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Simulation Analysis on the Thermal Stress Field of the Cement Burner

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Abstract: The thermal stress of cement burner is analyzed in finite element simulation through the HYPERMESH to simulate the temperature field and thermal stress field of the cement burner in actual use. Based on the simulation results, this paper puts forward the damage reason of the cement burner and inferences its damage form. Validated the feasibility and validity which using the computer aided engineering finite element analysis to study the cement burner, contrasting to the damage reason which gives by theoretical analysis and the actual damage form. The research on the influence in thermal stress of cement burner with different anchor forms (U type, Y type, Wave type) is done. The initial conditions and boundary conditions which based on the experimental results are exerted in the model. Simulate the temperature field and the thermal stress field of the cement burner with different anchors by HYPERMESH when the cement burner is in proper functioning. And then we compare and analyze the results which we can get from the simulation to determine the best form of anchor pieces. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Cement kiln burner, HYPERMESH, Simulation, Temperature field, Thermal stress field, Anchor.

1. Forward

Cement burners are mainly applied in fuel combustion, recovery heat exchange, chemical reaction, material transportation and so on. It can bear such an important responsibility because the fuel in the cement burners can provide a lot of energy when the fuel is burning [1]. Only burners with excellent performance can guarantee that burners provide adequate heat to obtain a proper temperature field, in order to make full use of the kiln system and realize the high quality, efficiency, low cost, long lifespan, protecting the environment [2]. Generally the lifespan of a cement burner is always 1 to 5 months but sometimes it is just used a few days and must be repaired or replaced because refractory castable fall off which may disturb normal work of production line [3]. So it is important to analyses the case of damage and find a solution. What's more, the shape and distribution of the anchoring piece have an important influence on the service life of the cement burner [4]. For the importance of the anchoring piece in the burner using, this paper uses CAE method to simulate different shapes (U type, Y type, Wave type) of anchorage burner's temperature field and thermal stress field when the cement burner works [5]. According to the results of simulation analysis for the actual production of cement burner structure design, we provide theoretical guidance to improve the using status of burner.

2. The Brief Introduction of the Cement Burner

2.1. The Brief Introduction of the Structure of the Cement Burner

Now cement burner is constituted of three parts which are the castable, anchors and burner tube. The anchors are shown with red color. And the castable is modeled with a transparent cylinder while the burner tube is described with a blue cylinder (Fig. 1).

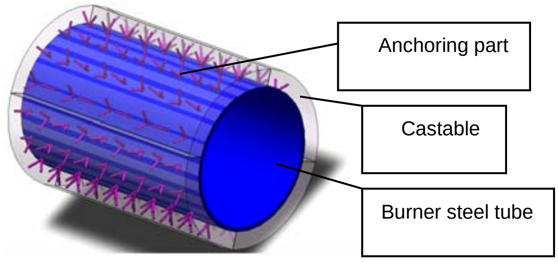


Fig. 1. Three-dimensional CAD model of the cement burner.

2.2. The Damage Form of the Cement Burner

Cement burner service life is very short in china, generally only 1-5 months. Extremely it may be out of work after a few days using and need be repaired or replaced because refractory castable fall off which disturbs normal work of production line. Cement burner damage are mainly caused by the damage of the internal configuration of the burner cement which includes castable damage, castable loss and the burner structure damage. The specific form of damage in practical use is shown in Fig. 2 - Fig. 4.

2.3. The Reasons of the Cement Burner's Damage

The damage reasons of the cement burner primarily include:

1) The material, thickness and quality of construction of the castable;

2) The material, welding method, shape and arrangement of the anchoring parts;

3) The chemical corrosion, abrasion and thermal shock.

2.4. The Method and Procedure of the Simulation Analysis of the Damage Reason of the Cement Burner using CAE

1) First the three-dimensional CAD model of the cement burner completed with Solidworks and then transferred into HYPERMESH for the pretreatment of analysis. All parts of the burner are meshed with hexahedral elements and contacting elements are established at contact interface between different parts.

Fig. 2. Castable and anchor detach from the burner.

Fig. 3. Damage of the end.

Fig. 4. The detached castable and anchors.

2) The physical properties of the castable parameter are obtained and initial and boundary conditions are set according to not only the data measured at production line but also some relevant literatures. The performance parameter and the thermal boundary conditions are applied on the 3D

model and thus thermal analysis CAE model can be obtained. The CAE model is imported to ANSYS to analyze the thermal process of the cement burner in the kiln, and the related results of the thermal simulation analysis can be achieved.

3) The temperature distributions calculated in last step were used as the thermal field load for the stress analysis. This load was read and applied to stress analysis model automatically by LDREAD command in ANSYS. Thus, the thermal stress field can be calculated and analyzed.

4) After the simulation analysis of thermal stress of the whole cement burner, the anchors on the burner are needed to be analyzed. The optimum type of anchors can be obtained by comparison of the effect of different types of anchors on the temperature distribution and stress field.

3. The Simulation Result Analysis of the Cement Burner

3.1. The Establishment of Finite Element CAE Model

We establish the finite element models according to the two-dimensional drawing of the cement burner provided by Beijing Tongda refractory technology limited liability Company. Because this paper mainly focus on the reasons for damages of the cement burner by CAE method, the end part of the cement burner which most easily damaged and inserted in the kiln is taken into consideration.

A quarter part of the burner end is modeled and simulated for the thermal stress analysis because of its axial symmetry. In the process of establishing the finite element model, all the structures adopt the hexahedral element to make the mesh generation, and we established the contact elements at the contact parts among the steel pipe of burner, castable and anchor.

The established cement burner's CAE model is listed as following graphs on Figs. 5-7:

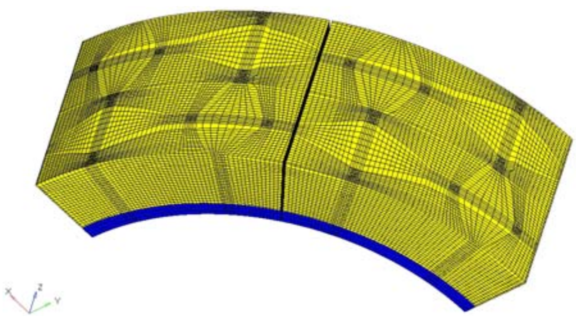


Fig. 5. 1/4 CAE model.

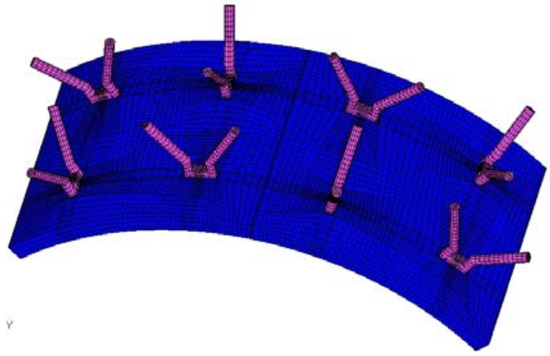


Fig. 6. CAE model of anchors and pipe.

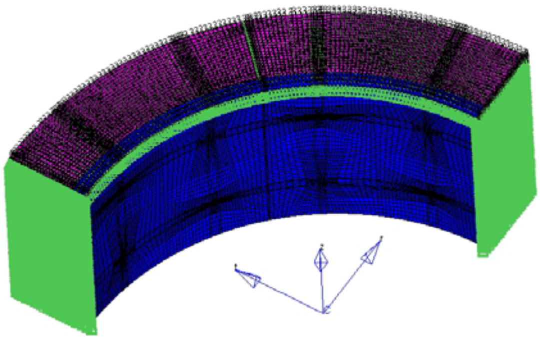


Fig. 7. The symmetry constraint.

3.2. The Simulation Analysis of the Temperature Field

The temperature field of the whole cement burner, the castable, the anchor and the steel pipe in the burner are shown in Fig. 8~Fig. 10.

As shown in Fig. 8 and Fig. 9, it can be observed that the temperature changes uniformly from a lower temperature at the inner surface of the steel pipe to a higher temperature at the inner surface of the castable material [6]. Further more, the temperature at the outside surface of the castable tends to increase from the left to the right (castable end). Fig. 10 shows that temperature increase along the anchors from the root part to the top part. And this temperature can be as high as 976 °C.

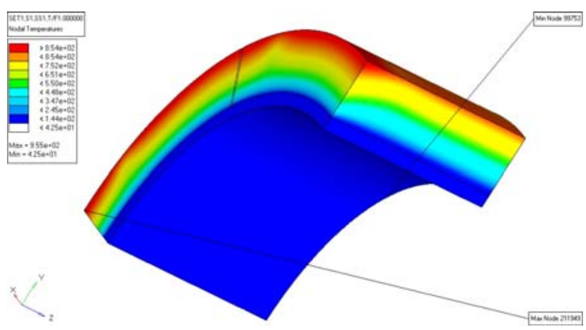


Fig. 8. The cement burner.

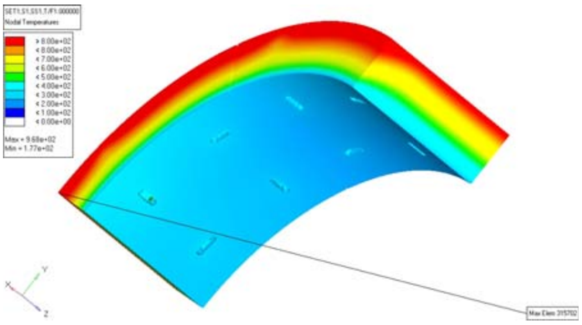


Fig. 9. The castable.

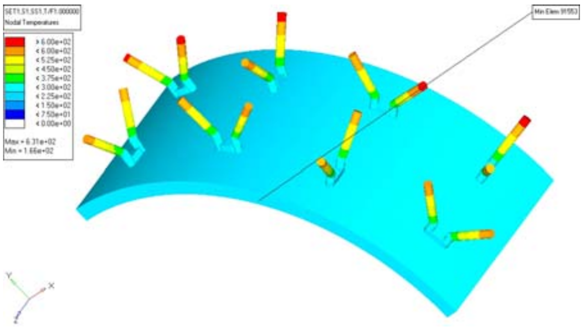


Fig. 10. The anchors and steel pipe.

3.3. The Result of the Simulation Analysis of Thermal Stress Field

3.3.1. Displacement Distribution Cloud Charts of the Model

Fig. 11 gives the displacement distribution of the whole burner.

It is formed that the displacement deformation in the castable end is relatively larger and it increases from interface between the castable and steel pipe to the outside surface of the castable.

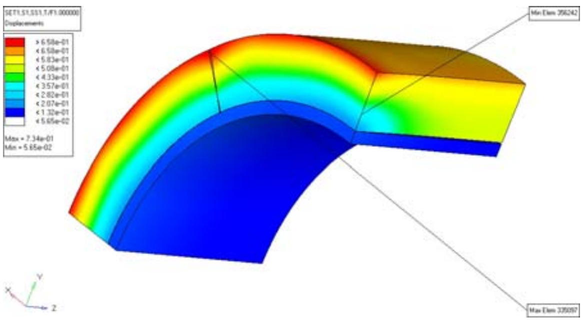


Fig. 11. The displacement distribution of the whole model.

From Fig. 12, it is not difficult to find that the anchors have a tendency to be stretched out and some of the anchors tend to expand and get larger in diameter.

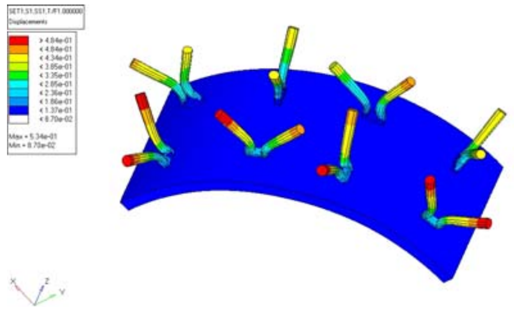


Fig. 12. The displacement distribution of the anchors and steel pipe.

3.3.2. The Stress Distribution Cloud Charts of the Models

Fig. 13-Fig. 15 shows the stress distribution of the castable, anchors, and the steel pipe in the burner respectively. The part where the relatively bigger stress in the castable located is at the position connection with the anchor roots as shown in Fig. 13. This is primarily because the anchor impedes the expansion deformation of the castable [7]. It is because the interaction between the castable and the anchors that the anchors are stretched in some intend by castable, causing a stress concentration at the root part of anchors welded on the steel pipe of the burner shown in Fig. 14 [8]. The greatest stress can reach as high as 1530 MPa. Further more, the deformation of the anchors lead to the deformation of the steel pipe in the cement burner and thus produce the stress distribution shown in Fig. 15.

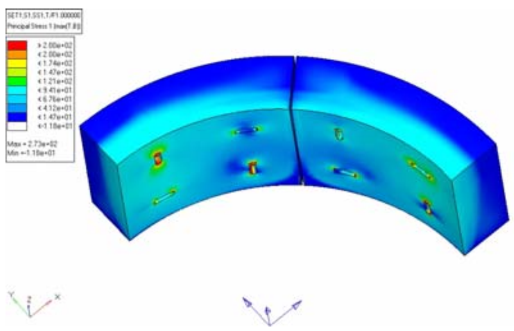


Fig. 13. 1st main stress of castable.

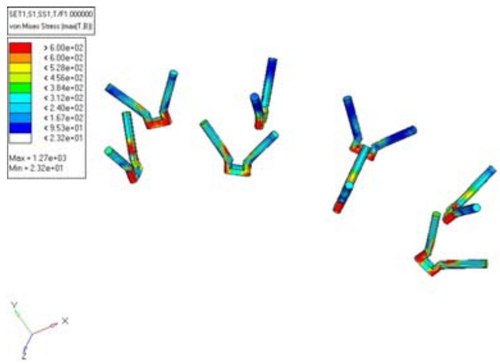


Fig. 14. The von_sises stress of the anchors.

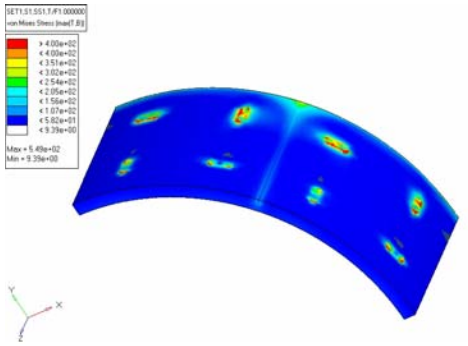
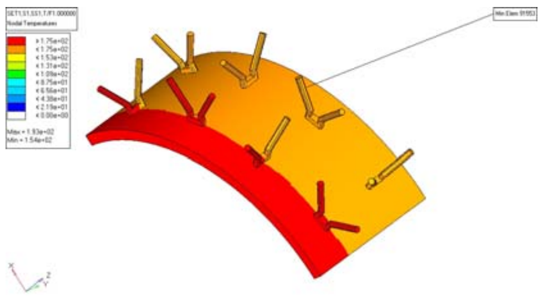


Fig. 15. The von_sises stress of the steel pipe.

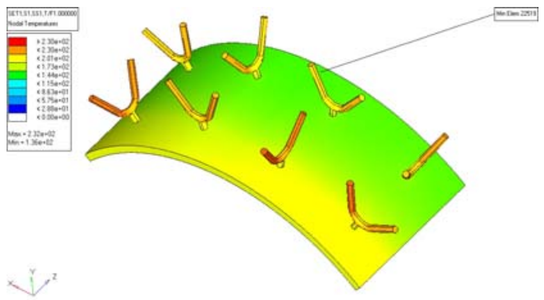
4. Thermal Stress Analysis of Burners with Different Type of Anchors

4.1. The Analysis Results of Thermal Field Simulation

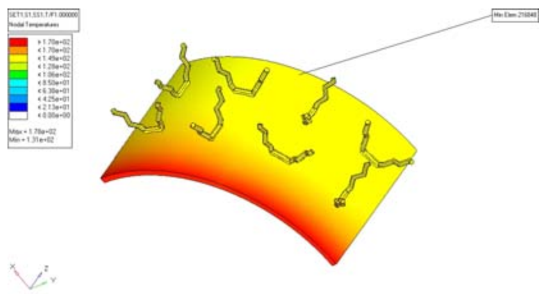
There are three type anchors widely used in our daily manufacture. The three type anchors are the U type anchors, Y type anchors and Wave type anchors. So this paper focus on the three type anchors when they are working. The temperature clouds are shown in Fig. 16.



U type



Y type



Wave type

Fig. 16. Temperature contour of the pipe of burners with different type of anchors.

Fig. 16, it shows that the images of temperature field of anchors and the pipe of burner change with the different type of anchors. The highest temperature distributes in the pipe for U and Wave-anchor cement burner, while the Y-anchor's highest temperature is in anchors [9]. What's more, the working temperature is lowest for Y and highest for U when cement burners are considered as a whole.

4.2. Stress Field Simulation Analysis Results

But in actual production, the cement burner not only have temperature field, but also have stress field [10]. So we will take the stress field into consideration. And their stress field is given by Fig. 17~Fig. 19.

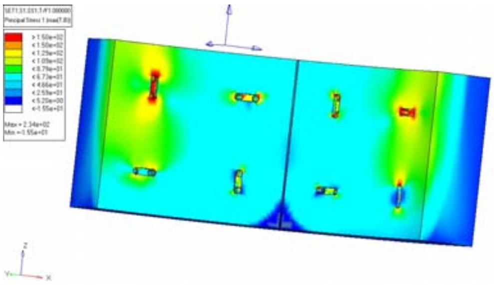
From stress contours Fig. 17 to Fig. 19 show that: when the cement burners are considered as a whole, Y-anchor cement burners perform best and the other two come be worse [11]. What's more, we can find the highest stress come into the roots of anchors which wielded to the pipe. In a word, the shape of anchors has a great influence on the structure stress distribution. Based on thermal stress analysis of cement burner, temperature and stress field are obtained as in Table 1 and Table 2.

Table 1.

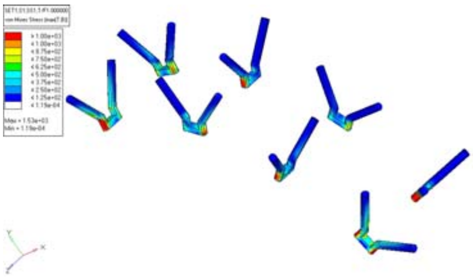
σ=0.1 mm	Temperature/°C		
	Anchor	**Pipe**	**Castables**
U-type	51.4	63.1	976
Y-type	118	50.1	985
Wave-type	34.7	50.2	985

Table 2.

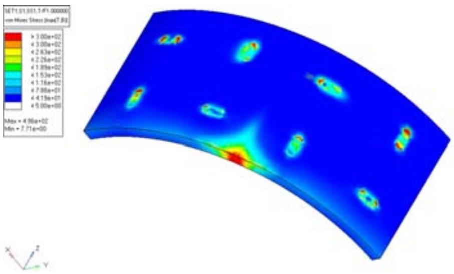
σ=0.1 mm	Thermal stress/MPa		
	Anchor	**Pipe**	**Castables**
U-type	1530	496	234
Y-type	2080	1100	374
Wave-type	2380	1290e	804



1st principle stress of refractory castables



Equivalent stress of anchors



von_mises stress of the pipe

Fig. 17. Thermal stress contour of burners with U-anchor.

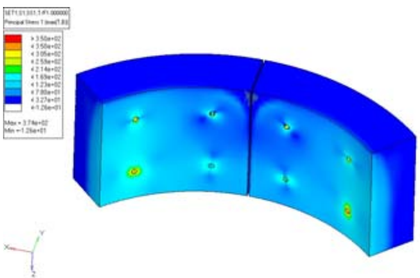


Fig. 18 (a). Thermal stress contour of burners with Y-anchor: 1st principle stress of refractory castables.

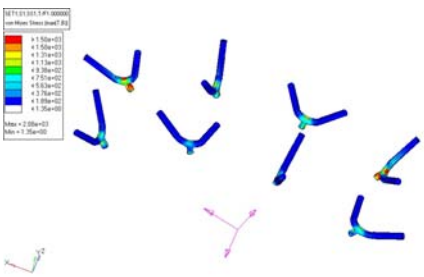


Fig. 18 (b). Thermal stress contour of burners with Y-anchor: equivalent stress of anchors.

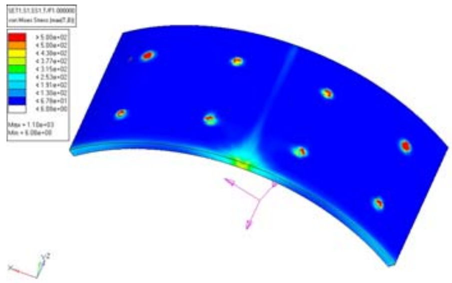
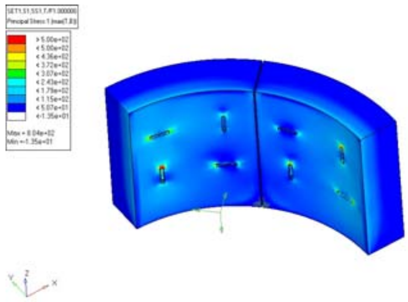
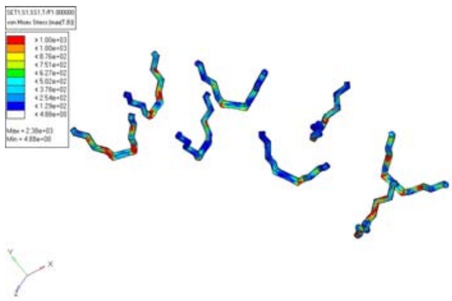


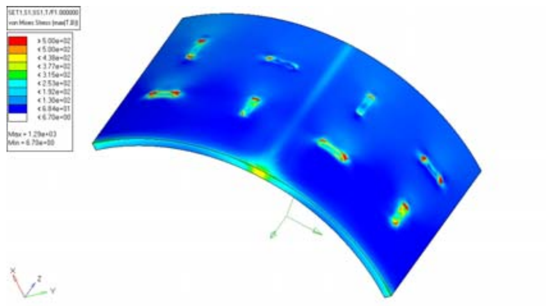
Fig. 18 (c). Thermal stress contour of burners with Y-anchor: von_mises stress of the pipe.



1st principle stress of refractory castables equivalent stress of anchors



Equivalent stress of anchors



Von_mises stress of the pipe

Fig. 19 Thermal stress contour of burners with Wave-anchor.

5. Conclusions

According to the results of the CAE simulation analysis:

1) We can see from the simulation results of temperature field distribution cloud charts that the

cement burner's castable, the anchoring part and the steel pipe of the burner all increased in ladder distribution from inside to outside. This result is primarily same as the temperature condition of every part in practice.

2) According to the displacement deformation cloud graphs, the outermost layer of the ends where the castable is close to has the biggest displacement deformation and the stress of the contact parts with the anchoring parts is relatively high. This kind of stress and deformation can eventually lead to a shed of the outer castable which near the ends. This simulation result basically tallies with the shed form of the burner's castable ends in practical engineering application.

3) According to the displacement deformation of the anchoring part and the distribution of the stress, there was a concentration of stress which can cause fraction even entirely drawn up of the anchoring parts in the root of the anchoring part. In comparison with the practical damage condition (Fig. 2, Fig. 4), the simulation analysis result tallies with the damage form in practice of the anchoring part.

4) Though Fig. 16, the stress in anchors is bigger than that in other parts, which means that the failure of anchors mainly causes the damage of the burner. So the different anchors have a great influence on the service life of the cement burner.

5) According to Fig 16, we can see that the highest temperature lies in the castables and the highest stress lies in the anchors. After the analysis of the thermal stress field of the three type cement burners, we can get a conclusion that the U-anchor cement burners performs best.

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