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THE PROBLEM WITH FLOW IN RADIAL CHANNELS SYNCHRONOUS MACHINE

This paper describes the use of computational methods for solving the flow of the air-cooling in the large synchronous machines where it is used to cool the stator winding and stator radial channels which are located between the stator packet sheets. The overall process flow is mostly influenced by the size of air gap between stator and rotor, the shape of the radial channels, and by flow rates in machines. This paper mostly discusses about the influence flow rate of the cooling medium which has effects on the pressure distribution and flow rate in the radial channels. Cooling medium considered in this article an air and for and for calculation was chosen ANSYS CFX.

1. INTRODUCTION

1.1. Boyle's law and Charles' law

The kinetic energy of the molecules increases with increasing temperature. The important effects of this fact are given in Boyle's law and Charles' law, which state that the volume of a perfect gas varies inversely with absolute pressure and directly with absolute temperature, respectively The total effect is more properly stated by the equation of state:

$$p = \rho RT \tag{1}$$

where p is pressure, ρ is density [kg/m3], R is gas constant [J/mol.K], T is absolute temperature [K].

In the design of the majority of fan systems, the gas may be considered as incompressible without introducing significant error. The normal boundary, between the assumption that the gas is incompressible or that it is compressible, as accepted in ISO 5801 is for pressures up to 2 kPa. In many calculations, therefore, the air density may be considered constant and the absolute pressure is directly proportional to the absolute temperature. Since an ideal gas is assumed to be composed of molecules, which are very small perfect spheres, and the collisions of these molecules with one another and solid boundaries are assumed to be elastic,

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an ideal gas can only exert pressure normal to a surface. Thus, no frictional force exists in any ideal gas, even if strong velocity gradients exist. All gases, however, consist of molecules, which do not behave as elastic spheres, and thus no gas is truly ideal. Real gases are capable of exerting pressure parallel to the surface of a body, which is moving with respect to the gas. The magnitude of the force parallel to the surface is used to define an important property of real gases - viscosity. The effects of viscosity on the behaviour of real gases cause resistance to flow; the resistance is proportional to the velocity gradients, which exist in the gas [1].

1.2. Viscosity

The absolute viscosity (m)is defined as the shearing stress for a unit rate of change of velocity. It has the units of Newton-sec per metre squared in the SI system. The shearing stresses are proportional to the ratio of absolute viscosity to density, called kinematic viscosity. Viscosity (the ability to flow)is a property of fluids (both liquids and gases) treated under the heading of rheology. The work theology derives from the Greek "rheos" meaning flow. Between two layers of fluid flowing at different speeds, a tangential resistance, a shear stress, is developed because of molecular effects. We say that the shear stress is caused by the internal friction of the fluid or conversely that the fluid transmits shear forces by reason of its internal friction. A liquid in motion is continuously deformed by the effects of these shear forces. The magnitude of the stress depends on the rate of shear deformation and the sluggishness of the liquid, i.e. the viscosity. Viscosity is defined for flow in layers, laminar flow, by Newton's law of viscosity and is illustrated diagrammatically in Figure 1 [1].

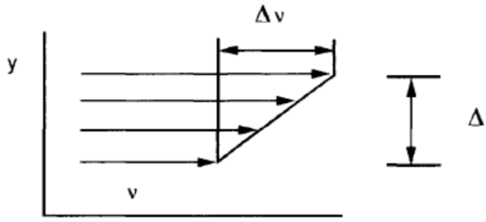

Fig. 1. Definition of viscosity [1]

$$\tau = \mu \frac{\Delta v}{\Delta y} \tag{2}$$

where τ is shear stress [N/m^2], μ is dynamic viscosity [kg/ms], Δv is change in viscosity [m/s], Δy is distance between layers [m]

In viscous flow equations the dynamic viscosity divided by the density of the liquid is given the symbol v. This parameter is called kinematic viscosity.

$$\nu = \frac{\mu}{\rho} \tag{3}$$

where ν is kinematic viscosity [m2/s], μ is dynamic viscosity [kg/ms], ρ is density [kg/m3].

1.3. Atmospheric air

Atmospheric air is a mixture of gases, water vapour and impurities (both solid and gaseous). The proportions of the important constituents for dry air at sea level are given in Table 1. This table may be considered representative of air at all the altitudes usually experienced in fan engineering.

Table 1. Constituents of atmospheric air [1]

Constituent	Chemical symbol	%by Volume	% by Weight
Nitrogen	N_2	78.09	75.52
Oxygen	O_2	20.95	23.15
Argon	Ar	0.93	1.28
Carbon dioxide	CO_2	0.03	0.04
Also traces of helium, hydrogen, krypton, neon, ozone etc.			

Table 1 shows that air is primarily a mixture of nitrogen and oxygen,(both of which are diatomic gases) with molecular weight calculated from the average constituents. For purposes of uniformity, standard air has been defined as air with a density of 1.2 kg/m 3 and an absolute viscosity of 18.19 × 10 -6 Pa.s. This is substantially equivalent to air at a temperature of 20 ~ 50% relative humidity and a barometric pressure of 101.325 kPa. [1]

2. CALCULATION PARAMETERS

Air velocity is changed from 0.001 to 0.05 m/s on the inlet side. On the Fig. 2 to 9 you can see pressure distribution in the color distribution from -8×10^{-6} to 5×10^{-5} Pa.

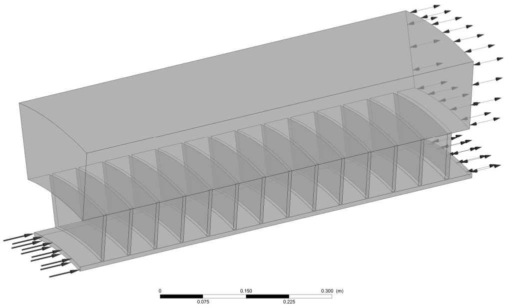

Fig. 2. Model of the air

3. RESULTS

The Fig. 3 to 9 shows the pressure distribution in the section of the air gap, radial channels and of the synchronous machine.

Fig. 3. Air velocity on the inlet side of the machine – 0.001 m/s

Fig. 4. Air velocity on the inlet side of the machine – 0.002 m/s

Fig. 5. Air velocity on the inlet side of the machine – 0.003 m/s

Fig. 6. Air velocity on the inlet side of the machine – 0.004 m/s

Fig. 7. Air velocity on the inlet side of the machine – 0.005 m/s

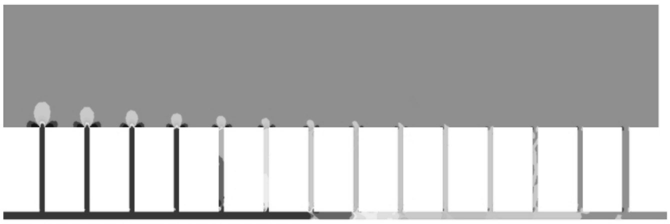

Fig. 8. Air velocity on the inlet side of the machine – 0.01 m/s

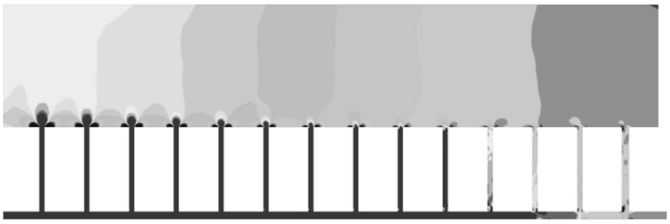

Fig. 9. Air velocity on the inlet side of the machine – 0.05 m/s

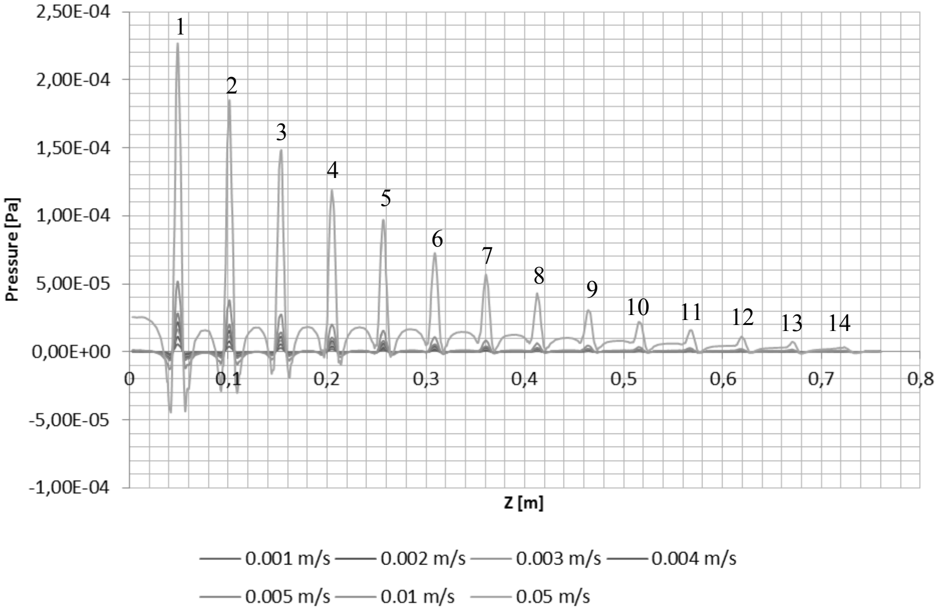

Fig. 10. Pressure distribution in the all radial channels

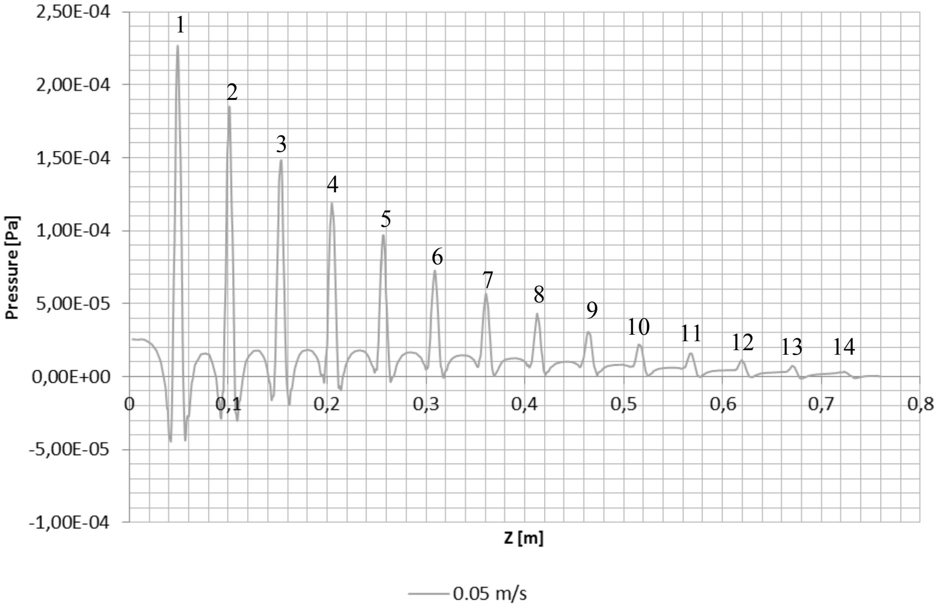

Fig. 11. Pressure distribution in the first radial channels – air velocity is 0.05m/s

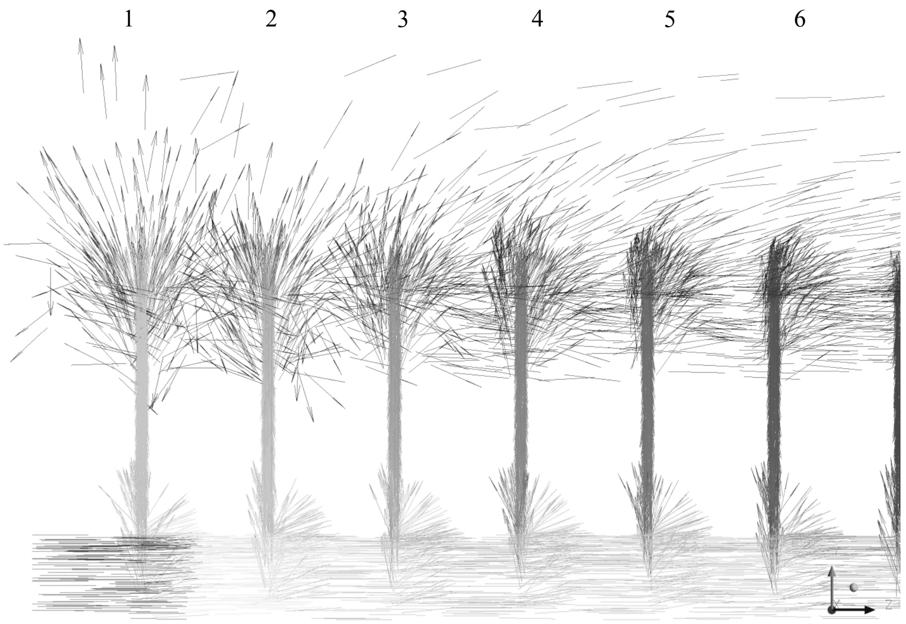

Fig. 12. Vector pressure distribution in the radial channels – air velocity is 0.05m/s

4. CONCLUSION

If is the velocity cooling media is too small is cooled only input side of the stator where has the radial channels placed on the input side of the machine high pressure and high flow rate. While in the case of higher velocity cooling medium on the input side synchronous machine is cooled the whole surface of the stator windings and stator sheets. If the air velocity exceeded a certain threshold so would cooling medium to flow only in the air gap.

Next thing which has effects on the flow rate in radial channels is the shape of these channels. The number of radial channels, their size and other properties can also greatly affect the flow rate and pressure distribution in these channels.

On the Fig. 10 to 12 you can see pressure distribution in the radial channels. Every channels are descripes by the numbers. First radial channel has number 1 and last channel has number 14.

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