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THERMAL EQUILIBRIUM ANALYSIS OF HEAVY OIL BOX-TYPE SUBSTATION

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ABSTRACT

In order to further improve the operating efficiency of the heavy oil box-type substation and reduce the construction cost, through the combination of theoretical analysis and simulation calculation method, this paper established mathematical and physical model of box-type substation outflow field, with a box-type substation as the research object.this work numerically simulated thermal equilibrium distribution under different parameters of box-type substation under two kinds of environmental, respectively getting temperature field distribution of the box-type substation under the calm and natural ventilation environment, obtaining by comparative analysis the influence of calm and natural ventilation environment on temperature field distribution.

Keywords: Box-type substation, Thermal equilibrium, Numerical simulation.

1. INTRODUCTION

At present, benefiting from its easy transportation, low cost, waterproof, dust proof and noise proof etc., the industry is rapidly expanding in these years [1]. The box-type diesel generator set is becoming more and more popular to customers, especially in some countries which have rich oil. The number of small power station is increasing, improving the speed of building and reducing the cost will become the key [2]. But the unit power of most power station is below 1000kW, the price is expensive, to set up a considerable size of the power plant, it needs a large number of units, so that the purchase costs rise and the use of maintenance engineering is huge, it does not adapt to the growing demand for electricity in the region. And to adopt a large unit, the diesel generator set, the installation, quick transport, the overall layout become the design difficulties [3]

In order to further improve the operating efficiency of the box-type substation and reduce the construction cost, this paper establishes the model of the overall layout of the box-type power plant. According to the input conditions (the size of the container unit, the heat, the local wind speed and the calculation of the surrounding area), the influence of the thermal equilibrium is given. And comparing the different characteristics of the two kinds of environment, it provides an important theoretical basis for the further optimization of the general layout of the box type power plant.

2. PHYSICAL MODEL

The model in this paper is four sets of units of a heavy oil box-type substation, a diesel engine placement, a generator and an air-cooled radiator is placed in each container. A transformer is placed at one end of each container, each of the two transformer units in a container, and a container control box for the placement of the emergency generator, a high-voltage cabinet for power transmission. At the other end of the generator, the tank is equipped with a sewage tank and a heavy oil tank. At present, the layout of the unit is spaced in the same distribution by line, set aside the maintenance channel, the electrical control equipment and oil tank area present concentration distribution. Field layout is shown as figure 1.

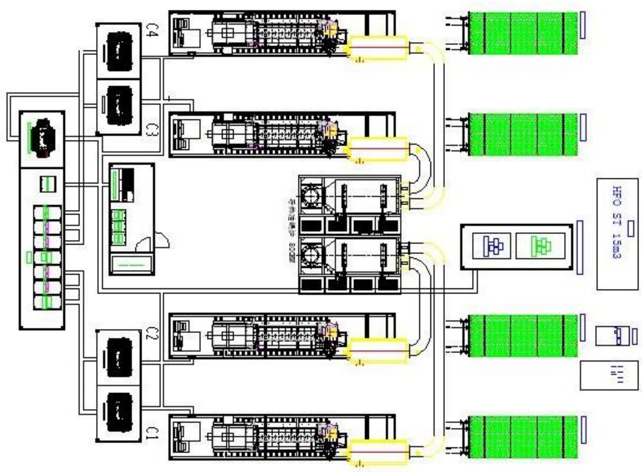


Figure 1. Distribution of box-type power station

For the box type power station, the flow field heat balance problem belongs to natural convection, in the atmosphere of the box type power station, the surface of heat transfer through natural convection in the form of heat exchange, and transfer through air to the outside environment. Convection heat transfer is one of the basic ways of heat transfer, and its physical mechanism is usually considered to be a heat transfer problem in fluid motion. As the fluid movement can carry the heat, the heat transfer capability of the convective heat transfer is much stronger than that of the pure heat conduction.

In the study of the thermal equilibrium of the box type power station, the realistic environment is a complicated system, and the temperature distribution and the distribution of the air flow need to be approximated and generalized in the real world. The real world should be transformed into a physical model, then it is abstracted as a mathematical model, and then it can be analyzed by means of computer technology.

In order to facilitate numerical calculation, the following assumptions are made as follow: the heat transfer coefficient is calculated by the fixed heat transfer coefficient. The surface temperature of air cooling radiator, the transformer box, the control box and the high pressure cabinet is lower, and the calculation unit only be selected as four generator container and the outer space. Because of the uniform temperature distribution in the peripheral space, the surrounding environment of the generator container is selected, and the wall is the temperature boundary condition.

3. MATHEMATICAL MODEL

3.1 Theory

Based on the spatial discretization method and the basic equation of heat transfer, the heat transfer is an effective method for the complex boundary conditions and complex geometries. The numerical simulation of the fluid dynamics software STAR-CCM+ is carried out.Numerical calculations are used in the three basic equations of fluid mechanics,as follow:

Continuity equation:

$$\frac{\partial \rho}{\partial \mathrm{t}} + \rho \nabla \mathrm{gVr} = 0 \tag{1}$$

Navier-Stokes equation：

$$\frac{\mathrm{DV}}{\partial \mathrm{t}} = f - \frac{1}{\rho}(\mu' + \frac{1}{3}\mu)\nabla(\nabla \bullet V) + \frac{1}{\rho}\mu\nabla^2 V \tag{2}$$

Energy equation：

$$\frac{\mathrm{De}}{\partial \mathrm{t}} = -\mathrm{P}\frac{\mathrm{D}}{\mathrm{Dt}}\left(\frac{1}{\rho}\right) + \varphi + \frac{1}{\rho}\frac{\partial}{\partial \mathrm{x_i}}\left(\lambda \frac{\partial \mathrm{T}}{\partial \mathrm{x_i}}\right) + \mathrm{q_R} \tag{3}$$

Based on Boussinesq hypothesis, the following two points are presented:

①Beside the difference of the density of the fluid flow, the other parameters in the differential equation of the convection heat transfer are set as constant;

②For air, when the speed is less than one-third of sound velocity, it can be considered as incompressible fluid, the fluid density difference and is proportional to temperature difference. Therefore, the flow field of the box type power station belongs to the incompressible fluid flow around the blunt body and the flow length is large, which belongs to the problem of turbulent flow.

3.2 Mesh model

The body mesh is generated by STAR-CCM+ Trimmer mesh. The two layer boundary layer is generated on the surface of the power plant. The local mesh is encrypted, and the number of the grid is about 310000, as shown in Figure 2.

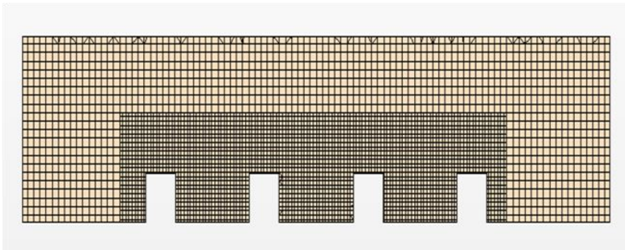


Figure 2. Mesh model

3.3 Boundary conditions

The numerical simulation of the flow field of the box-type substation is carried out in the area of the limited air flow field around the generator set. Therefore, it is necessary to set the boundary conditions of the four generators (the bottom surface of the container) to be the temperature wall, T=293K. air temperature Within the catchment is 318k, the bottom surface of the power plant design for insulation wall, the calm environment ,which is box type power extreme working conditions ,should be taken into consideration, and should be given a minimum security according to the condition, so firstly, thermal field distribution of box type electric station under the condition without wind speed should be simulated, and the other five wall of power plant are set for the wall temperature and T=273K, as shown in Figure 3.

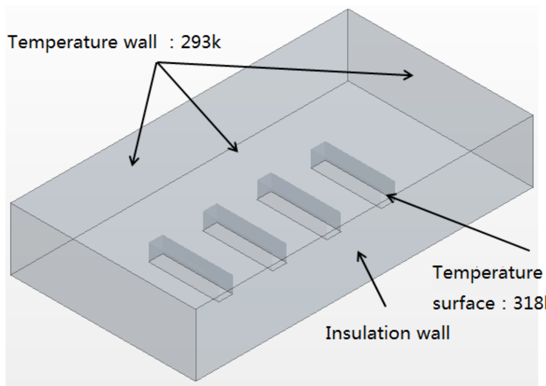


Figure 3. Boundary condition under calm condition

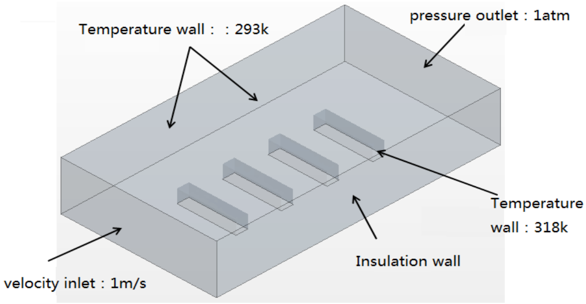


Figure 4. Boundary condition under natural ventilation

In the actual situation, the working environment of the box type power station is natural ventilation, but the wind direction is not static, so the selection is the most unsatisfactory situation in natural ventilation, that natural wind is perpendicular to the generator container large section. In the establishment of the model, the left and right sides in the power plant should be added speed inlet and pressure outlet conditions. As shown in Figure 4, it is used to simulate the effect of natural wind on the heat dissipation.

4. RESULTS ANALYSIS

4.1 Temperature distribution in calm condition

Figure 5 is the temperature distribution in the main view of the flow field unit under different distances in calm condition. The graph says the temperature of the container is obviously decreased with the increase of L.

How to determine the distance between the optimal box and the temperature distribution more reasonable should need a standard, so the introduction of the basis points to the quantitative is used to analysis of the temperature between the containers, as shown in figure 6. The average value of the temperature at the six points, the reference point ①, ②, ③(X ,Y the middle of the containers, Z the distance from the ground is 2 meter) was collected. The change curve of the temperature of the reference point with the distance between the containers is shown in Figure 7.

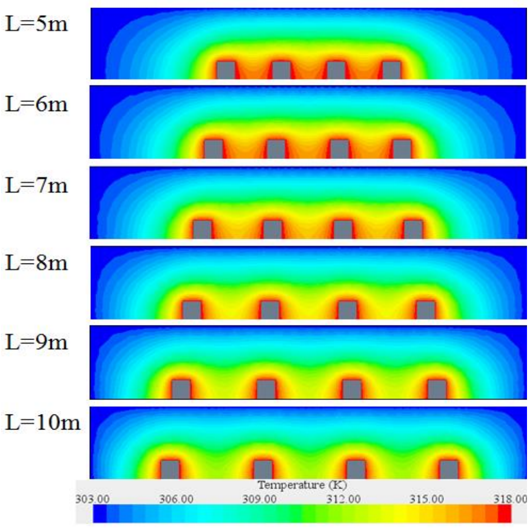


Figure 5. Temperature distribution of different space units in the outflow field

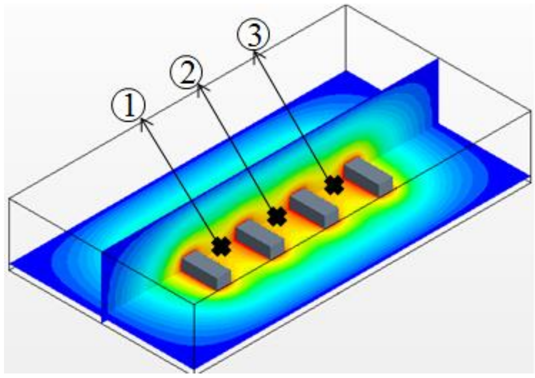


Figure 6. Reference point set

From Figure 7, it can be seen that the temperature at the reference point increases with the distance between the containers. The trend is more pronounced after the distance is more than 7m. In the case of the installation site, the spacing distance (>7m) of the container should be increased as far as possible.

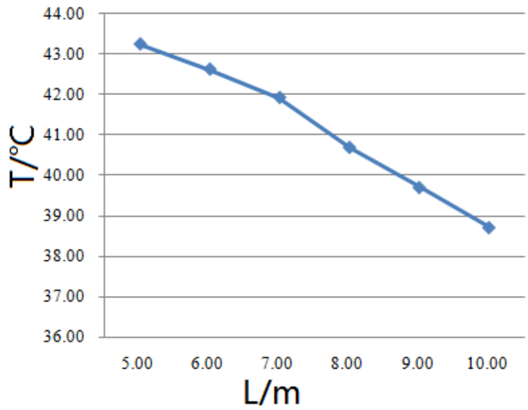


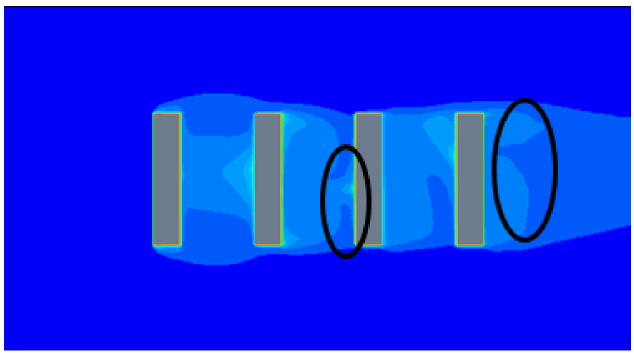
Figure 7. Temperature variation curve of reference point

4.2 Temperature distribution under natural ventilation

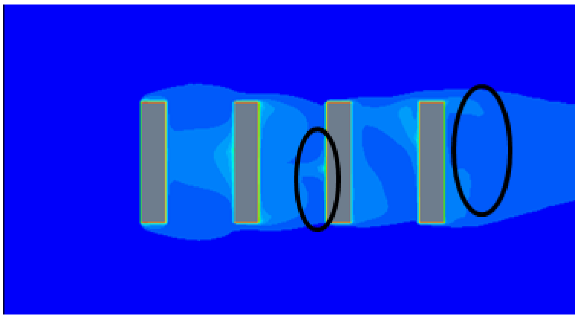
Figure 8 is temperature distribution of the outer flow field of the container group under different wind speeds under the condition of natural ventilation.

By the graph, the temperature of the container group decreases slightly with the increase of wind speed, but the high temperature area of the container group still exists.

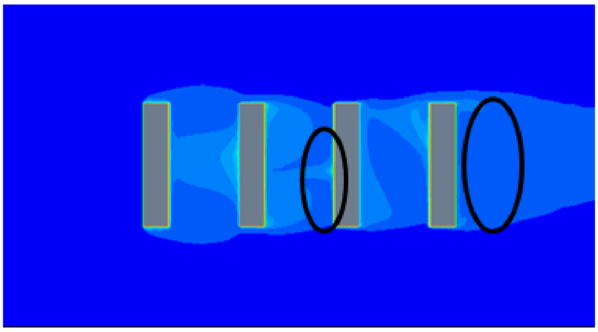
In summary, the influence of the wind speed on the temperature of the container outflow can be neglected in other conditions.



V=1m/s



V=2m/s



V=3m/s

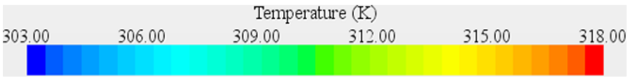


Figure 8. Temperature distribution of the outer flow field of the container group under the condition of natural ventilation

6. CONCLUSIONS

Numerical simulation is conducted quickly and effectively, for a heavy oil box power station flow field, which gets the influence of various factors on the temperature field under the calm and natural ventilation environment and provides sufficient theoretical basis for the further optimization of the overall layout of the box power station. The conclusions are as follows:

1) Under windless condition, the temperature between the container decreases with the increase of the spacing, and when the distance is greater than a certain value, the trend of the decrease in temperature is more obvious, so in the allowed installation site, the interval distance between the container is greater than the value as far as possible.

2) Under natural ventilation, with the increase of the wind velocity the change of the temperature of the container flow field is small, and there is still a high temperature area in the container. So we can ignore the influence of wind speed on the temperature of the container outflow, in particular, we need pay attention to the high temperature area in the presence of natural ventilation.

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