life-span have a close relationship with the productivity, quality, consumption and many other technical-economic indicators of steel. Many scholars, at home or abroad, have adopted various of measures on the furnace roof to lower production costs and enhance its heat preservation performance, such as improving the material, increasing alumina content of the brick, increasing camber of furnace roof and the height between center of furnace roof and weld pool surface, improving operation, adopting full water cooling furnace roof, etc. These measures do have some effect, but they do not really solve many problems. It is hard to install refractory brick furnace roof. Service life of furnace roof is too short. The develop trends of larger capacitance and high power density of furnace roof cannot be satisfied. Full water cooling technology produces too much heat loss. So the installation period of electric furnace roof, heat preservation ability and the life-span main become the main reasons that restrict the benefit of steel enterprise, which make great influence on its productivity and economic benefit. As the result, the measures that shorten the installation period of furnace roof and raise the life-span are significant for electric steel making technology to reduce production costs and improve its competitiveness.

Electric furnace roof is an important device for electric steel making, whose heat preservation performance and life-span have a direct impact on the economic benefits of iron and steel enterprise. Considered the disadvantages of firebrick roof like its short life-span, bad thermal stability and difficult installing, the prefabricate block roof is made. This paper establishes the CAD/CAE model of the two furnace roofs based on a 30t electric furnace roof real model of a steel factory, simulates the temperature and stress field of the firebrick roof and the prefabricate block roof with ANSYS.

2. Modeling

The firebrick roof is made with high alumina bricks. The prefabricate block roof is assembled with prefabricate blocks casted by refractory material like building toy blocks together. Although they are manufactured with different methods, their appearance and geometrical dimension are identical. So all furnace roof CAD models can be built according to the real geometrical dimensions of a 30 t furnace roof from a steel factory. The main dimensions are below: the diameter of the charging hole is 150 mm, the diameter of the electrode hole is 250 mm, the diameter of the circle that with the center of the electrode hole on is 90 mm, the diameter of the upper end face of the center roof is 1730 mm, the diameter of its lower end face is 1606 mm, the diameter of the external end face circle is 3218 mm, the diameter of the inner end face circle is 3000 mm. Because of the effect of the geometrical dimensions, it is not operable to cast the whole furnace roof. This paper only establishes the CAD model of the firebrick roof and three kinds of prefabricate roof casted by different pans.

The CAD models of the two furnace roof are established in Fig. 2-5.

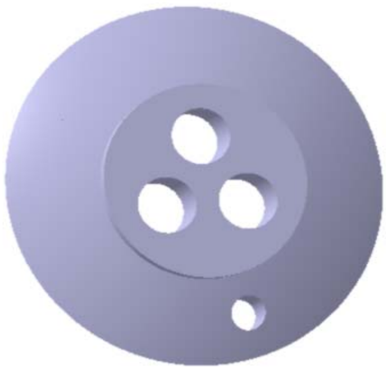


Fig. 1. Electric furnace roof model.

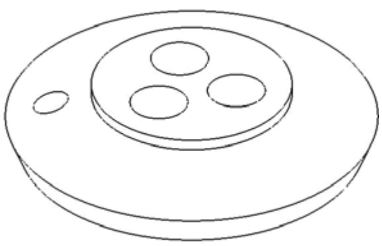


Fig. 2. Firebrick roof CAD model.

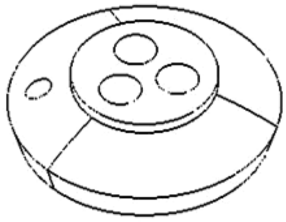


Fig. 3. Prefabricate block roof model (3 blocks).

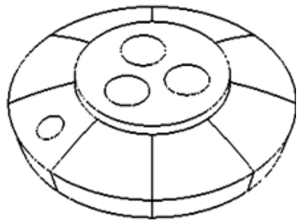


Fig. 4. Prefabricate block roof model (8 blocks).

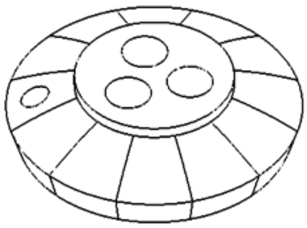


Fig. 5. Prefabricate block roof model (12 blocks).

To do thermal analysis with ANASY, the CAD model should be built firstly, then establish the finite element model. After building the CAD model, the CAE model should be established mainly including the definition of the material of the electrical furnace roof, the choice of the type of analytic elements and the control of mesh dividing.

The finite element model of firebrick roof is established in Fig. 6 and the model of prefabricate roof is the shadow zone of Fig. 6. The number of the elements and nodal points are in Table 1, and prefabricate roof model contains contract elements.

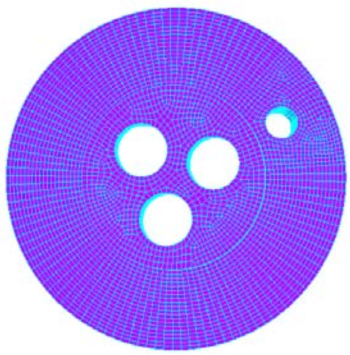
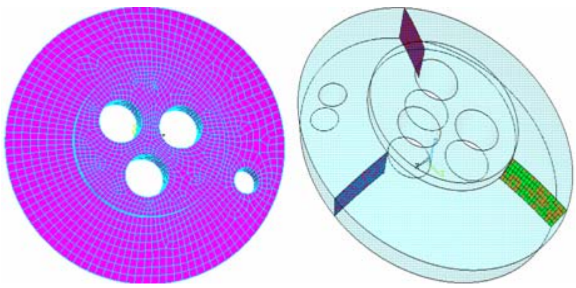
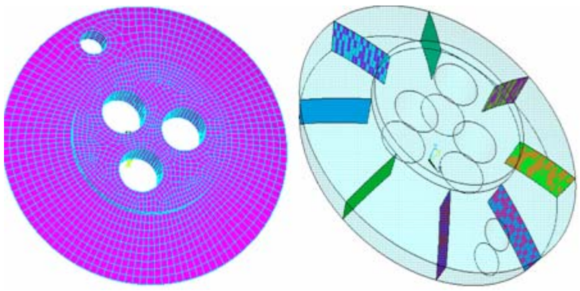


Fig. 6. Firebrick roof CAE model.



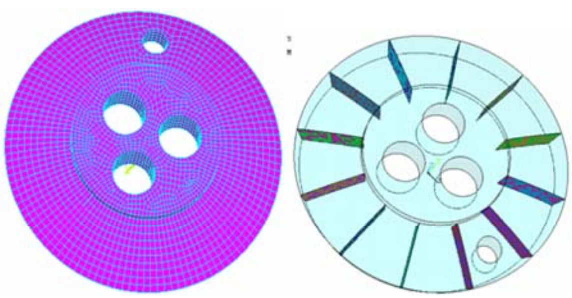
(a) (b)

Fig. 7. Prefabricate block roof CAE model (3 blocks) and its contract pairs.



(a) (b)

Fig. 8. Prefabricate block roof CAE model (8 blocks) and its contract pairs.



(a) (b)

Fig. 9. Prefabricate block roof CAE model (12 blocks) and its contract pairs.

Table 1. The ACE parameters of the furnace roofs.

Part	Firebrick roof	Prefabricate block roof (3 blocks)	Prefabricate block roof (8 blocks)	Prefabricate block roof (12blocks)
Center roof	535.68~ 670.612	480.874~ 621.888	488.592~ 628.748	479.145~ 620.351
Furnace Roof	670.612 ~1210	621.888~ 1186	628.748~ 1189	620.351~ 1185

3. Temperature and Stress Field of the Electrical Furnace Roof

After setting the loads and boundary conditions, run the macro document LG.mac, get the calculated results of each models. To show the temperature variation of the furnace roof on section of the charging hole, slice the firebrick roof and prefabricate roof along the center symmetry plane by the ANASY work plane, the temperature equivalent slices contours are in Figs. 10-13.

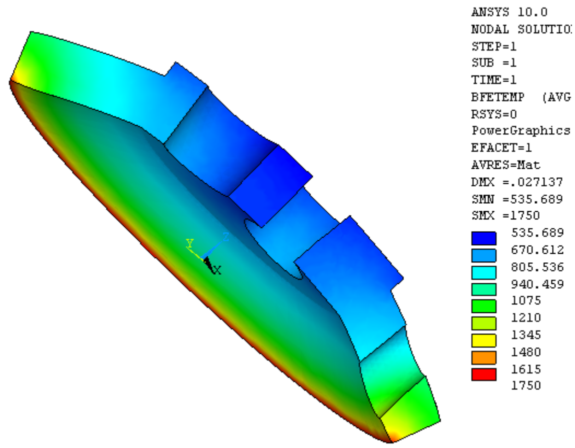


Fig. 10. Isograms slice image of firebrick roof temperature.

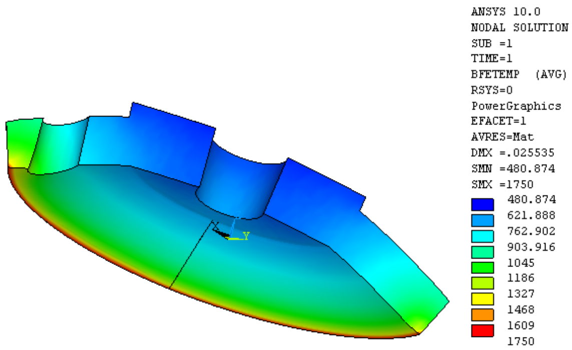


Fig. 11. Isograms slice image of prefabricate block roof (3 blocks).

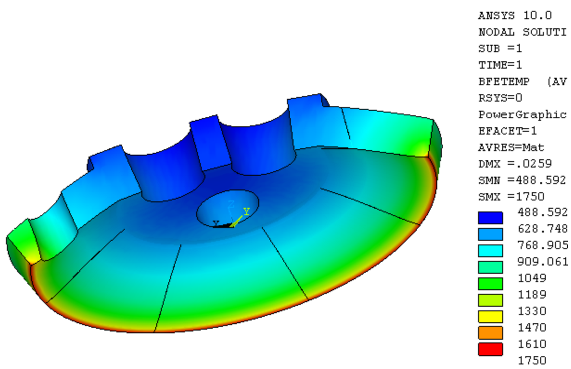


Fig. 12. Isograms slice image of prefabricate block roof (8 blocks).

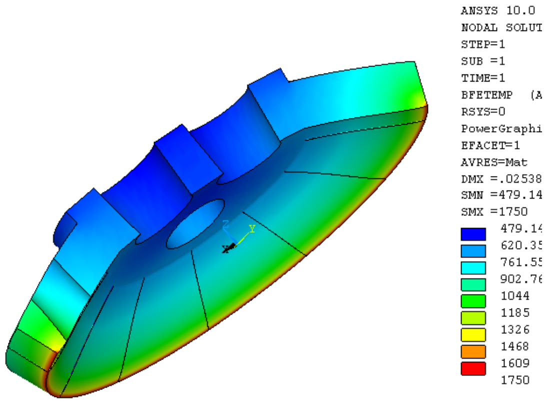


Fig. 13. Isograms slice image of prefabricate block roof (12 blocks).

As the origin point of the last work plane of the CAD model is on the axis of the charging hole, the Z axis is the height direction of the charging hole, so rotate the YZ plane by 90 degrees; meanwhile since the charging holes are set uniformly on the center roof circle, on furnace roof with different number of prefabricate bricks, the relative positions of electrode holes and charging holes are different on roof with different number of prefabricate bricks. The section of the three electrode holes and charging holes can not be shown at the same time. So there are only 1 or 2 of the electrode holes that can be shown.

The Figs. 10-13 indicates that, in last melting stage, the center roof temperature of the firebrick roof ranges from 535.689 °C ~ 670.612°C, but the temperature of the other zone is 805.536 °C ~ 1210 °C; the temperature of center zone of the roof composed with three prefabricate bricks ranges from 480.874 °C ~ 621.888 °C, the temperature of the most part of the roof is 621.888 °C ~ 1186 °C; the temperature of center zone of the roof composed with eight prefabricate bricks ranges from 488.592 °C ~ 628.748 °C, the temperature of the most part of this roof is 628.748 °C ~ 1189 °C; the center zone temperature of the roof composed with twelve prefabricate bricks ranges from 479.145 °C ~ 620.351 °C, the temperature of the most part of this roof is 620.351 °C ~ 1185 °C. All the temperatures along the roof thickness gradually decrease and their maximum values are 1750 °C, at the bottom of these roofs. This paper equalizes the thermal radiation absorbed by roof to temperature degrees of freedom, so the maximum temperature distributions are at the same area of each roof; this area is closest to molten steel of the high temperature zone and electric arc, squaring to the fact; and cause there are differences between the overall structures of the firebrick roof and the prefabricate block roof as the different manufacturing technology, there is no interface in the firebrick roof, but the prefabricate block roof has interface as its making up with several blocks. So the heat transfer rates of each roof at diameter direction and in thickness direction are different, so the temperatures are different.

In the diameter direction, temperature is higher on the outer circumference of the roof and lower in the center of the roof. In the thickness direction, temperature of the roof is higher on the inside wall of roof and lower on the surface of roof. This is because the bottom and inside wall of the roof are closer to the steel water, these areas will absorb more heat radiation. The result is consistent with the reality. The average temperature distribution statistics of each roof model are in Table 2.

Table 2. The average temperature distribution statistics of each roof model (°C).

CAE model	**Fire-brick roof**	**Prefabricate block roof (3 blocks)**	**Prefabri-cate block roof (8 blocks)**	**Prefabricate block roof (12 blocks)**
Number of element points	18906	19305	20122	21400
Number of nodal points	22068	23278	24070	25140

The calculated results indicates that, in last melting stage, the average temperature of firebrick roof is higher than prefabricate block roof and the temperature distribution law of each roof are basically the same.

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4. Conclusion

This paper simulates the stable temperature and stress field of firebrick roof and the prefabricate block roof in last melting stage. The result corresponds to the theory of transferring heating subject, indicating that the simplification of model and the operation to boundary are reasonable, proving the responsibility of the temperature analysis. The result shows that the heat preservation performance of prefabricate block roof is better than that of firebrick roof, providing theory support for prefabricate block roof from heat preservation perspective.

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