USING OF NUMERICAL METHODS TO SIMULATE THE COOLING OF ELECTRIC MACHINES

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Abstract - This project deals with the air cooling of electric machines, is focused on synchronous generators with salient poles. For correct the thermal analysis by these machines it is important to determinate the air conditions inside the machine. These ratios were determined by using ANSYS, that it is based on the finite element method. Main of this project is to investigate the distribution of coolant to the stator radial channels, which provides better cooling of the windings of the machine and dependence passing through the media to position rotor. Results obtained in this project can be used for the design of electric machines with salient poles.

Keywords: Dissipation factor, mesh, finite element method, Ansys, element, nodes.

1. INTRODUCTION

Turbulent models

The solution of CFD problems is important to realize that in the flow model will be. Whether it will be mostly laminar flow, mostly turbulent, or will be located in a transitional zone between laminar and turbulent. Based on these findings we have to appropriately set the simulation environment, since the solution of CFD problems there are several computational turbulence models. Which include the k-epsilon (2 equations model), the omega (2 equations model), the transition of SST (4 equations model), the transition to a KL-omega (3 equations model).

Depending on the speed of air passing through different parts of the machine, changing the value of the Reynolds number according in

$$\mathrm{Re} = \frac{v \cdot D}{\upsilon} \ , \tag{1}$$

where v … velocity of air [m/s]

      D … diameter of channel [m]

      υ … kinematic viscosity [m^2/s]

The transition between laminar and turbulent flow depends on Reynolds value, when the value of Re = 2000. This value was found in smooth circular channels. For electric machines, this threshold may vary, because it depends on the prevailing influence of turbulence affecting whether turbulence reduces or supports. Given this situation, the transition area expands to an area of the range of Re = 1800 ÷ 4000, also known as a transient field. The strong supporting effects of turbulence, turbulence can occur even at Re = 1000 or less (for electrical machines it happens very often). In this transition area mainly depends on the frequency and distribution of inequality, therefore, depends on the whole nature of wall roughness. It depends on the field, where the flow is, as the coefficients of friction, depends on Reynolds value. Only in the turbulent field are constant coefficients of friction.

2. PRACTICAL PART

Change in the quantity of air and its influence on the distribution media into the radial channels of the stator

To find the dependency created four simulations with different settings of input air mass flow rate.

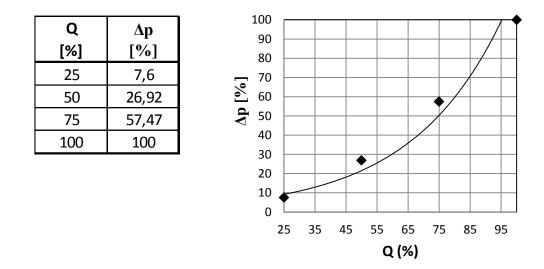| Q [%]	Δp [%]
25	7,6
50	26,92
75	57,47
100	100

Figure 1: The percentage difference between the pressure dependence of input and output volume and flow resistance characteristics given by the machine.

Calculations the ventilation is very important idea, how and in what proportion coolant through the various parts of the machine. The use of numerical methods is one possibility to resolve the issue of distribution of coolant in the machine. It is important not only for cooling but also for the machine design. The cooling medium can prepare the way for those sources of heat that needs cooling.

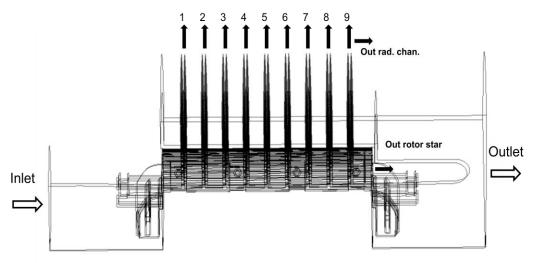Figure 2 is implied by the procedure of plotting the results of simulations, and for Q = 25%, 50%, 75%, 100% of Q_{max}.

Figure 2: Topological diagram of the tables with results [3]

Q$_{in}$=25%		Q$_{in}$=50%		Q$_{in}$=75%		Q$_{in}$=100%	
Number of radial channel	Q$_{rad\_chan1/4}$ (%)	Number of radial channel	Q$_{rad\_chan1/4}$ (%)	Number of radial channel	Q$_{rad\_chan1/4}$ (%)	Number of radial channel	Q$_{rad\_chan1/4}$ (%)
1	11,89	1	10,39	1	9,07	1	8,48
2	11,44	2	10,31	2	8,93	2	8,32
3	9,92	3	9,97	3	9,69	3	9
4	8,23	4	9,1	4	8,81	4	8,73
5	9,43	5	8,75	5	8,44	5	8,92
6	8,85	6	8,8	6	8,57	6	9,14
7	8,16	7	8,6	7	8,89	7	9,04
8	9,37	8	9,26	8	9,56	8	9,23
9	7,31	9	8,28	9	9,14	9	9,34
Out of rad. chan.	84,87	Out of rad. chan.	83,47	Out of rad. chan.	81,1	Out of rad. chan.	80,19
Out of rotor star	15,13	Out of rotor star	16,53	Out of rotor star	18,9	Out of rotor star	19,81
Q$_{in25\%}$ (%)	100	Q$_{in50\%}$(%)	100	Q$_{in75\%}$(%)	100	Q$_{in100\%}$(%)	100

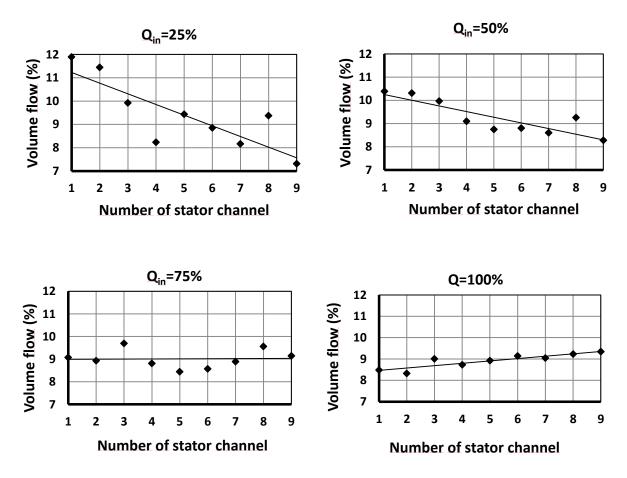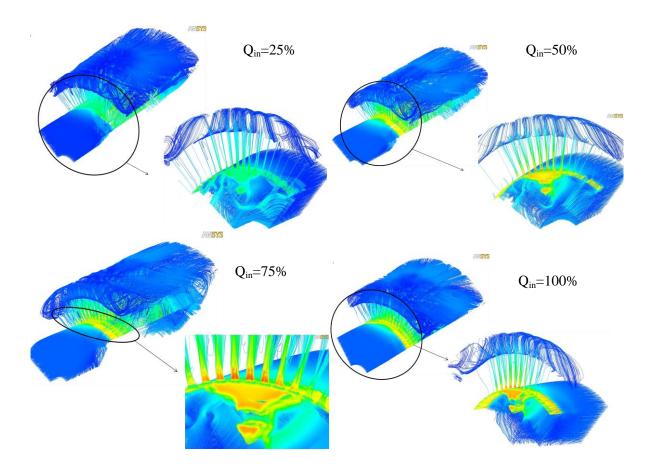Figure 3: table with flow results in individual radial channels

Figure 4 - graphs with flow results in individual radial channels

Colours indicate different streamline of air velocity in that part of the model. This is a model of synchronous machine with salient poles. For more accurate calculation was made symmetric simulation of the machine, and ¼. In simulating the symmetric part of the whole, these units can be divided into as many elements as the overall model, which can refine mesh of up to 75%. For example in solid model will be 2 000000 elements and the same value can be used by ¼ part of electric machine, refinement of results will be achieved by this step.

3. GRAPHICAL REPRESENTATION OF RESULTS

Figure 5: Graphical representation of the layout and detail of the nozzle inlet air to the rotor and then by 1 radial channel for Q = 25% [3]

4. CONCLUSION

In today's world of modern computers, is increasingly used by the possibility of replacing expensive production of prototypes of different devices, using numerical methods to calculate the physical properties and verify the functionality of the simulated model. Ansys is one of the software that can be used for these simulations. Simulations were performed for four different input volume air flow and the results were first developed resistance characteristics of the machine and plotted the distribution of characteristics of air into the stator of radial channels. If we evaluate the effect of inlet air speed of the machine for the distribution of each channel, we come to the conclusion that slow the entry of air into the machine is closer to bringing the channel to enter the machine compared to more distant. The increase in the amount of air entering the machine is due to the increase of velocity of the progressive application of remote channels. When Q = 75% of the maximum amount of air tested, there was a partial amount of medium volume compared to the radial inlet channels, which is important in terms of cooling the machine, one side does not heat up more than the other.

 For synchronous machines with salient poles and unilateral ventilation, is used to partition the end of the rotor, the cooling medium to resist, because the coolant passes through the path of least resistance, so if the output of the rotor has less resistance to the radial canals, there would be effective cooling stator windings. The results show that, through an air gap that does not fill seal, flow around the rotor of approximately 15-20% of the total air entering to the machine.

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