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Influence Factors on Temperature Distribution of Electric Furnace Roof

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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. This paper investigates the effect between the temperature level of electric furnace roof and the material parameters. Research indicates that they have a trend to change in the same direction. *Copyright © 2013 IFSA.*

Keywords: Electric furnace roof (EFR), Temperature field, Finite element method, Influence factors.

1. Introduction

EFR is an important part of the lining of electric arc furnace. The lifetime and insulation performance of EFR have a close relation with the production, quality, consumption, etc of steel. Domestic and foreign scholars had taken many measures to decrease its production cost and enhance its thermal stability. For instance, improving material, content of the alumina in brick, camber of bricklaying EFR, height between EFR center and molten pool surface, operation, using whole water cooling EFR. Although these measures had acquired certain effect, it failed to solve the problem that the difficulty of firebrick EFR's installation ,short service life, being unable to meet the requirement that the electric arc furnace is approaching to the large capacity and UHP ones and the great heat loss of whole water cooling EFR. So the installation time of EFR, heat insulation performance and service life become the main restrictive factors of steel plant benefit, which have important effects on the productivity and economic benefit of steel enterprises. So the measures to shorten the installation time of EFR and improve its service life are very important to reduce production cost and enhance competitiveness. Take the steel mill's 30t EFR as research projects. This paper studied the steady temperature field of high aluminum brick EFR and prefabricate block of EFR in typical operating condition and the influence law of EFR temperature field affected by material properties and the shape of prefabricate block. We try to compare the temperature level of high aluminum brick EFR and prefabricate block of EFR to provide theoretical support for scheme of prefabricate block of EFR.

2. Building the CAD Model of EFR

The high aluminum brick EFR is constructed by molding high aluminum brick. Prefabricate block of EFR is assembled from prefabricate blocks casted by refractory material according to fight blocks principle.

Although there is difference in manufacturing process, its shape and geometry size are the same. So in the process of model building, we build all the CAD model of EFR based on the real geometry size of 30t EFR of a steel mill (The 3D effect graph is shown in Fig. 1). On one hand, we take the structure of EFR and real situation in load into consideration, for another hand, we neglect the steps that are relatively small and don't influence the whole. The assumptions are as follows.

1) All the geometry models are built according to Fig. 1. All the models are completely built like that which include central cover and EFR. The main sizes are as follows. The diameter of feeding hole is 150 mm. The diameter of electrode hole is 250 mm. The diameter of circle where the center of the circle of electrode hole is 900 mm. The diameter of upper end face of central cover is 1730 mm. The diameter of lower end face is 1606 mm. The swing diameter of external end face of EFR is 3218 mm. The swing diameter of internal EFR is 3000 mm.

2) Because the fabrication process is different. High aluminum brick EFR is structurally one integrated mass. There is no interface in the internal EFR; prefabricate block EFR consist of many bulks, so there exist interface between prefabricate block EFR. In the process of building model, we take different Boolean operation. Namely, taking GLUE operation to the high aluminum brick EFR, bonding EFR and central roof for a whole, which guarantee that the node of physical interface coincide; for the prefabricate block EFR, according to the different number of prefabricate block, setting the VGEN command parameter to guarantee that there is interface between prefabricate block and take preparation for creating contact pair between prefabricate block. Meanwhile, taking that it is close from the bottom of EFR to molten steel and arc , circumferential expansion is larger than radial expansion when in thermal shock .Contact between prefabricate and central roof can be neglected, taking GLUE operation for prefabricate block and central roof, eliminating composition plane to guarantee the node of prefabricate block and central roof interface coincide. The two CAD models of EFR are shown in Fig. 2.

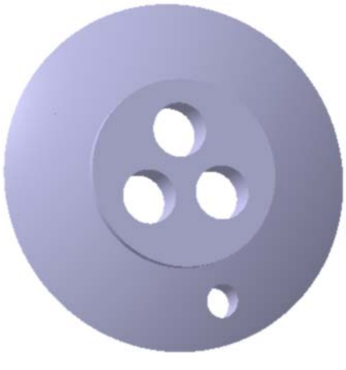

Fig. 1. Graph together of EFR.

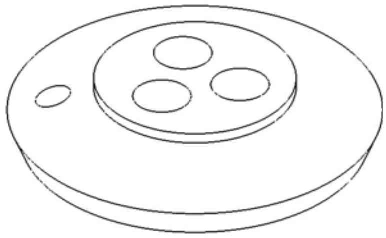

Fig. 2. CAD model of the whole high aluminum brick EFR.

After building CAD model, build the CAE model, it includes the definition the material parameters of EFR, selection of element type and control of mesh generation. High aluminum brick EFR and prefabricate block of EFR are made of refractory material in different production process. Its main ingredients are AL_2O_3. Definition of material properties in the finite element model is treated according to the same material. The finite element model of high aluminum brick EFR is shown in Fig. 3.

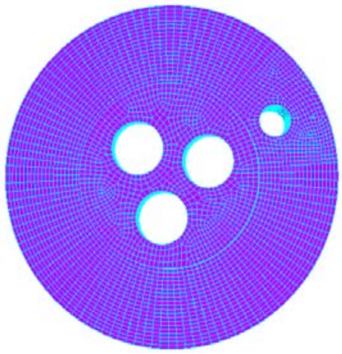

Fig. 3. CAE model of High aluminum brick EFR.

3. Temperature Field of EFR

After setting Loads and boundary conditions as the previously described, running LG.mac macro file, setting N value operation analysis to respectively obtain the calculation result file for each model. In order to display the temperature change of EFR on the cross section of the feeding hole, Cutting along the central symmetry plane using ANSYS working plane and draw the temperature contour section nephogram of high aluminum brick EFR and prefabricate block EFR. It is shown in Fig. 4. Because the final working plane origin is on the axis of the feeding hole in the CAD modeling, the Z axis is the height direction of the feeding hole, so the YZ plane is rotated by 90 degrees; meanwhile, the electrode hole are uniformly set in the circumferential direction of central roof, the amount of prefabricate blocks of EFR is different, the location ranges from feeding hole to electrode hole, the cross-section of the three electrode holes and feeding hole can't be shown simultaneously, therefore only one or two of the electrode hole can be shown.

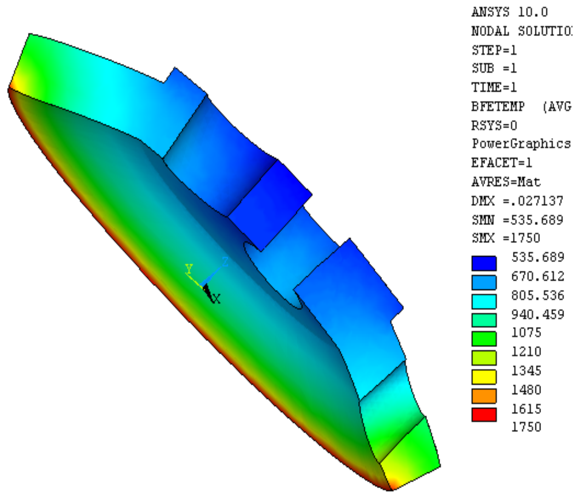

Fig. 4. Temperature contour section nephogram of the whole high aluminum brick EFR.

As can be seen from Fig. 4 in the melting end stage of the same working conditions, the central roof temperature distribution is between 535.689 °C - 670.612 °C, however, the temperature distribution of the most area of furnace roof is between 805.536 °C - 1210°C.

4. Analysis of Influence Factors on Temperature Field of EFR

By the physics knowledge, the material properties of the model will directly affect the value of the physical quantity. Aiming at EFR model of this article, the thermophysical properties parameters and the mechanical properties of EFR material will have a direct impact on EFR of the temperature and stress level; from the equivalent integral form of finite element theory foundation-differential equations, the geometry and structure of model directly affect the solving domain and boundary conditions, thus also affect the distribution law of physical quantities.

1) Material parameters of EFR.

EFR is all made by the high aluminum material in different manufacturing process, its finite element model only contains high aluminum material. Therefore the coefficient of thermal conductivity of the high aluminum material directly affect the heat conduction matrix of EFR model, thus it will affect the temperature field of EFR. For high aluminum brick, the percentage of raw material quota has been standardized by industry regulations. Once sintering and taken out of kiln, its physical parameters will be identified, so the temperature field of high aluminum brick roof can be considered immutable.

2) Structure of EFR.

Geometric relationships of EFR of the internal structure have a great impact on the temperature field, there exist high thermal resistance owing to the interface between the prefabricate block inside of the prefabricate block EFR, it hinders the heat transfer, so the temperature level of prefabricate block EFR is integrally low than the one of high aluminum EFR; meanwhile, the electrode hole pore size and its setting position, the feeding hole pore size and its layout position, the opening diameter of the EFR thickness and the thickness dimension will all affect the distribution of the temperature level of the EFR. circumferential size of EFR which is related to the production capacity of electric furnace has been standardized, it follows that the circumferential size of EFR is not allowed to change for the electric furnace of specific production capacity, the thickness dimension could be reduced and analyze its temperature and stress. We don't study in-depth aiming at the analytical purpose of this article, comparing to influence of material properties the structure size is relatively small.

Comprehensive consideration, the castable thermal conductivity of prefabricate block EFR has a greater impact on the temperature field. The physical meaning of thermal conductivity is for the unit thickness of the object having a unit temperature difference, within a unit time per unit area of heat conduction. Its magnitude is related to the material composition structure, density, moisture content, temperature and other factors.

When in analysis, despite the thermal conductivity of material parameters, the thermal conductivity is respectively set from the original 20 w/(mgK) to 10 w/(mgK), 40 w/(mgK). The loads and boundary conditions are all set in accordance with the previous. Running LG.mac, setting the KX values of 10 w/(mgK), 40 w/(mgK) in the main macro file running window, counting twice, then calculation result documents can be obtained when the thermal conductivity is 10 w/(mgK), 40 w/(mgK). As the structure, loads and boundary conditions of EFR don't change. So the changes of material parameters only affect the magnitude of the physical quantities. It will not affect the qualitative distribution law. The temperature counter maps are shown in Figs. 5-6.

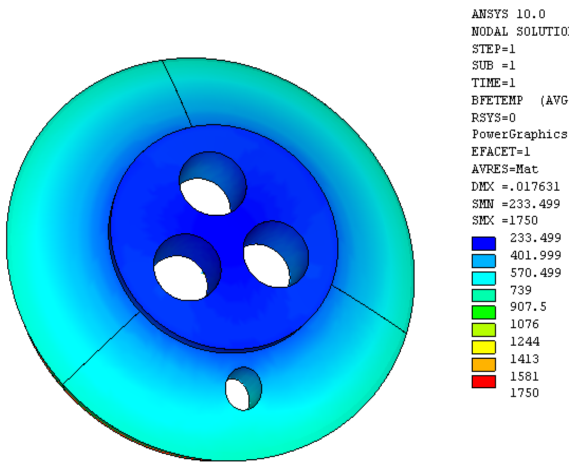

Fig. 5. Temperature contour map of EFR when thermal conductivity is 10 w/(mgK).

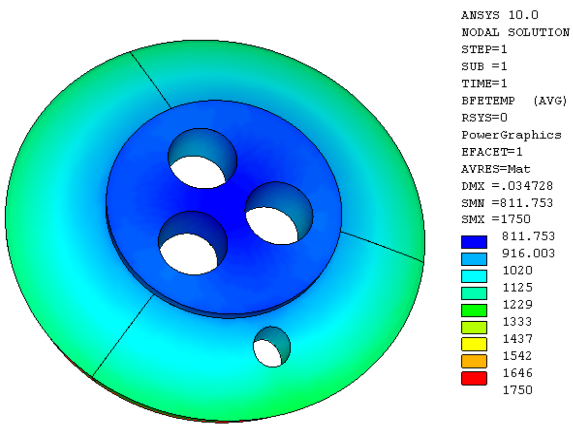

Fig. 6. Temperature contour map of EFR when thermal conductivity is 40 w/(mgK).

As can be seen from Fig. 5. We only change the thermal conductivity of casting material in case that other parameters and conditions remain unchanged, its value decrease from 20 w/(mgK) to 10 w/(mgK), the exine temperature of prefabricate block EFR is about 233.499°C. The temperature of the most EFR is 401.999 °C – 1076 °C; as can be seen from Fig. 6, when the thermal conductivity of casting material is 40 w/(mgK). The exine temperature of EFR rises which is about 811.753 °C. The temperature of the most EFR is 916.003 °C - 1333°C.

The change of thermal conductivity does not affect the law of temperature distribution, but it has a large impact on the temperature level of EFR. With the increase of thermal conductivity, the overall temperature level will increase, the heat absorbed by EFR increases, namely, the heat insulation performance of EFR will decline. Therefore, the temperature level of EFR changes in the same direction with thermal conductivity, however, there is a reverse change between the heat insulation performance of EFR and thermal conductivity. Above all, the temperature level of EFR increase with the increasing thermal conductivity, decrease with the decreasing thermal conductivity in the same direction variation; the heat insulation performance and service life of EFR show the reverse variation law into the thermal conductivity.

5. Conclusion

It studies that the influence of casting material thermal conductivity on temperature field of prefabricate block EFR. Studies have shown that the temperature level of EFR changes in the same direction with thermal conductivity. There is a reverse change between the heat insulation performance of EFR and thermal conductivity. Service life of EFR shows the reverse variation law into the thermal conductivity.

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