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Stress Distribution Model of Prefabricate Block Electric Furnace Roof

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Abstract: The furnace cover is an important equipment of electric arc furnace steelmaking, the thermal insulation performance and service life directly affects the economic benefits of iron and steel enterprises. Considering the contact between the precast block, this paper establish the CAD/CAE model of high aluminum brick furnace cover and a precast furnace cover (casting three block, eight block, twelve block) , based on heat transfer theory apply the finite element software ANSYS analyzes the stress field of steady state about high aluminum brick furnace cover and a precast block furnace cover in the last stage of melting, which facilitates the analysis of the stress level and distribution of furnace cover, provides the theory support for the production and promotion of precast block furnace cover. *Copyright © 2013 IFSA.*

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

1. Introduction

Arc furnace as a major method of large-scale steel-making, which it 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 price is low 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.

Electric furnace cover is an important part of electric arc furnace lining, the length of life of the furnace cover and thermal insulation performance, technical and economic indexes of steel production, quality, and consumption has a very close relationship. Domestic and foreign scholars on the furnace cover has taken many measures to reduce the production cost, enhance the thermal stability, such as improving the furnace cover material, improve the content of alumina brick, increase the camber of furnace roof and height of the furnace lid center to the weld pool surface, improvement of operation, using water-cooled furnace cover brick furnace cover. Although these measures have achieved some results, still failed to solve the those problem of refractory brick furnace cover that difficult installation, short service life, the water-cooled furnace cover heat loss and can not meet the needs of development that electric arc furnace turn 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 complete CAD/CAE model of the electric furnace roof with finite element software which it is based on the geometric model of a 30t electric furnace roof of a steel industry, and respectively calculates stress field of the high aluminum brick roof and the prefabricate block roof.

2. Established CAD/CAE Model of the Electric Furnace Roof

High alumina brick furnace cover is formed by moulded high aluminum brick, 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 are same. So during the CAD modeling process, based on a real geometry of a certain steel 30t electric cover (the 3D effect graph as shown in Fig. 1) to establish CAD model of all the furnace cover.

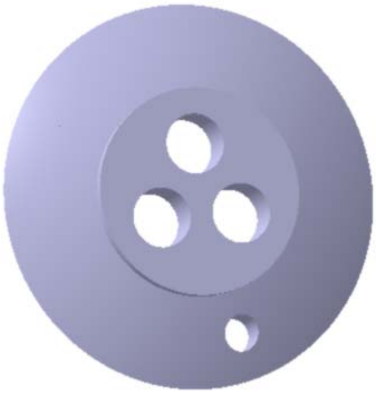

Fig. 1. The entity of electric furnace cover.

Taking into account the thermal cover transfer between center cover and furnace cover, all models were established the complete model which including center cover and furnace cover. Its main dimensions: 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 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 set 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 model of two kinds of furnace cover are shown in Figs. 2~5.

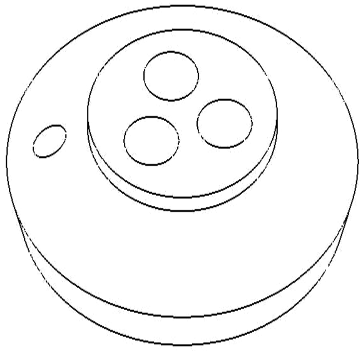

Fig. 2. The CAD model of the whole high aluminum brick furnace cover.

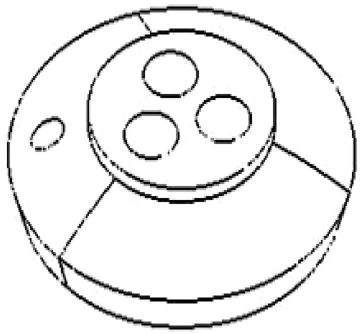

Fig. 3.CAD model of precast block furnace cover (casting three).

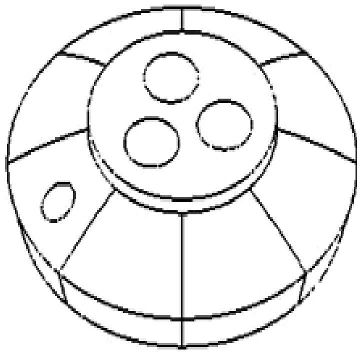

Fig. 4. CAD model of precast block furnace cover (casting eight).

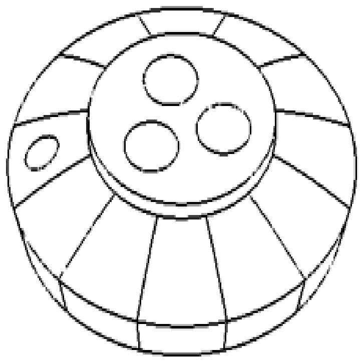

Fig. 5. CAD model of precast block furnace cover (casting twelve).

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

3. The 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 it cannot completely free expansion and contraction will lead to the generation of heat stress. In the last stage of melting furnace cover under thermal shock is very strong, so it will produce thermal stress. In this chapter, a furnace cover temperature field as an initial condition ,at the same time, carry out a boundary treatment of structure analysis on the furnace cover in need, make numerical simulation for the stress level and distribution .

Using the sequential coupling method when calculate stress field of the furnace cover, which is mean calculated model of the temperature field at first , then regard the result of temperature field as body load to calculate stress field of it. This paper focuses on precast block of furnace cover whether can withstand temperature shock and not to burst damage, so when processing the stress analysis, just set the node temperature into the model as the body load, 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 need external force to push in when build the furnace cover with refractory brick,

(2) Considering a furnace cover deadweight, acceleration of gravity were 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, and ignore 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 obtain the calculate destination file, draw the equivalent stress pattern of furnace covers model 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, to obtain the equivalent stress slicing image of each furnace cover model, as shown in Figs. 6~9.

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.

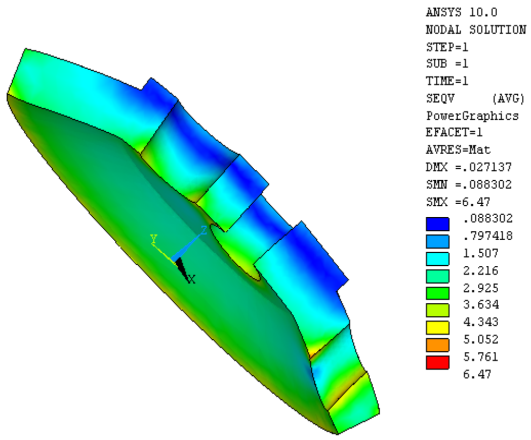

Fig. 6. Equivalent stress slicing image of the whole high aluminum brick furnace cover.

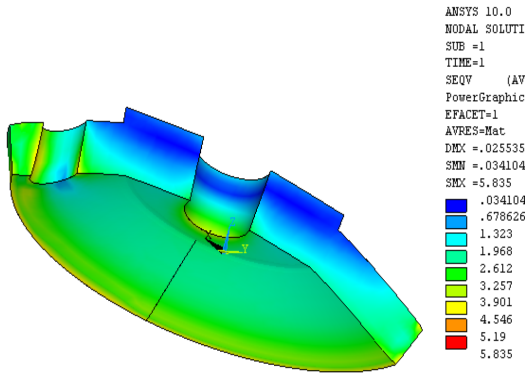

Fig. 7. Equivalent stress slicing image of precast block furnace cover (casting three pieces).

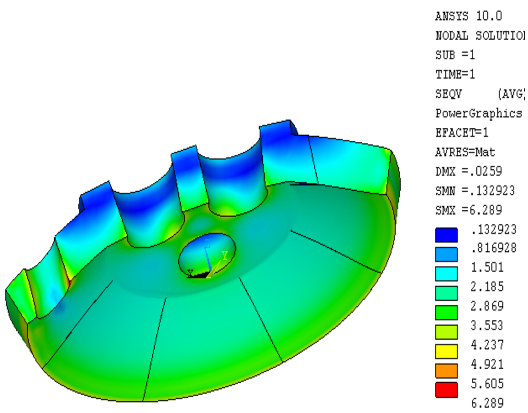

Fig. 8. Equivalent stress slicing image of precast block furnace cover (casting eight pieces).

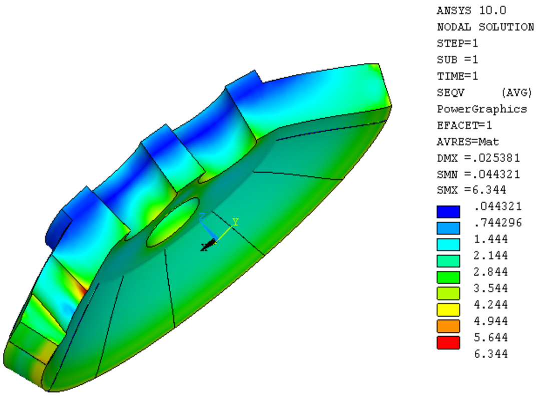

Fig. 9. Equivalent stress slicing image of precast block furnace cover (casting twelve pieces).

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

The Fig. 6~9 show that it is different equivalent stress level in two 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. 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] furnaces and the high aluminum brick EAF arch is generally 80~120 furnaces. Fully illustrates that precast block furnace cover has longer service life than high aluminum brick furnace cover, 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, but also in according with theoretical analysis, which is mean that is reasonable for the established model, load and handle boundary condition, proves the reliability of the simulation, provides theoretical support for the production and promotion of precast block furnace cover.

4. Conclusions

Having simulated the 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 present two trend that 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 which is the most likely to damage parts. For the precast furnace cover, recommended taking measures that changing the size of the feeding hole and set it position to reduce the stress concentration; increased 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 recommend change the faying surface of them to groove shape or enforce the fastening device; Among casting solutions, the furnace cover which is assembled by three pieces of casting precast block obtain lower stress levels, has a longer service life, provide a quantitative reference for selection of casting scheme.

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