FLOW IN THE RADIAL CHANNELS SYNCHRONOUS MACHINES

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Abstract: This paper describes the use of computational methods for solving the flow velocity in the air gap large synchronous machines. 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 and in the air gap synchronous machines. Cooling medium considered in this article an air and for calculation was chosen ANSYS CFX.

Keywords: flow, radial channels, velocity, Reynolds number

1. INTRODUCTION

When flow speed is higher in the air gap synchronous machine creates turbulence flow. This turbulent flow is characterized by the Reynolds number.

1.1. REYNOLDS NUMBER FLOWS

The Reynolds number is the most important dimensionless number in fluid mechanics. It is defined by:

$$\mathrm{Re} = \frac{\rho U L}{\mu} \tag{1}$$

In which U is a characteristic velocity scale, L is a characteristic length scale, ρ is the density of the fluid and μ is its dynamic viscosity. The “characteristic” velocity and length scales are different for different problems. For a relatively simple and well defined flow, such as the flow through a cylindrical tube, the characteristic scales are easily defined: U is the mean flow velocity in the pipe, and L is the pipe diameter. For more complex problems, the definition of characteristic scales may be more difficult, sometimes, even, the problem cannot be described by just one single Reynolds number. [1]

The Reynolds number represents the ratio of the importance of inertial effects in the flow, to viscous effects in the flow.

“Inertia” is the property of an object to remain at a constant velocity, unless an outside force acts on it. An object with a large inertia will resist strongly to a change in velocity, in other words it is difficult to start or stop its movement. An object with a small inertia, on the other hand, will almost instantaneously start or stop when acted upon by some external or internally generated force. Inertia of fluid flows is caused by non-linear interactions within the flow field. These non-linearity’s may cause instabilities in the flow to grow, and therefore the flow can get turbulent when inertial effects are dominant, that is, for large Reynolds numbers. For small Reynolds number, on the other hand, the flow will always be laminar. For pipe flow, the critical Reynolds number above which turbulence may exist is about 2000.

“Viscosity” is the resistance of a fluid to flow under the influence of an applied external force. It is the source of drag on objects moving through the fluid. For such an object, inertia hence strives to keep the object going, whereas viscosity tries to stop it. [1]

Fluid flow is described by the Navier-Stokes equation that describes the evolution of the velocity vector field:

$$\frac{\partial \bar{u}}{\partial t} + (\vec{u} \cdot \nabla)\vec{u} = -\frac{1}{\rho}\nabla p + \frac{\mu}{\rho}\nabla^2 \vec{u} \qquad (2)$$

In this equation, $\vec{u}$ is the velocity vector and p is the pressure. On the left-hand side, the first term is the unsteady (time-dependent) inertial component (in fact, it is the acceleration of the flow). The second term is the non-linear inertial term. On the right hand side, the first term is the driving pressure gradient, and the final term represents viscous dissipation.

We are going to estimate the relative importance of the various terms in the Navier-Stokes equation by scaling the terms using a characteristic velocity U and a characteristic length L. Hence:

The velocity $\vec{u}$ scales with U, the spatial derivative ∇ scales with $1/L$, time t scales with L/U (this is called the “adjective” time scale). [1]

If the Reynolds number is very small, i.e. much smaller than one, Re << 1, the inertial terms can be neglected in the Navier-Stokes equation, which in that case may be written as:

$$0 = -\nabla p + \mu \nabla^2 \vec{u} \qquad (3)$$

In this form, the equation is known as the Stokes equation. Low Reynolds number flow is also called Stokes flow. Equation (3) implies that there must be a balance between the pressure term and the viscous term, and therefore, the pressure must scale as [1]

$$p = 0\left(\frac{\mu U}{L}\right) \qquad (4)$$

1.2. DIFFERENCE BETWEEN LOW AND HIGH REYNOLDS NUMBER

Table (2) summarizes the general differences between low (<<1) and high (>>1) Reynolds number flows.

High Reynolds number flow >>1)	Low Reynolds number flow (Re << 1)
Inertial forces dominate	Viscous forces dominate
Flow separation (e.g. vortex shedding)	No flow separation
May be turbulent	Always laminar
Not reversible	Reversible
Non-linear	Linear
Large momentum (vortices in wakes)	Small momentum (no vortices in wakes)
Coasting	No coasting

Table 1: Characteristics of low and high Reynolds number flows [1]

2. CALCULATION PARAMETERS

Air velocity is changed from 0.00001 to 0.001 m/s on the inlet side. On the Figure (1) you can see used geometries air gap. In the left side is first simulated geometries with one radial channel and the right side is the second simulated geometries with four radial channels. The size air velocities and geometry radial channels are used only for example flow in the radial channels.

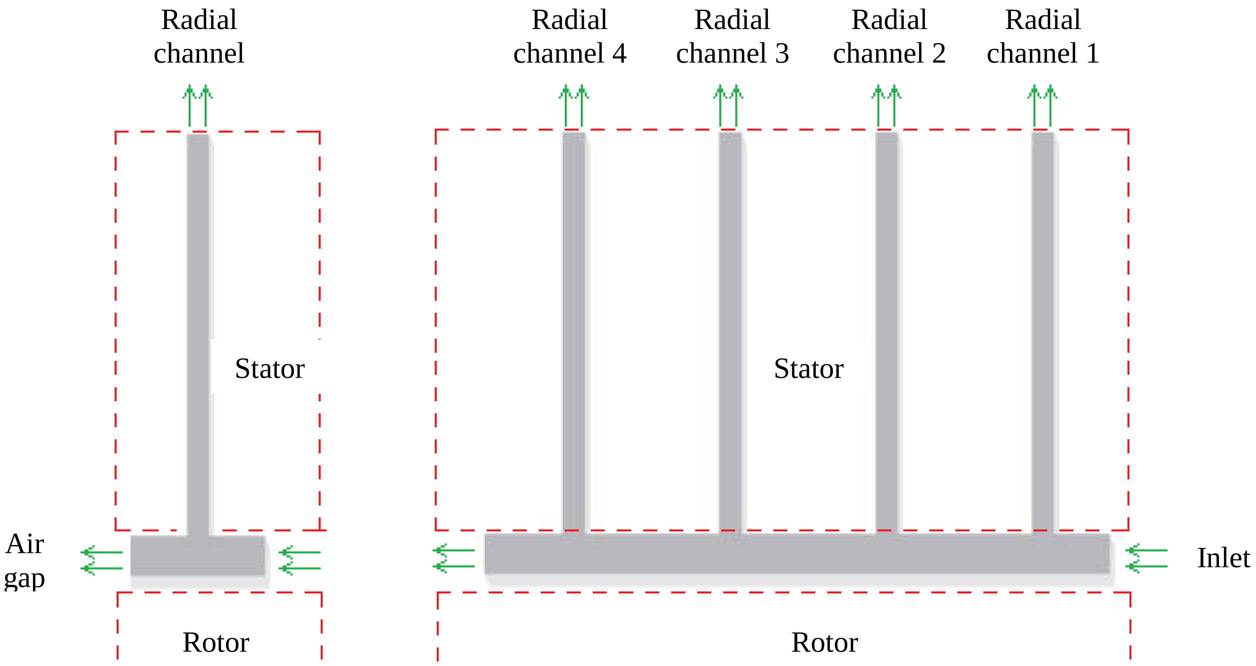

Figure 1: Two simulated geometries

3. RESULTS

3.1. SIMULATED GEOMETRY WITH ONE RADIAL CHANNEL

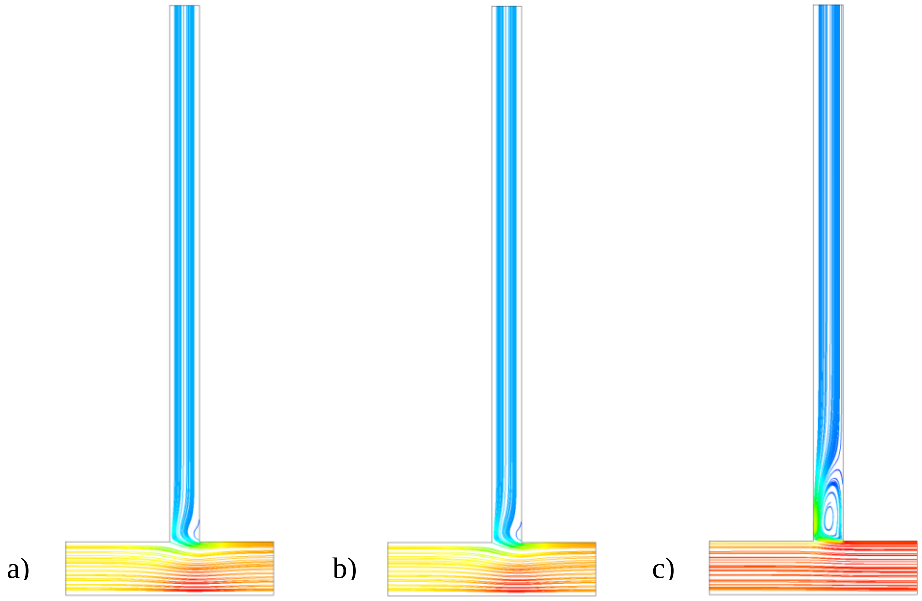

Figure 2: Air flow a) 0.00001m/s b) 0.001m/s c) 0.1m/s

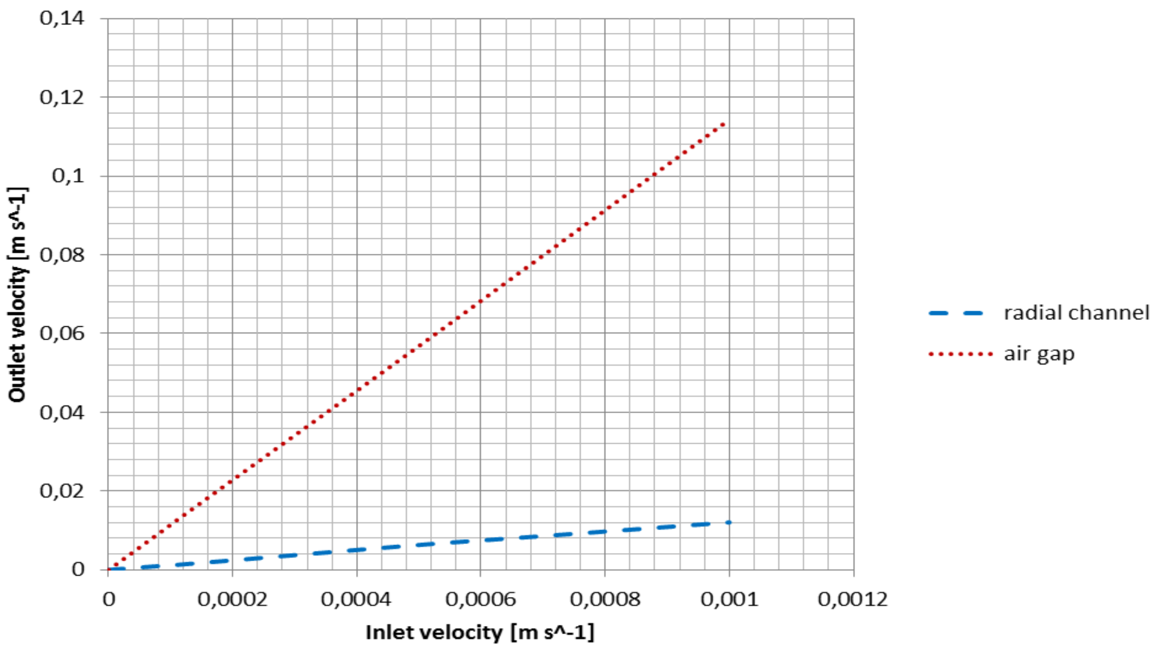

Figure 3: Velocity in air gap and one radial channel in the synchronous machine

3.2. SIMULATED GEOMETRY WITH FOUR RADIAL CHANNEL

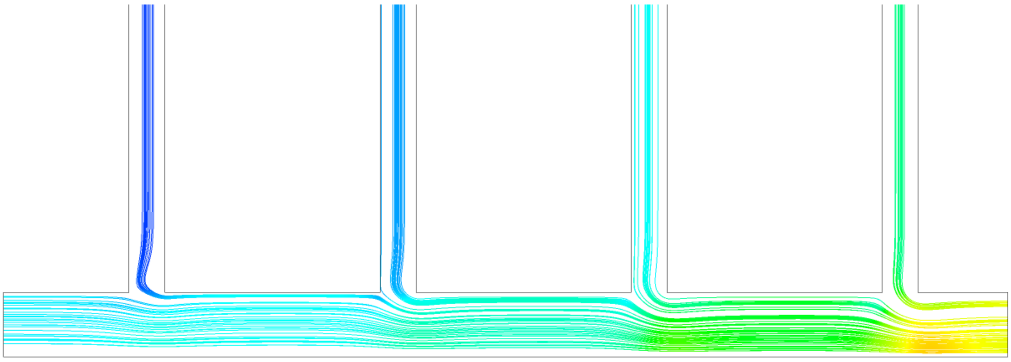

Figure 4: Air flow - 0.001m/s

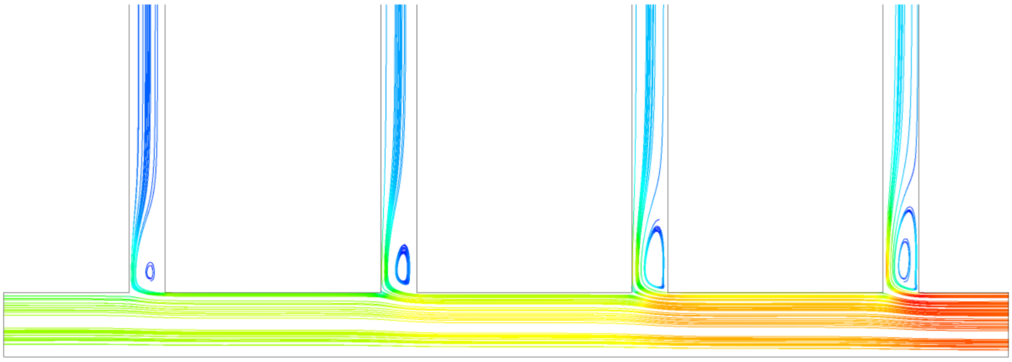

Figure 5: Air flow - 0.1m/s

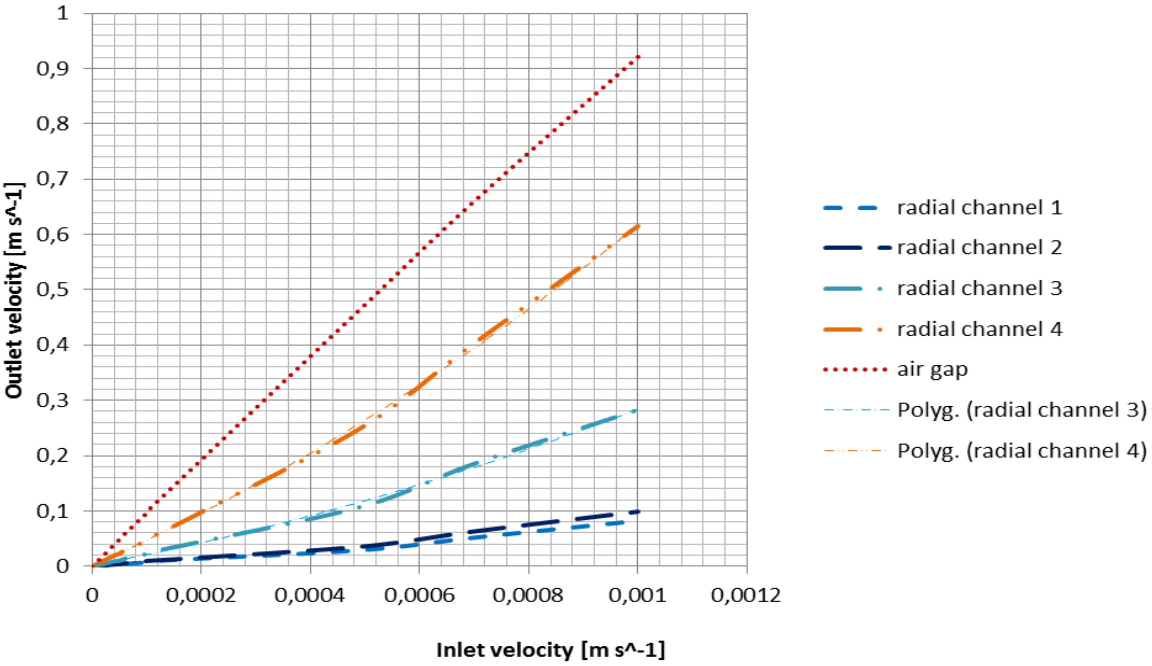

Figure 6: Velocity in air gap and four radial channels in the synchronous machine

4. CONCLUSION

The paper used two types of air gap geometry. The first geometry is characterized by an air gap between rotor and stator with one radial channel in the stator. The second geometry is characterized by an air gap between rotor and stator with four radial channels. Flow speed depending on the speed at the entrance of the air gap changes the speed in the radial channels. When exceeding „characteristic“ velocity in the air gap and radial channels there is turbulent flow. In Figure 2 and Figure 5 can be seen when the velocity increased in the air gap and created turbulence in the radial channels. Such turbulence is undesirable.

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