

Fluid Finite Element Analysis for Hot-Air Valve Duct

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Abstract. Hot-air valve can be easily ineffective during the operation due to the bad influence of the eddy heat on the bottom outer-edge of the valve plate. COSMOSFlowworks software was used to analyze the flow field of DN1800 hot-air valve duct in a certain domestic company, by adopting the classical formula of heat transfer theory's convective recuperative system as reference. The analysis results showed that during the beginning opening of hot-air valve duct, the bottom outer-edge of valve plate receive the influence that the hot-air enforce convection heat exchanger, while during the late opening of hot-air valve duct, the bottom outer-edge of valve plate receive the influence of eddy heat exchange. Based on this analysis, the paper suggests the measures which bring down the temperature of outer-edge of valve plate.

Introduction

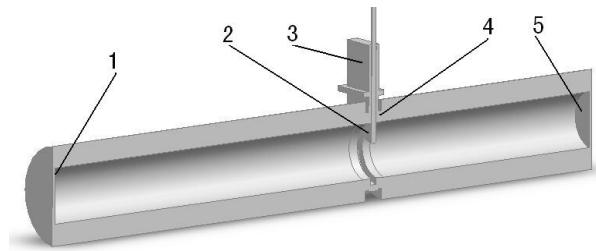
Hot-air valve is one of the various valves that are used in ironmaking hot-air furnace. It consists of valve plates, valve body and valve bonnet etc. Its working principle is that the valve plate moves up and down in the cavity of valve body and the movement completes opening and closing of hot air duct. The valve plate itself is a kind of gate valve.

Hot air valve works at the temperature between 900 ~ 1300 °C^[1], so it is one of valves that take the heat load most severely in the hot-air furnace^[2~3]. When the hot-air valve is in use, the bottom of the valve plate outside part is seriously exposed to the hot air wind. Because of thermal shock and thermal fatigue, the bottom of the valve plate outside part is usually cracked. When the situation is serious, the valve plate will leak water, causing the overall equipment fail^[4~5].

According to the situations mentioned above, the velocity field of hot air valve duct DN1800 is analyzed by using COSMOSFlowworks software. The heat exchange is analyzed by using classical formula of thermal transmission convection flow heat transfer coefficient in this paper. The purpose is to improve the hot-air valve outside plate heat transfer in order to improve the lifetime of the valve plate.

3D modeling and calculation space determination

3D modeling. By using solidworks software, valve plate, valve bonnet and valve body are constructed. In the process of construction, there are several simplifications for the parts where there are no connections with wind field. However, since valve plate has a very important influence on wind field simulation, so the authentic shape is constructed. Valve bonnet and body external structure has nothing to do with the wind field analysis, so they simplified when modeled. However the bonnet and body's internal cavity is maintained the same and at the same time, inlet and outlet are closed in order to form a wind-tight cavity (see chart 1). After modeling, restrictions are added and all the parts are assembled together.



1-outlet 2-valve plate 3-valve bonnet 4-valve body and duct 5-inlet

Fig. 1. Hot-air valve's duct sectional drawing

The calculation space determination. COSMOSFlowworks software geometry space check command is executed and the software will automatically calculate the cavity volume and the entity volume, if the cavity volume is zero, meaning the cavity is not closed, the model needs to be modified until the cavity is closed ^[1]. Closed cavity is named calculation space (see chart 1).

Construct COSMOSFlowworks analysis items and set boundary conditions

Hot air physical parameter settings depend on the analysis of the COSMOSFlowworks guidance.

COSMOSFlowworks analysis items setting. Enter COSMOSFlowworks analysis guidance and define the items below

- (1) Create analysis name,
- (2) Define unit, this paper uses mm-g-s system,
- (3) Define analysis type as internal flow, and ignore the cavitations effect,
- (4) Select fluid. The paper uses medium hot air and its specific property parameters such as the density, viscosity are obtained from references ^[6],
- (5) Set the surface conditions. Based on the relevant literature, the roughness, is identified as $R_a = 10\mu\text{m}$ ^[7], and the wall is adiabatic,
- (6) Determine the initial conditions. According to the actual working conditions, air valve determine initial pressure is 0.5 MPa, and initial temperature is 1373.2 K,
- (7) Set resolution for 10mm,
- (8) Complete settings.

Set Boundary conditions. According to the engineering practice, the boundary conditions of entry are speed boundary, set to 50000mm/s; Export of boundary conditions is pressure boundary conditions, set to 0.5 MPa.

Results and discussion

Heat transfer coefficient. When the duct opens, the valve plate lower part is swept by hot air and its surface heat transfer is forced into the flow turbulence flow heat. Based on formula ^[2] (1) the designing dimensions are calculated.

$$d_e = \frac{4f}{U} \quad (1)$$

where: d_e —equivalent diameter, m; f —duct sectional area, m^2 ; U —duct peripheral, m.

According to Renault criterion equation (2) Re is calculated as below and flow pattern, is judged.

$$Re = \frac{u_m d_e}{\gamma_f} \quad (2)$$

where: u_m —hot-air average fluid velocity on the section. m/s; γ_f —fluid movement viscosity, m^2/s .

When the valve plate is in the open state, the valve plate lower part surface was swept by hot air and some parts can approximately as flow along a flat plate by the hot air. According to spoil taken flat plate outside the turbulent average heat standard relational (3), the Nusselt number can be approximately calculate ^[2].

$$Nu_f = (0.037 Re_f^{0.8} - 870) Pr_f^{1/3} \quad (3)$$

where: Nu_f — hot air Nusselt number, Re_f — for hot air Reynolds number, Pr_f — hot air Prantel number .

According to formula (4) , forced convection heat transfer coefficient is calculated.

$$\alpha = Nu \frac{\lambda}{d} \quad (4)$$

where: α —convection heat transfer coefficient, $W/m^2 \cdot ^\circ C$, λ — hot air thermal conductivity coefficient, $W/m \cdot ^\circ C$, d — feature size, m.

From the formula (2) to (4), heat transfer coefficient with hot air sweeping speed is proportional to the 0.8 times power.

The results

Plate opening early stage (place and duct overlap period).For example, when the plate was lifted 671mm (see chart 2), simulation is run and COSMOSFlowworks software will automatically compartmentalize grids and get the computational results.

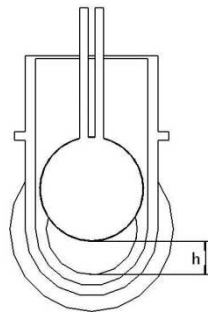


Fig. 2. Travel graph

Figure 3 shows the axial velocity distribution of the section. From Figure 3, The velocity of hot air is high when the valve is in the opening stage with the maximum speed 171.5 m/s. With the expansion of flow area, the hot air speed gradually decreases. Meanwhile the hot air has whirl in the back valve, forming the circulation of low speeds. Because the plate at the lower part has a high speed hot air coming, based on the formula (1) to (4), the valve plate lower part is attached by fiercely forced convective heat.

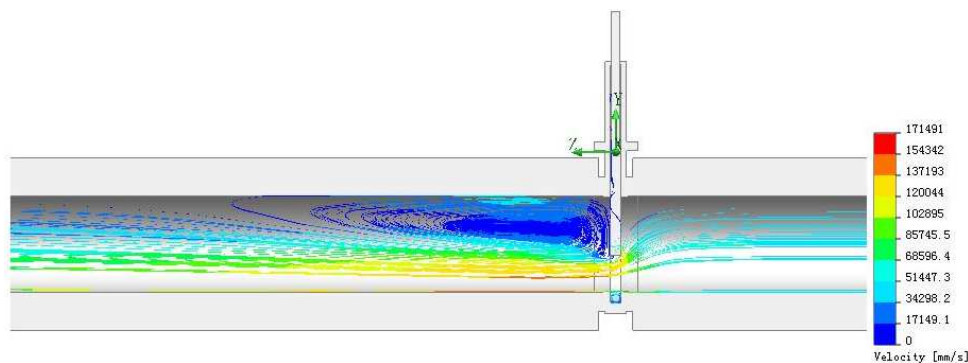


Fig. 3. Velocity of axial section scatter gram

The valve plate late open stage(plate ascending to the location above the duct).For example, when the plate reaches 1955mm (see chart 2), the simulation is run and the plate in section of the radial velocity distribution is shown as in figure 4. From figure 4, hot air velocity is 50m/s in the main duct. Meanwhile in the valve body and plate outside lower part, there is some eddy current and heat transfer. However because eddy current speed is low, heat transfer intensity is not big.

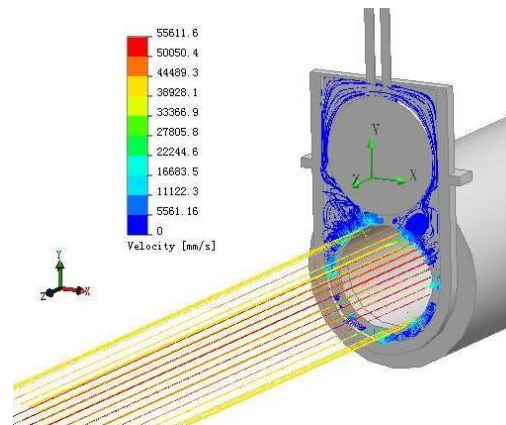


Fig. 4. Velocity of radial cross section scatter gram

To sum up, in order to improve the life of outside valve plate, the following suggestions are given:

- (1) In the process of opening the valve plate, it shall be done quickly. During the process, even though the hot air speed is high and there exists fierce convective heat transfer, the thermal inertia will help release the thermal load attacked as long as the lifting time is short enough, avoiding the burn-out of the valve plate outside lower part.
- (2) In the late stage of opening the valve plate, the plate shall be lifted to a certain height since the higher the plate is lifted, the smaller the convection density and strength. The heat exchange strength is getting smaller too. Therefore, the thermal load is decreased and the lifetime of the plate is enhanced.

Conclusion

The following conclusions are given by using COSMOSFlowworks software as tool, adopting the classical formula of heat transfer theory's convective recuperative system as reference, in order to improve the hot air valve life, focusing on a Heavy Engineering Machinery Corporation's DN1800 hot-air valve duct flow field analysis:

- (1) The valve plate shall be lifted as fast as possible before opening the valve plate by using the inertia of heat transfer to constrain the fast heat up of lower part of valve plate.
- (2) After the valve plate is opened, the valve plate shall be in a certain height in order to decrease the convection heat transfer strength, resulting in the decrease of heat load from lower part of outside valve plate.

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