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# Study of Three-Dimensional Temperature Field with Changed Structures of Air-Cooled Turbo Generator Stator

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### *Abstract*

*Aimed to ventilation system of large air-cooled turbine generator, using the principle of CFD and following characteristics of the stator cooling system, mathematical and physical models of three-dimensional flow and heat ventilation systems built, and two schemes proposed. One was only changing the thickness of the iron core lamination with stableness total effective length of the core, total ventilating ducts, and every duct constant axial length, the other was changing the number of ducts with stableness total effective length of the core. Corresponding basic assumptions and boundary conditions selected, fluid field and temperature field coupled solutions solved, flow field and temperature field of the original and variation structure and the spatial distribution characteristics of each part of the motor analyzed, as well the performance of the stator under different structure was compared. More effectively Structure selected.*

***Keywords:*** *air-cooled turbo generator; stator; temperature field; ventilation scheme*

## 1. Introduction

Large air-cooled turbo generator temperature is an important parameter when the generator is running, the temperature distribution of the generator should be calculated accurately, especially the highest temperature distribution when the generator is running. It is not only a criterion of selection of the generator material, but also reflects the operating life of large turbine [1, 2]. The fundamental task of the generator cooling is dissipating the heat loss inside the generator. With the increase of turbo generator capacity, high efficient and reliable cooling technology is particularly important, a new calculation method of the cooling system, the three-dimensional CFD (computational fluid grid system) developed [3, 4]. With the computer's capacity getting larger, local cooling gas flow state of the generator analyzed and calculated, more detailed gas flow characteristics and the distribution of temperature field have gotten. Using CFD numerical method, more detailed and accurate reference for the turbine generator ventilation cooling system provided, calculated and analyzed [5-7].

A 350MW turbo generator is as an example in this paper, multiple air ducts are used as the ventilation mode, computational fluid dynamics theory is used as the basis, coupling field calculation model of the original and variable structure of the turbo generator stator is established [8]. The appropriate boundary condition selected the coupling field of fluid flow and heat transfer of the stator radial ventilation ditches calculated and analyzed by using the fluent software. Compared and calculated the results of multi-scheme by using

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the finite volume method, it can be the evidence for optimizing the structure of the generator theoretically.

## 2. Physical Model

According to the characteristics of the structure of air cooling turbo generator, a groove and two half gears are chosen in circumferential direction, both two sides which are vertical circular are adiabatic surfaces, half of the core ontology that is symmetry distribution in two sides is chosen in axial, the cross section of the center is the adiabatic surfaces, just shown as in Figure 1. There are three routes that fluid flows into the generator, the first route is that fluid flows into the rotor and flows into the air gaps after cooling the rotor; the second route is that fluid flows into the generator from the air gaps; the third route is that fluid flows into the stator core from the cold wind zones. Fluid that is used to cool the generator and flows into the air gaps and the rotor converge in the air gaps, flow through each ventilation ditch, and flow away from the hot wind zone outlet.

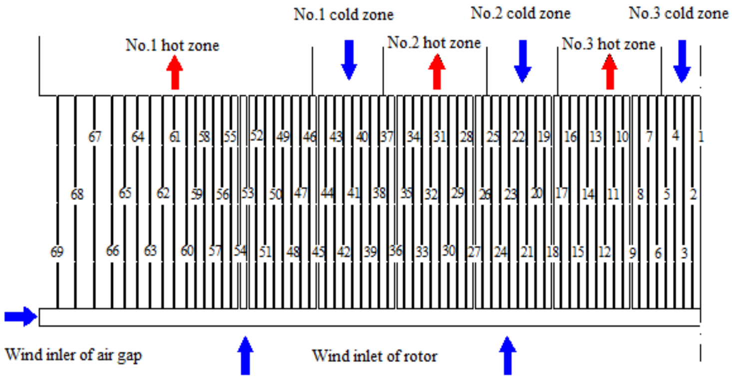



**Figure 1. The Original Model and Pattern Number of the Original Stator Structure**

No. 1 hot zone in this model has 24 period of iron core lamination, those near the end is thick and have large heat capacity, the middle of the hot zone is the motor's hottest part, but the ventilation condition is the same situation with the other thinner stack segment, so the temperature in this part of the core and winding is the highest. The air duct structure of NO.1 hot zone needs to be changed.

One structure is to keep the total effective length and ventilation channel numbers, the thickness of the iron core lamination is changed. Except the three core lamination closed to the end, the rest length of the core in NO.1 hot zone is divided into 21 segments equally, keeping other structures unchanged. The structure is shown in Figure 2.

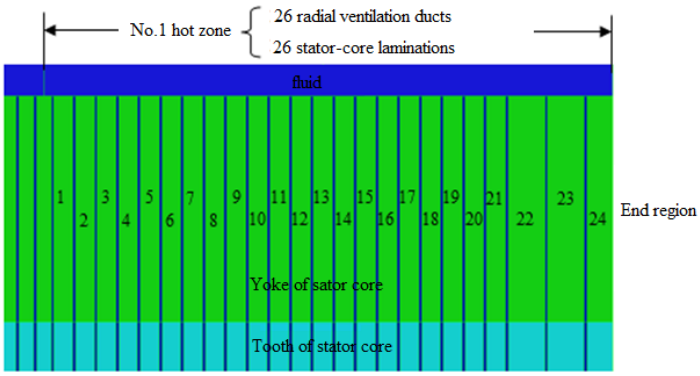



**Figure 2. 24 Ventilation Groove Models of No.1 Hot Air Zone in Scheme 1**

The other structure is to keep the core length unchanged, the number of the wind gap is added from 24 to 26, the first three segments of lamination length are maintained, 11 to 26 core lamination length is the same as the actual model, only the 4 to10 thicker section in the middle of the iron core is divided into 9 portions equally.

## 3. Boundary Conditions

(1) The boundary conditions of three hot zones in solving domain are the pressure outlet boundary and the pressure is one standard atmosphere;

(2) The flow inlet boundary conditions are given to Inlet1、Inlet2、Inlet3(stands for No. 1、No. 2 and No. 3 entrance of the cold fetch)、air gap and rotor inlet entrance, the fluid temperature of the cold fetch and air gap is 48 ℃,the rotor flow entrance is 75℃;

(3) The loss of heat source density is considered with average distribution;

(4) The axial center sides of the core segments, the axial end faces of the wire rod, yoke center of symmetry sides, teeth center of symmetry sides are all adiabatic surfaces;

(5) All surfaces in contact with the fluid solution domain are radiating surfaces, including the side surfaces of the ventilation groove winding insulation, the up and down winding insulation surfaces, the iron core inside surface of the ventilating ducts, the air gap surfaces of the iron core and the back yoke surfaces of the core.

## 4. Result and Analysis

Some results are gotten from the velocity profile: minimum fluid flow velocity of the cold wind zones appears in the yoke, minimum fluid flow velocity of hot wind zone 1 appears in the yoke is more possible, minimum fluid flow velocity of hot wind zone 1 appears in the top of the teeth is less possible, and minimum fluid flow velocity of hot wind zone 2 and 3 appear in the top of the teeth. The numerical solution is used to solve the coupling field on the basis of fluid flow field calculation results and the temperature distribution of the stator three-dimensional temperature filed is gotten and shown in Figure 3. the temperature of the stator end is the highest, the temperature of the iron core yoke in three cold wind zones is the lowest, the temperature of the teeth tip in hot wind zones is bigger than other parts of the hot wind zones, the temperature from a stator end to another stator end through the axial direction increases gradually and the range of high temperature is increased gradually along the radial direction.

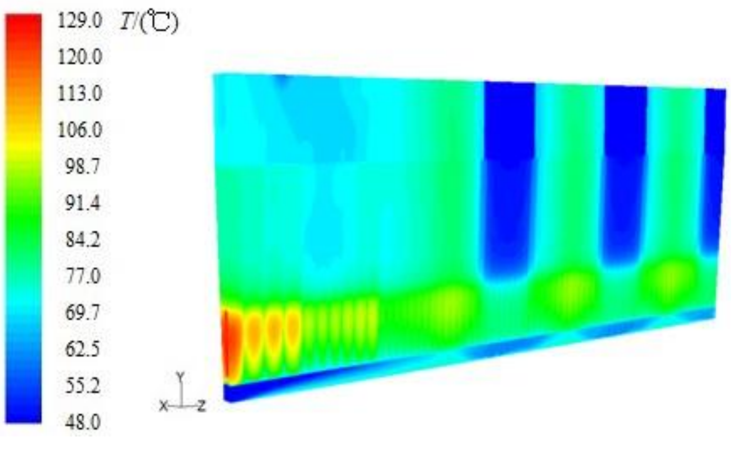
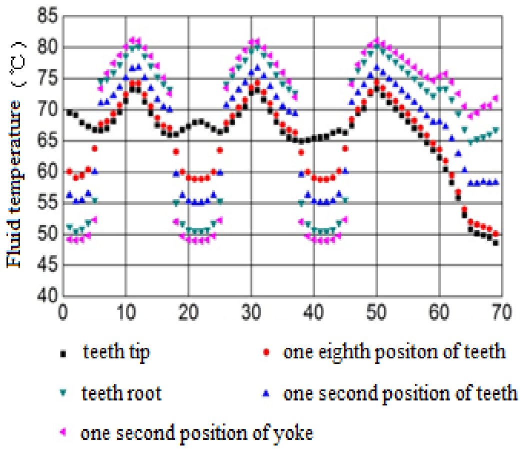
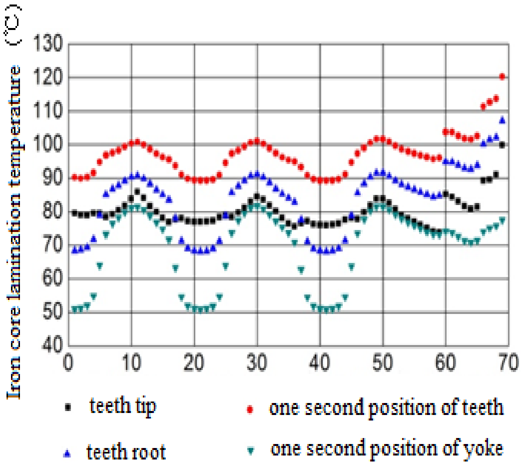



**Figure 3. Solving Domain Temperature Profile of Coupled Field**

The fluid temperature of five positions in the radial ventilation ditches of the stator is shown in Figure 4(a); the temperature distribution of the ventilation ditches is gotten from the temperature distribution curves. Minimum fluid temperature of the cold wind zone 1, 2 and 3 appears in the yoke, which is 48.9℃ in the No. 42, 22 and 2 ventilation ditch separately; maximum fluid temperature appears in the teeth tip, which is 66.6℃ in the No. 44 ventilation ditch, 68℃ in the No. 22 ventilation ditch, 69.5 ℃ in the No.1 ventilation ditch separately.




**(a) Fluid temperature** **(b) Iron core lamination temperature**

**Figure 4. Temperature Distribution in Different Position of Duct and Stator**

The temperature distribution of each position of the iron core in the stator is shown in the Figure 4(b). Maximum temperature appears in the middle of the iron core teeth and minimum temperature appears in the middle of the yoke; the temperature fluctuation of four positions which are near the teeth tip of the iron core in the stator end, one second position of the iron core, the teeth root and one second position of the yoke is bigger because the thickness of the iron core Laminations is thicker. As each position of the teeth tip in the ventilation ditches is at the stroke end of the cold wind zones, the temperature is higher than other positions, except at the stator end. Cold air goes through the yoke of the iron core firstly and the yoke is at the stroke end of the hot wind zones, the cooling effect is better, so the temperature of the yoke is the lowest; the temperature of the teeth tip and root is between maximum temperature of the teeth tip and minimum temperature of the yoke.

The temperature distribution in the stator core gear center is given in Figure 5. In structure one, changing the stator core lamination thickness, near the end of the iron core lamination are the thickest, heat along with the cooling medium in the process of flow is limited, the cooling effect is not obvious, and so the highest temperature is in the No. 1 hot zone, the center position in the temperature of 116 ℃. The highest temperature of hot zone 2 and 3 is located in the middle of the stator core location of No. 30 and 11 core lamination teeth, temperature of 96 ℃ and 97 ℃ respectively, and the rest of the iron core lamination temperature decreases from middle to both sides. In the other structure, that the wind duct number was increased, iron core lamination thickness was changed two times in hot zone 1 , temperature variation in the center of the tooth of the iron core lamination have taken place obviously. The first section iron core lamination that is near the end of hot zone 1 has the highest temperature-118 ℃. The high temperature area is the same in hot zone 2 and 3, as only changing the structure of iron core lamination, the highest temperature change is not large, and far below the critical value of safe operation.

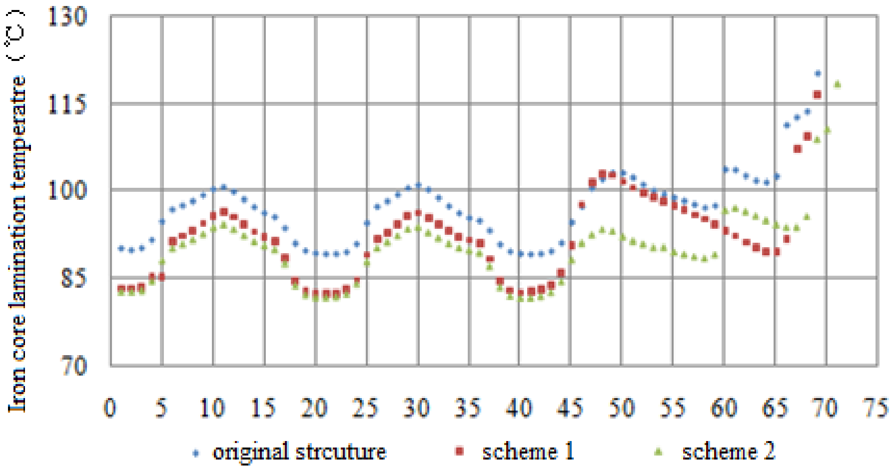



**Figure 5. Temperature Profile of Teeth at the Center of the Core Lamination**

Through the longitudinal analysis of the chart, it can be concluded that the structure which has been increased the number of wind duct relatively has uniform temperature distribution by comparing three kinds of structure. The temperature distribution uniformity whose structure is only changed by the thickness of the iron core lamination is better than the previous two structures, the No. 1 wind zone temperature which exists in the highest temperature zone reduces partly compared to the original structure or only changed by the thickness of the iron core lamination structure.

Engineering calculation method called Flow master is used to calculate the flow field, the temperature field of original structure of the stator was tested by the motor factory, the maximum temperature of the stator with engineering calculation was obtained that is 110 ℃. Although the temperature of the stator can't be measured before running test by multiple factors, according to the operation of the steam turbine generator, the result of experimental calculation method is proved to be safe and reliable. The maximum temperature of 110 ℃ was gotten by using Flow master engineering calculation method, and the value 120 ℃ was simulated by the Fluent software. Obviously, the simulation results of changing structure with the two schemes are compared to the original structure, in which the temperature is dropped. The flow field and temperature field distribution trend is accord with the facts. So the numerical simulation method is reliable.

## 5. Conclusions

The conclusions are gotten by large air-cooled turbo generator fluid flow field and temperature field coupling calculation, which are fluid minimum temperature of the cold air zones appears in the yoke and the value is 48.9℃, maximum temperature appears in the teeth tip and the value is 69.5℃; fluid maximum temperature of the hot air zones appears in the yoke and the value is 81.1℃, minimum temperature appears in the teeth tip and the value is 48.6℃. The temperature distribution trends of the solid part of the stator can be estimated roughly. According to the results of the simulation calculating, maximum temperature of the iron core of the stator is 118.2℃, the position of maximum temperature is at the center of the teeth in the end of the stator, the temperature of other positions of the iron core do not float greatly. Maximum temperature of the copper winding bars in the stator is 129.4℃, the position of maximum temperature is at the teeth tip of the upper winding bar and near the insulating interlayer. Variable structure fluid velocity increased significantly compared to the original structure, velocity of the fluid in the scheme is greater than the velocity of the fluid in scheme 2. In the analysis of stator core lamination temperature, structure of scheme 1 has great influence on the iron core at the position of the highest temperature; the effect was particularly marked in scheme 1. Although the temperature of laminated core decreased, the cooling effect of the end is not as well as scheme 1. Compared the ventilation cooling effect of the overall structure scheme, scheme 1 will be better.

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