3D Thermo-Fluid Dynamic Analysis of Heat Exchanger for Electric Machine

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Introduction: In this research a 3D thermo-fluid dynamic simulation of an electric machine equipped with rubber belts and cooled by two fans has been performed through COMSOL Multiphysics with the aim of mapping the temperature distribution of the whole motor, expecially on the shaft and on the finned heat exchanger that is mounted on it.

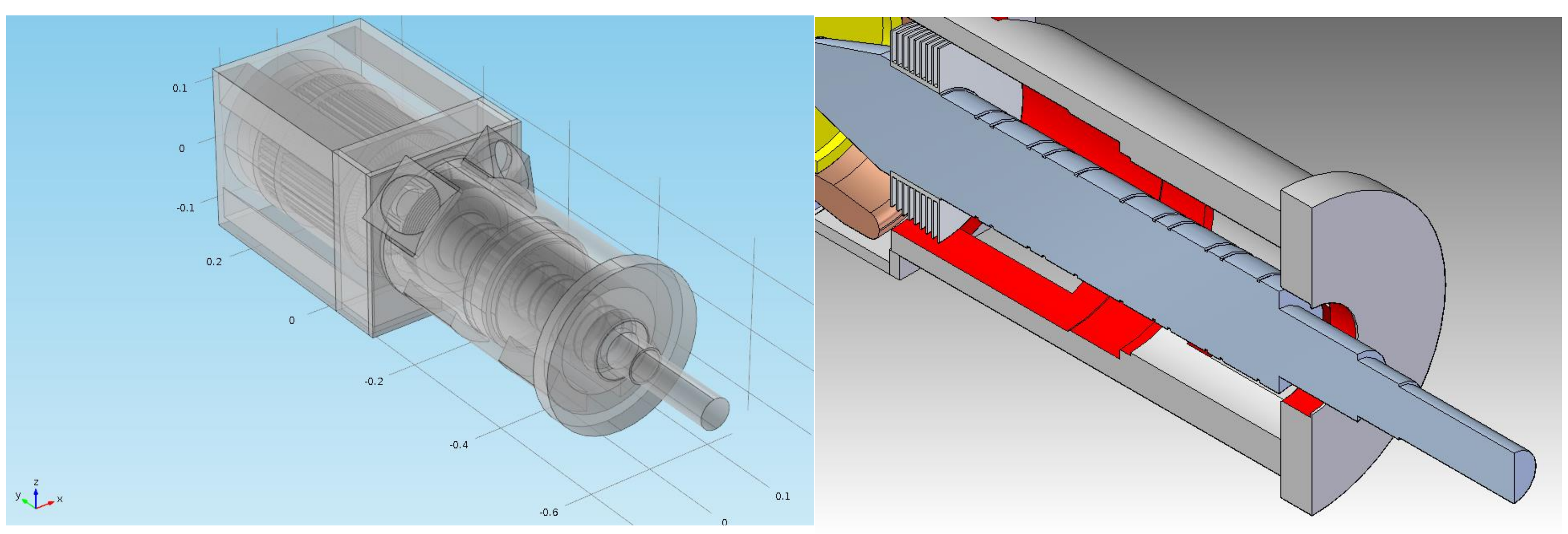

Figure 1. Electric machine and heat exchanger position.

Computational Methods: Laminar Conjugate Heat Transfer is the physic used in this model. The equations for the numerical calculation are the following:

$$\nabla \cdot (\rho \boldsymbol{u}) = 0$$

$$\rho(\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = \nabla \cdot \left[-p\boldsymbol{I} + (\nabla \boldsymbol{u} + (\nabla \boldsymbol{u})^T) - \frac{2}{3}\mu(\nabla \cdot \boldsymbol{u})\boldsymbol{I} \right] + \boldsymbol{F}$$

$$\rho c_P \boldsymbol{u} \cdot \nabla T = \nabla \cdot (k \nabla T) + Q$$

They describe conservation of mass, momentum (Navier-Stokes) and energy. F takes into account the gravitational forces, Q takes into account the electrical heat sources calculated through electromagnetic simulation (Table 1). Figure 2 shows the inlet and outlet surfaces of the airflow in the model.

Stator	160 W
Rotor	43 W
Windings	990 W

Table 1. Loss values

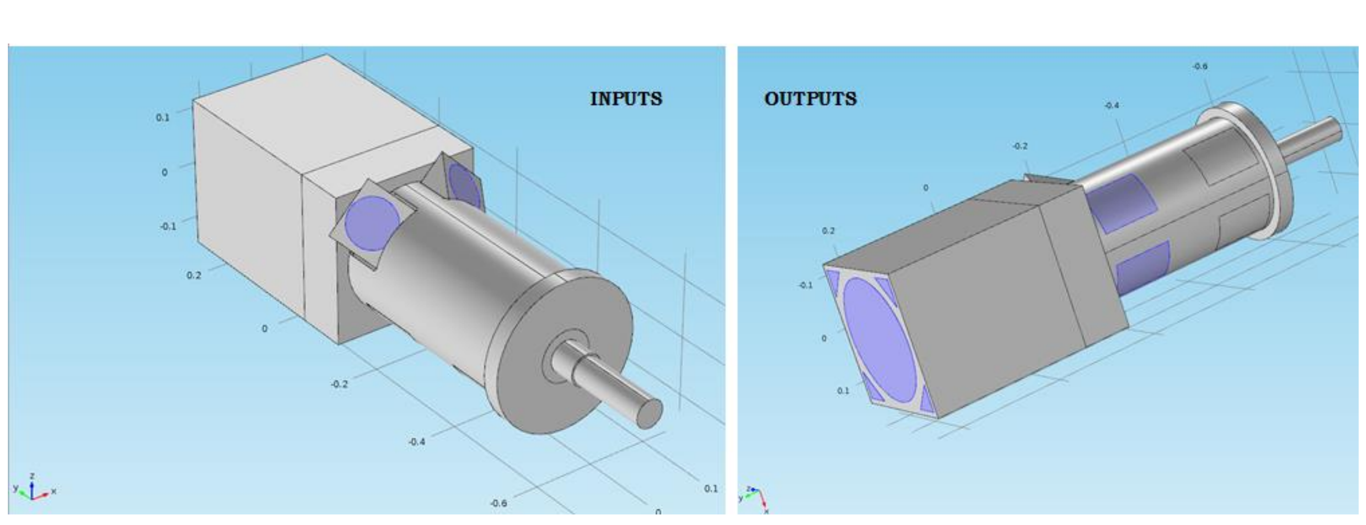

Figure 2. Inlets and outlets of the airflow

Results: Three different cases studies have been pointed out: the first one is the original configuration, in the second one a different orientation of the inlet airflow and the last one in which the topology has been modified. Figure 3 shows the streamlines of airflow that highlight temperature distribution of the model, while figure 4 shows the temperature distribution on the heat exchanger for the three different cases.

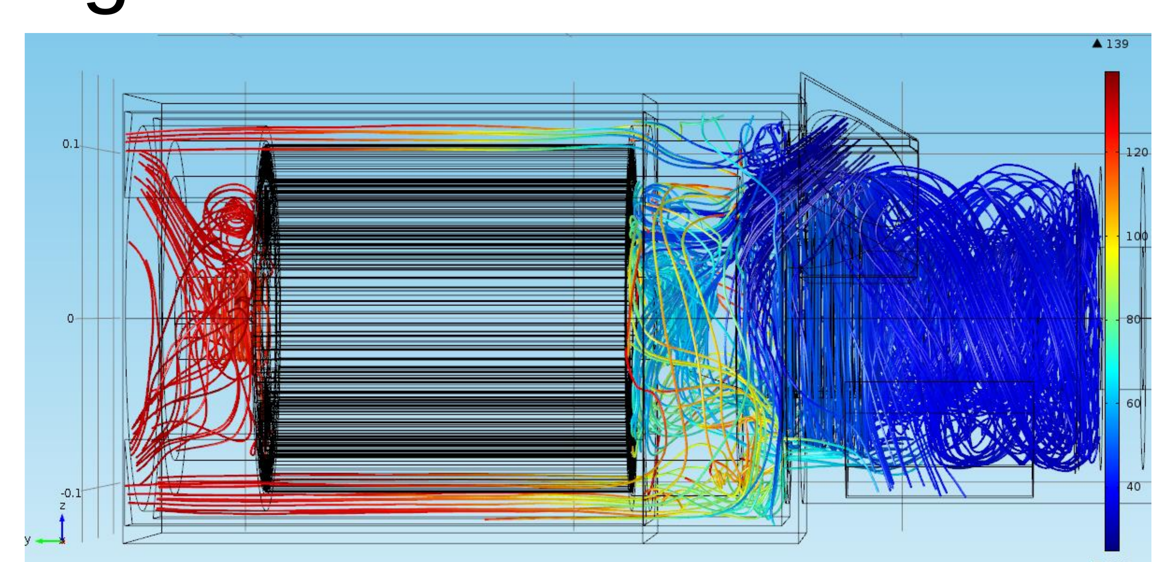

Figure 3. Streamlines of airflow in function of temperature

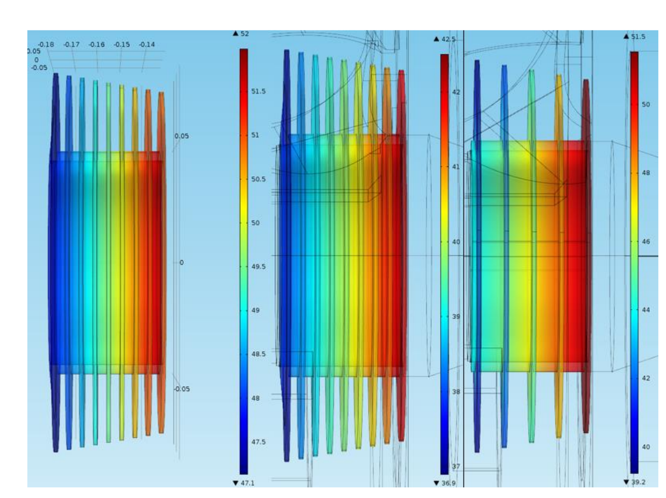

Figure 4. Heat exchanger temperature of three different cases

Conclusions: The best configuration seems to be that one in which the slot between the fins of the heat exchanger is increased. This solution allows to reach a good convective heat transfer coefficient between the fins due to the possibility of the airflow to flow better between them.

References:

1. "B. Desmet", "B. Water", "S. Harmand", Influence of fin spacing and rotational speed on the convective heat exchangers from a rotating finned tube, International Journal of HEAT AND FLUID FLOW, 21(2):221-227, (1999)
2. "S. Harmand", "B. Latour", "P. Bouvier", Convective heat transfer on a rotating finned cylinder with transverse airflow, International Journal of HEAT AND MASS TRANSFER, 54(2):4710-4718, (2011)
3. "K. Morgan", "R.W. Lewis", "O.C. Zienkiewicz", Numerical Methods in Heat Transfer, Wiley, (1981)

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