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Research on Temperature Field and Stress Field of Prefabricate Block Electric Furnace Roof

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Abstract: This paper establishes the CAD/CAE model of high aluminum brick furnace cover and a precast furnace cover (casting three block, eight block, twelve block) based on a 30t electric furnace roof real model of a steel factory and simulates the temperature and stress field of the firebrick roof and prefabricate block roof with ANSYS. The calculation results have indicated that the contact stress between furnace cover and precast block will affect the performance of the furnace cover and the furnace cover which is assembled by three pieces of casting precast block obtains lower stress levels has a longer service life, providing a quantitative reference for selection of casting scheme. *Copyright © 2013 IFSA.*

Keywords: Electric Furnace Roof, Temperature field, Stress field, Finite element method.

1. Introduction

Arc furnace, as a major method of large-scale steel-making, makes use of high temperature melting ore and metal that was produced by electrode arc, the advantage of its rich raw material source, power supply and the lower price. It is a strategic significance for our steel industry to get rid of bad situation and make our country from steel large produced into steel strong.

The length of life and thermal insulation performance [3] of the electric furnace cover, an important part of electric arc furnace lining, has a very close relationship with technical and economic indexes of steel production quality and consumption. Domestic and foreign scholars have taken many measures for the furnace cover to reduce the production cost, enhance the thermal stability, such as improving the furnace cover material, improving the content of alumina brick, increasing the camber of furnace roof and height of the furnace lid center to the weld pool surface, improvement of operation, using water-cooled brick furnace cover. These measures have achieved some results, still failed to solve those problems of refractory brick furnace cover that difficult installation, short service life, the heat loss of water-cooled furnace cover and can not meet the needs of development that electric arc furnace turns into large capacity ultra high power. Therefore, it is the main factor of restricting steel benefit that the installation period, thermal insulation performance and the service life, which it has a crucial impact on productivity and economic benefits of the iron and steel enterprise. Therefore, how to shorten the furnace cover the installation period and improve its service life has become an important measure to reduce the production cost and enhance the competitiveness of electric arc furnace steelmaking technology.

This paper establishes the CAD/CAE model of high aluminum brick furnace cover and a precast furnace cover (casting three block, eight block, twelve block) based on a 30 t electric furnace roof real model of a steel factory and simulates the

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temperature and stress field of the firebrick roof and prefabricate block roof [1-2] with ANSYS.

2. Model of the Electric Furnace Roof

High alumina brick furnace cover is formed by moulded high aluminum brick, and precast block electric furnace cover is made of fireproof material casting precast block in accordance with the principle of assemble building blocks together. Although the manufacturing process is different, the shape and size is same, so during the CAD modeling process, the CAD models [8] of all the furnace cover are established based on a real geometry of a certain steel 30t electric cover (the 3D effect graph as shown in Fig. 1).

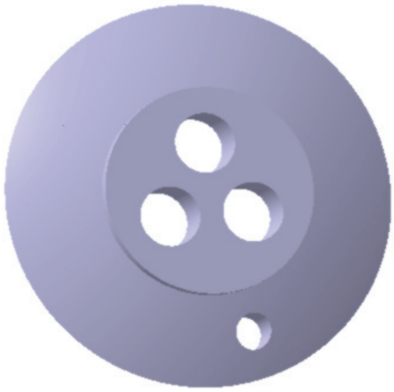

Fig. 1. The entity of electric furnace cover.

Taking the thermal cover transfer into account between center cover and furnace cover, all models were established the complete model which includes center cover and furnace cover. Its main dimensions: The charging hole diameter is 150 mm, the electrode hole diameter is 250 mm, the circle diameter of electrode hole center is 900 mm, the upside surface of center cover diameter is 1730 mm and the downside surface diameter is 1606 mm, the turning diameter of the outer surface of furnace cover is 3218 mm and the inner surface diameter is 3000 mm. Due to the influence of the furnace cover geometry, it is difficult to cast the whole furnace cover, at the same time, according to the demand of the project, this paper sets up only block furnace high aluminum brick furnace cover and precast furnace cover (three, eight and twelve) of three kinds of casting solutions.

Established CAD models of kinds of furnace cover are shown in Fig. 2 - Fig. 5.

Applying ANSYS to thermal analysis, first a geometric model is established, then the finite element model is built. The CAD model is created, then CAE model is created including the parameter definition of electric furnace cover material and choice of analysis unit type and mesh control.

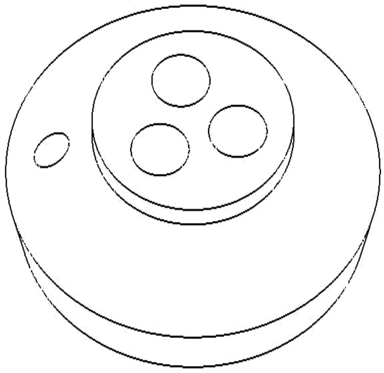

Fig. 2. The CAD model of the whole high aluminum brick furnace cover.

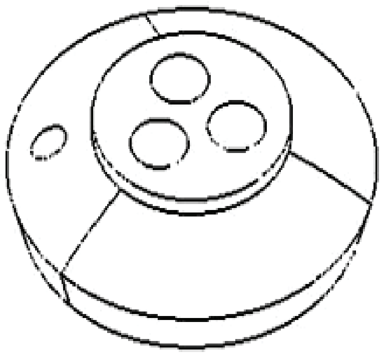

Fig. 3. CAD model of precast block furnace cover (casting three).

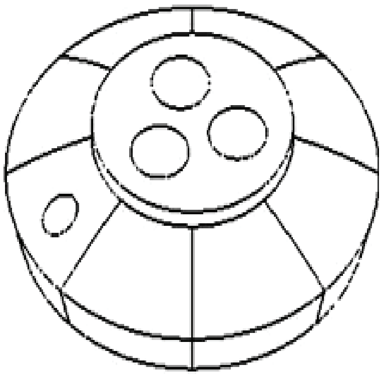

Fig. 4. CAD model of precast block furnace cover (casting eight).

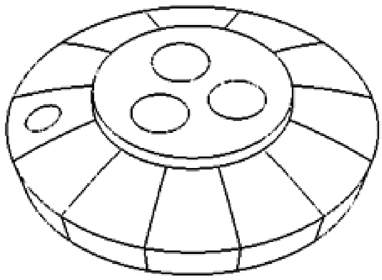

Fig. 5. CAD model of precast block furnace cover (casting twelve).

3. Temperature Field of the Electrical Furnace Roof

After setting the loads and boundary conditions, the macro document LG.mac is run, the calculated results of each models are obtained 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 [6] slices contours are in Fig. 6-Fig. 9. 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 rotating 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 three electrode holes and charging holes can not be shown at the same time. So there is only 1 or 2 of the electrode holes that can be shown.

The Fig. 6-Fig. 9 indicate 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 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 most part of the roof is 621.888 °C - 1186 °C.

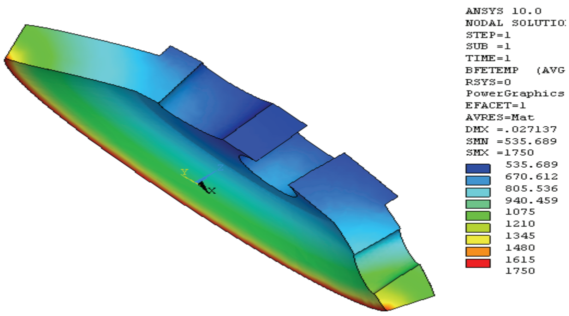

Fig. 6. Isograms slice image of firebrick roof temperature.

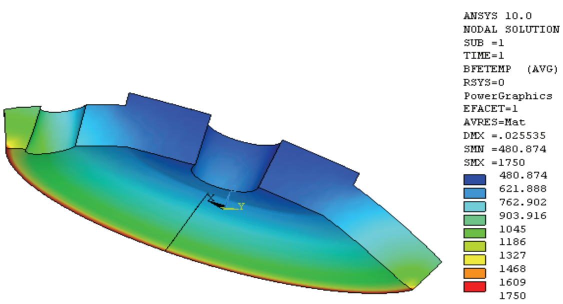

Fig. 7. Isograms slice image of prefabricate block roof (3 blocks).

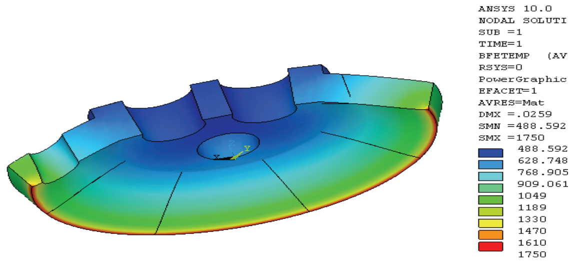

Fig. 8. Isograms slice image of prefabricate block roof (8 blocks).

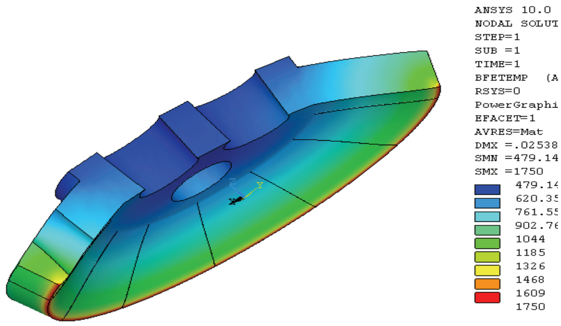

Fig. 9. Isograms slice image of prefabricate block roof.

The temperature of center zone of the roof composed with eight prefabricate bricks ranges from 488.592 °C - 628.748 °C. The temperature of 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 of 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 there are differences between the overall structures of the firebrick roof and the prefabricate block roof due to the different manufacturing technology, there is no interface in the firebrick roof, but the prefabricate block roof has interface as its components 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.

4. Stress Field Analysis of Electric Furnace Cover

Only when the material's temperature changes, due to the external constraints and mutual constraints of each part internal, so that not being completely free expansion and contraction will lead to the generation of heat stress. The furnace cover bears a very strong thermal shock in the last stage of melting, so it will lead to thermal stress. In this chapter, temperature field of a furnace cover is as an initial condition ,at the same time carries out a boundary treatment of structure analysis on the furnace cover in need, making numerical simulation for the stress level and distribution.

Adopting the sequential coupling method [7] when stress field of the furnace cover is calculated, which calculates the temperature field of model at first, then regards the result of temperature field as body load to calculate stress field of it. This paper focuses on precast block of furnace cover whether it can withstand temperature shock and not to burst damage. So when in processing of the stress analysis, just the node temperature into the model as the body load is set. Considering the placement situation when assembling the furnace cover and the furnace body, and the locate function of bevel on furnace cover bottom with the cooling water pipe, the boundary condition and the load of stress analysis were treated as follows:

1) The last brick needs external force to push in when building the furnace cover with refractory brick;

2) Considering a furnace cover deadweight, acceleration of gravity is applied for all models in Z direction (MPA units in 9800);

3) All nodes that lie in bevel of the bottom of furnace cover were constrained under Descartes coordinates system, ignoring the function of drive, lifting, rotating on the furnace cover;

4) Regarding the node temperature value of thermal analysis as the body load of structural analysis.

Due to size and shape, furnace cover will be changed with thermal shock, it should be according to the fourth strength theory to determine the stress level. The equivalent stress of ANSYS (Von Mises Stress) is calculated according to the fourth strength theory. So, after obtaining the calculate destination file, the equivalent stress pattern of furnace covers model is drawn in ANSYS universal post processor to show that the variation of stress level in direction (thickness) of charging hole cross section. Using ANSYS slice functions split each model along the center symmetry plane of feeding hole, the equivalent stress [5] slicing image of each furnace cover model is obtained, as shown in Fig. 10 - Fig. 13.

The statistics about maximum, minimum and the average stress and contact stress level of each furnace cover model are shown in Table 1, MPA system of units, unit of stress is MPa.

The Fig. 10 – Fig. 13 show that it is different equivalent stress level in kinds of fabrication process of the furnace cover. The maximum equivalent stress of high aluminum brick furnace cover is 6.47 MPa, Most of the stress level of the furnace cover is range from 1.507 MPa to 4.343 MPa, which is higher than precast block furnace cover in maximum and average stress.

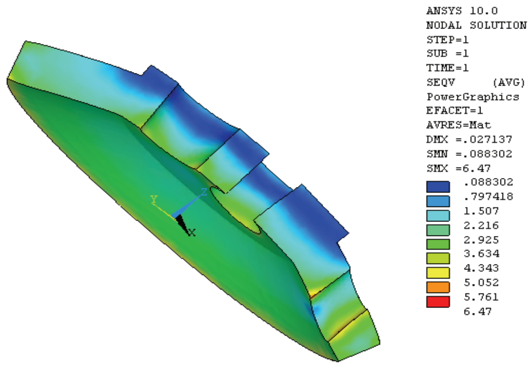

Fig. 10. Equivalent stress slicing image of the whole high aluminum brick furnace cover.

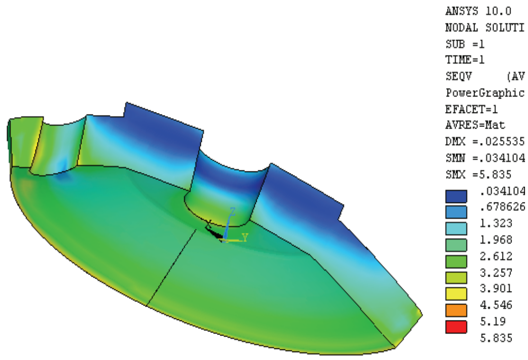

Fig. 11. Equivalent stress slicing image of precast block furnace cover (casting three pieces).

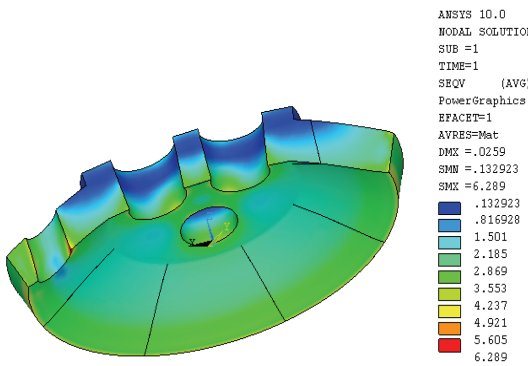

Fig. 12. Equivalent stress slicing image of precast block furnace cover (casting eight pieces).

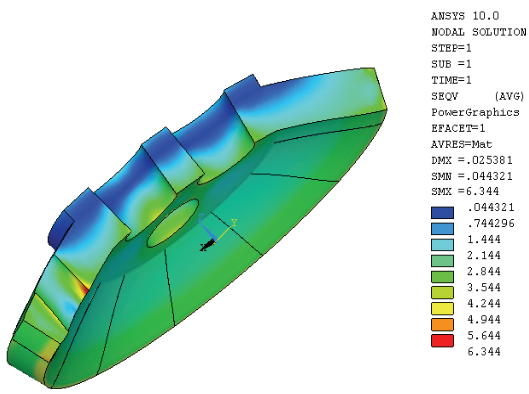

Fig. 13. Equivalent stress slicing image of precast block furnace cover (casting twelve pieces).

Table 1. Statistics of the model of stress level.

Stress	High aluminum brick furnace cover	Precast block furnace cover (casting three pieces)	Precast block furnace cover (casting eight pieces)	Precast block furnace cover (casting twelve pieces)
Maximum	6.47	5.835	6.289	6.344
Minimum	0.088	0.034	0.132	0.044
Average	1.507-4.343	1.323-3.257	1.501-3.553	1.444-3.544
Average of contact stress		0.007-1.997	0.027-1.996	0.012-1.95
Maximum of contact stress		3.588	3.57	3.5

According to the fourth strength theory, material failure is mainly caused by the deviator strain energy which is equivalent stress, the higher equivalent stress that material bear, then the shorter service life of it. From which we can infer, because the equivalent stress level of precast block furnace cover is low, it has longer service life than the high aluminum brick furnace cover, This is coincide with the experiment that the service life of high alumina EAF arch prefabricated block in a factory is more than 600 [4] that the high aluminum brick EAF arch is generally 80 - 120 furnaces. It fully illustrates that precast block furnace cover has longer service life than high aluminum brick furnace cover, and shows that simulation results coincide with the test results, which the calculation result is consistent with the theoretical analysis.

The calculated results is not only coincide with experimental results [11], but also in according with theoretical analysis, which is mean that it is reasonable for the established model, load and handle boundary condition, proving the reliability of the simulation, providing theoretical support for the production and promotion of precast block furnace cover.

5. Conclusions

Having simulated the temperature field and stress field of high aluminum brick cover and precast furnace cover in the final stage of melting, the calculation results have indicated that the general stress level of precast block furnace cover is lower than high aluminum brick furnace. So service life of the precast block furnace cover is longer than high aluminum brick cover, which provides theoretical support for the production of precast block in respect of service life. The stress level of furnace cover presents two trends: one is in radical direction which is higher in around of outer circle than center. Another is in thickness direction which is higher in inner wall than outer. The around of charge hole in furnace cover is the most likely to damage parts. For the precast furnace cover ,measures can be taken that changing the size of the feeding hole and setting it position to reduce the stress concentration, increasing the conical degree of faying surface of center cover and precast block to prevent them separate. The contact stress between furnace cover and precast block will affect the performance of the furnace cover ,we can change the faying surface of them to groove shape or enforce the fastening device [9]; Among casting solutions, the furnace cover which is assembled by three pieces of casting precast block obtains lower stress levels has a longer service life, providing a quantitative reference for selection of casting scheme.

Acknowledgement

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