**JOURNAL OF MECHANICAL ENGINEERING,
MANUFACTURES, MATERIALS AND ENERGY**

Heat Transfer Simulation on the Wall of Rotary Cast Iron Smelting Furnace Capacity of 1 ton/hour

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Abstrak

Dapur peleburan putar adalah dapur peleburan besi cor dengan prinsip kerja bahan baku diputar dalam drum peleburan. Kesulitan yang dihadapi ialah apabila dinding dapur mengalami kerusakan akan sulit sekali menentukan koefisien konduksi yang tepat sebagai penggantinya. Untuk itu dibutuhkan analisis secara simulasi numerik dengan bantuan software Ansys untuk dapat memperdiksi suhu yang terjadi disepanajng dinding dapur. Analisa ini bertujuan untuk (1) mendapatkan distribusi suhu yang terjadi dengan menggunakan program ANSYS, dan (2) mendapatkan suhu pada permukaan dinding pada bagian dalam, tengah, dan permukaan dinding bagian luar. Secara teoritis analisa dapat ditentukan dengan menggunakan persamaan rambatan suhu secara konduksi. Kemudian simulasi numerik dengan bantuan software Ansys 9.0 pada kondisi beban thermal. Hasilnya diperoleh distribusi suhu yang dibutuhkan serta suhu yang terjadi pada permukaan dinding dalam, tengah, dan luar yang berturut-turut sebesar 1590 °C, 1470 °C, dan 110,4 °C.

Kata Kunci: Distribusi Suhu, Rotary Furnace, Simulasi Numerik

Abstract

The rotary smelting furnace is a cast iron smelting furnace with the working principle of raw material rotated in a melting drum. The difficulty of this type of furnace is if the furnace wall is damaged, it will be very difficult to determine the appropriate conduction coefficient material as a replacement material. Numerical simulations are required to obtain the heat transfer information that occurs on the furnace wall. This analysis aims to (1) obtain the temperature distribution occurring in the furnace wall, and (2) obtain the heat transfer coefficient on the wall surface on the inside, center, and outside of the melting furnace. Calculation of numerical simulation in this research is assisted by using Ansys software. The theoretical basis of numerical heat transfer simulation analysis can be determined by using the conduction temperature equation in each node. The load conditions in this case are assumed as thermal loads. The result obtained temperature distribution on the inner wall is 1590 °C, middle 1470 °C, and outside 1104 °C.

Keywords: Numerical Simulation, Rotary Furnace, Temperature Distribution

INTRODUCTON

Rotary Furnace is a cast iron melting furnace with rotating working principle. The fuel used is diesel oil with a working temperature up to 1500 °C and has a capacity of up to 1 ton/tapping. This furnace is generally used to melt gray iron castings Fe_3C (Liu, Li, Cheung, & Wu, 2016). The shape of equipment and size of this type of furnace are shown in Figures 1 and 2, respectively.

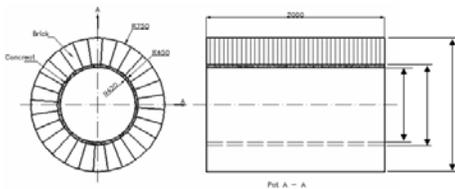Figure 1. Cast Iron Rotary Furnace

Figure 2. Cast Iron Rotary Furnace dimensions

The known variables are as follows: combustion chamber temperature 1500 ° C, diameter of combustion chamber 0.84 m, outer wall diameter 1.5 m, wall thickness 330 mm, and environmental temperature 38ºC. The wall of the furnace consists of walls with concrete cement material that has a thickness of 30 mm and walls with a fire brick material that has a thickness of 300 mm. The length of the walls is 2 m.

In the analysis will determine the amount of heat loss (heat loss) Q on each furnace wall (Lorbek, Poredoÿs, Kitanovski, & Poredoÿs, 2018). It is therefore necessary to analyze also the inner wall surface temperature (t_1), the wall layers 1 and 2 (t_2), and the surface temperature of the outer wall (t_3).

Theoretically the analysis can be determined by using the conduction temperature expression equation as shown in FIG. 3.
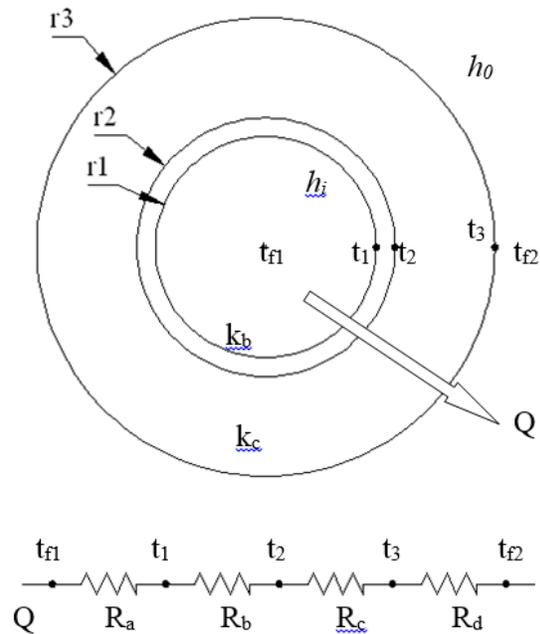

Figure 3. The analogy of electrical resistance to wall heat propagation

In this case each wall of the furnace is considered as an electrical resistance that serves as a slowing process of propagating the temperature from the inside to the outer surface of the kitchen wall (Kucukdogan, Aydin, & Sutcu, 2018).

The rate of heat loss is determined by using the equation (Nedin, Nesterov, & Vatulyan, 2016):

$$Q = \frac{tf1 - tf2}{R_r} \qquad \text{................} \quad (1)$$

Where: Q is the rate of heat loss, tf_1 is the temperature of the fluid in the kitchen, tf_2 is the surface temperature of the wall, and R_r is the total heat resistance. The total heat resistance due to convection is obtained by using the equation (Soleimanikutanaei, Ghasemisahebi, & Lin, 2018):

$$R_a = \frac{1}{h_1 A_1} \qquad \text{..........................} \quad (2)$$

Where h is a convection coefficient film and A is the surface area where heat is converted. The heat resistance due to conduction can be determined by using the equation (Han, Xu, & Wang, 2018):

$$Rb = \frac{\ln \dfrac{d_2}{d_1}}{2\pi L k_b} \qquad \text{..........................} \quad (3)$$

where d is the diameter of the layer, L is the length of the furnace, and k is the thermal conductivity.

The objectives of this study were (1) to obtain temperature distribution on the wall using numerical simulation assisted by ANSYS software, and (2) to obtain heat transfer coefficient on wall surface inside and outside of kitchen.

METODHOLOGY

The specifications of the tools and materials used in this study were obtained based on the certificate issued by the manufacturer. Specifications of such tools and materials are as follows:

Thermal conductivity Cement concrete (kb) of 1.0 W / m K, Thermal conductivity Fire Brick (kc) of 1.0 W / m K, Film Coefficient Gas in kitchen 10,000 W / m²K, and Air coefficient film 50 W / m²K .

The physical data of rotary furnace is as follows: the diameter of the furnace from the inside to the outside is d1 = 0.84 m, d2 = 0.9 m; d3 = 1.5 m, furnace length L = 2 m, ambient temperature tf2 = 38 °C, and working temperature tf1 = 1500 °C.

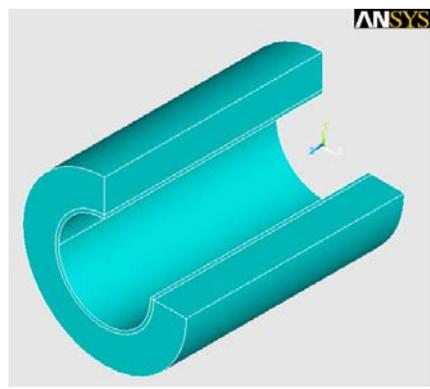Based on these data, modeling was made using Ansys software. The modeling form is shown in FIG. 4.

Figure 4. The shape of the kitchen wall modeling

The shape of the furnace model is further discretized into finite small parts called Mesh. The length of each mesh is 75 mm and the type of element suitable for this analysis is a triangular mesh type. The mesh shape set in the furnace model is shown in FIG. 5.
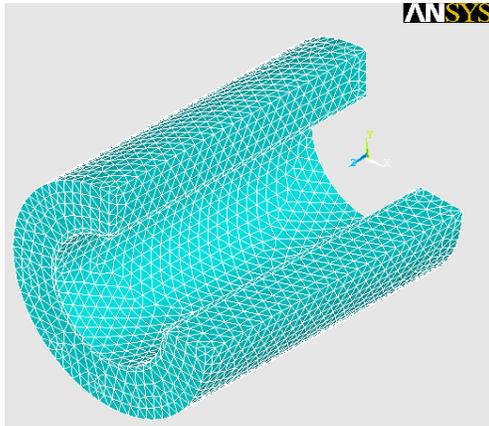
Figure 5. The shape and arrangement of mesh on the furnace model

In Ansys software, all external forces are assumed as loads. It also includes temperature, which is considered a load. The load given in the form of temperature coming from the inside of the furnace is 1500 °C. Also on the outside of the furnace wall there is a temperature environment in the form of convection heat transfer, which amounted to 37 °C. The temperature loads are then set on the model, as shown in FIG. 6.
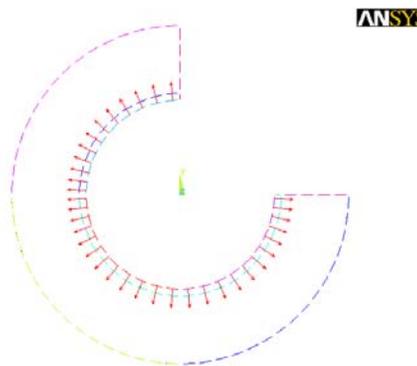

Figure 6. The setting of temperature loads on the furnace wall model

RESULT AND DISCUSSION

Theoretical calculation results are as follows:

Sectional area of each layer of kitchen wall:

$A_1 = \pi d_1 L = \pi \times 0,84 \times 2 = 5,275 \ m^2$

$A_2 = \pi d_2 L = \pi \times 0,9 \times 2 = 5,65 \ m^2$

$A_3 = \pi d_3 L = \pi \times 1,5 \times 2 = 9,42 \ m^2$

Heat resistance to each kitchen wall:

$$Ra = \frac{1}{h_1 A_1} = \frac{1}{(10.000 x 5,275)}$$

$$= 1,895 .10^{-5} \ K/W$$

$$Rb = \frac{\ln \frac{d_2}{d_1}}{2\pi L k_b} = \frac{\ln \frac{0,9}{0.84}}{2\pi.2..1} = \frac{0,069}{12,56}$$

$$= 0,0055 \ K/W$$

$$Rc = \frac{\ln \frac{d_3}{d_2}}{2\pi L kc} = \frac{\ln \frac{1,5}{0,9}}{2\pi.2..1} = \frac{0,51}{12,56}$$

$$= 0,0406 \ K/W$$

$$Rd = \frac{1}{h_0 A_3} = \frac{1}{(50 x 9,42)} = 0,0021 \ K/W$$

Total heat resistance of furnace wall is:

$$Rr = 0,00001895 + 0,0055 + 0,0406 + 0,0021 = 0,0482 \ K/W$$

The rate of heat loss in the furnace wall is:

$$Q = \frac{tf1 - tf2}{R_r} = \frac{\frac{1500 - 38}{0,0482}}{} = 30331,95 \ W = 30,33195 \ KW$$

Temperature on the surface of the furnace wall:

$$Q = \frac{t_3 - tf_2}{R_d}$$

$$30331,95 \ = \frac{t_3 - 38}{0,0021}$$

$$t_3 \ = 101.69 \ °C$$

In the same way, temperature is obtained on the inner wall surface of t_1 and the temperature at the outer and inner wall boundary of kitchen t_2, namely:

$$Q \ = \frac{tf1 - t1}{Ra}$$

$$30331,95 \ = \frac{1500 - t_1}{0,00001895}$$

$$t1 = 1499.4°C$$

$$Q \ = \frac{t_1 - t_2}{Rb}$$

$$30331,95 \ = \frac{1499.4 - t_2}{0.0055}$$

$$t_2 = 1332.5°C$$

The results of numerical simulation using Ansys software resulted in the form of temperature changes of each discretized element represented by certain colors. Each color represents a certain temperature, as shown in figure 7.
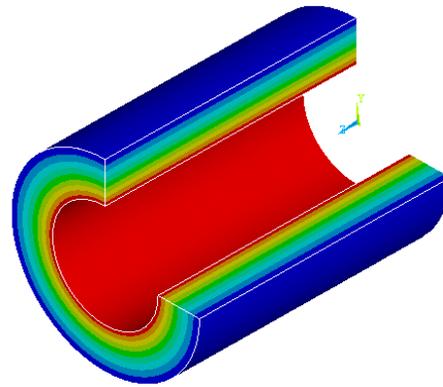

Figure 7. Results of numerical simulation using Ansys software

The highest temperature is the area with red color, which is 1499.98 °C. At the outermost surface area of the inner wall of the kitchen and the inner surface of the outer wall of the kitchen experience a decrease in temperature that is not too large. Based on simulation result temperature in this area about 1408.88 °C.

Significant temperature damping occurs on the second wall. On this wall the drastic temperature drop occurs from 1400 °C to 95 °C.

CONCLUSION

The amount of temperature distribution can be obtained by performing numerical simulations with the help of Ansys software. The magnitude of the temperature distribution along the furnace wall of the numerical simulation is shown in figure 7. Temperature distribution along the wall of the furnace theoretically on the inner wall surface of t_1 is 1499.4 °C, the middle wall is 1332.5 °C, and the outer wall 101.69 °C. The results of numerical simulation with Ansys software obtained temperature on inner wall of 1590 °C, middle wall 1470 °C, and outer 110,4 °C.

Direct measurement result using thermocouple tool obtained temperature for inner wall reach 1556 ℃ and outer 95,4 ℃.

ACKNOWLEDGMENTS

This research can be done in cooperation with PT. Sispra Jaya Logam, a foundry factory, located in Pekan Baru, Riau with Research Center of Numerical Simulation and Control System, Department of Mechanical Engineering, Univ. Medan Area.

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