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ASPECTS REGARDING THERMAL CALCULATION OF THE INDUCTION MACHINE

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Abstract: *The aim of the paper is to make a brief introduction to the study of optimal design of an induction machine seen as a multi physical system in which, the electromagnetically model is in close relation with the thermal and the mechanical one. So, after a short introduction about the heat transfer by conduction, convection and radiation, a simple example is shown about 'one – dimensional simplified heat transfer' in an induction machine, without "tab"-s. The abstract will have 7...10 lines.*

Key words: *induction motor, iron losses, conduction, convection and radiation heat transfer, thermal model and optimal design.*

1. Introduction

The Optimal design of electric machines, in accordance with the principles of sustainable development, requires the consideration of many physical phenomena, estimated in terms of performance or estimated in terms of constraints, imposed to be obeyed. Optimum electromagnetic alone is often a non-thermal effect and vice versa, without mentioning the noise and vibration.

In electric machines, the representation of heat transfer is of equal importance as the electromagnetic model of the machine, since the thermal rise of the machine eventually decides the output power of the machine. The control of heat and mass transfer in an electric machine is a far more difficult and complicated problem than the conventional electromagnetic model of an electric machine. The problems related to heat transfer can be avoided by utilizing empirical knowledge of machine constants available.

The electromagnetic model of the electric machine determines the exact geometry of the machine, and the machine parts are constructed according to strict tolerances. The dimensioning of the machine decides whether the machine produces the required torque or not. More, the dimensioning defines the voltages and currents of the machine as well as the dimensioning of the control unit of the power electronics of a frequency converter or of a doubly salient reluctance machine.

Some elementary methods for the calculation of heat transfer can be justified by the fact that unless the permitted maximum temperatures for the machine

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insulations are exceeded, the temperature rise is negligible when considering the torque produced by the machine.

2. Multi-physical Model of Asynchronous Machine

The So, we can consider the multiphysical model of asynchronous machine (fig. 1) to be efficient and to respect the main evolution trends respect to comparison with experimental results and analysis of the uncertainties influence.

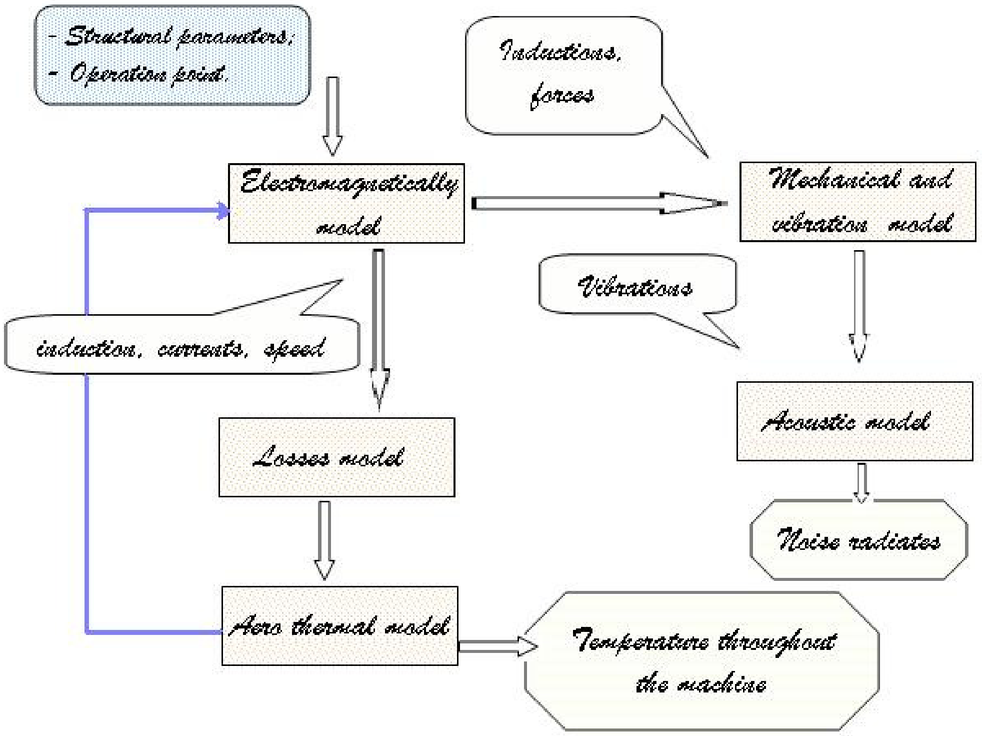

Fig. 1. *Multi-physical models of asynchronous machine*

3. Heat Transfer in an Asynchronous Machine

Heat removal and the temperature distribution within the asynchronous motor are the two major objectives of thermal design. Finding the highest winding temperature spots is crucial to insulation (and machine) working life. The thermal modeling depends essentially on the cooling approach.

So, heat transfer is related to thermal energy flow from a heat source to a heat sink.

The heat can be removed by convection, conduction and radiation. Usually, the convection is the most important method of heat transfer. In asynchronous machines, the thermal energy flows:

- from the windings in slots to laminated core teeth through the conductor insulation and slot line insulation;

- part of the thermal energy in the end-connection windings is transferred through thermal conduction through the conductors axially toward the winding part in slots;
- a similar heat flow through thermal conduction takes place in the rotor cage and end rings;
- from the stator core to the frame through the back core iron region;
- from rotor cage to rotor core, respectively, to shaft and axially along the shaft;
- part of the conduction heat now flows through the slot insulation to core to be directed axially through the laminated core.

The presence of lamination insulation layers will make the thermal conduction along the axial direction more difficult.

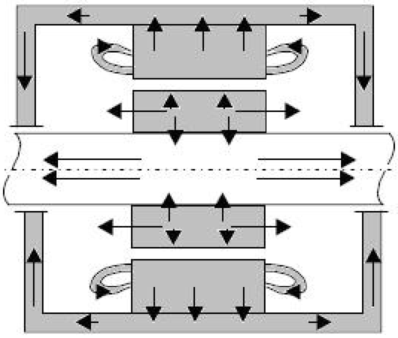

Fig.2. *Heat transfer in asynchronous machine*

The proportion of heat transfer by radiation is usually quite moderate, yet not quite insignificant. A black surface of the machine in particular promotes heat transfer by radiation.

4. One – Dimensional Simplified Heat Transfer

In a first approximation, the axial heat flow, described upper, may be neglected.

After accounting for conduction heat flow from windings in slots to the core teeth, the machine circumferential symmetry makes possible the neglecting of circumferential temperature variation. So, we end up with a one-dimensional temperature variation, along the radial direction.

The Fourier's law for one-dimensional heat conduction may be written, for steady state, with constant thermal conductivity K, as:

$$-K\frac{\partial^2\theta}{\partial x^2}=q \tag{1}$$

where q is heat generation rate per unit volume; θ is local temperature and K is thermal conductivity.

For one-dimensional heat conduction, the thermal conduction resistance R_{con}, $[°C/W]$ may be defined as similar to electrical resistance.

$$R_{con}=\frac{\Delta ins}{KA} \tag{2}$$

where: Δins is slot insulation and A is conduction area:

$$A=(2h_{c1}+b)l_{Fe}N_{c1} \tag{3}$$

and h_{c1} is height of stator slots, b width of stator slots, l_{Fe} stack length and N_{c1} stator slots (fig 3b).

The temperature differential between winding in slots and the core teeth $\Delta\theta_{Cu}$ is:

$$\Delta\theta_{Cu1}=P_{Cu1}R_{con}=P_{Cu1}\frac{\Delta_{ins}}{AK} \tag{4}$$

Heat transfer by convection is based on the transfer of heat between a solid surface and a fluid. Heat is always transferred simultaneously by convection and conduction.

In radiation, the density of the heat flow is defined by Stefan-Boltzmann equation and is of considerable significance in the total heat transfer of an electric machine.

5. Example of Calculus

Let us calculate the winding in slots temperature and the frame temperature for an asynchronous machine (fig. 3a), using 'One – Dimensional Simplified Heat Transfer' and the soft of Matlab.

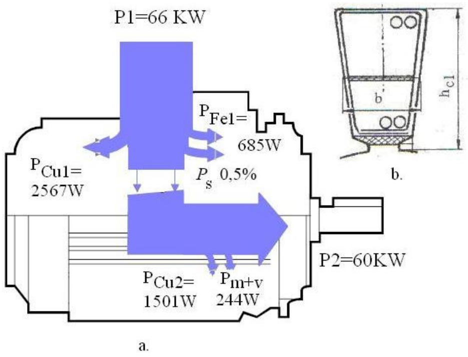

Fig.3. a.. *Asynchronous machine*, b. *stator slot*

The first assumption of calculus is that all rotor heat losses cross the air gap and it flows through the stator core toward the stator frame. So, it has to be calculated the temperature differential of the windings in slots.

Second, we consider that stator winding in slot losses, rotor cage losses, and stator core losses produce heat that flow radial through stator core by infinite conduction.

Third, all these losses are transferred to ambient through the motor frame through combined free convection and radiation.

The numerical results are:

- the stator winding in slot temperature differential is $\Delta\theta_{Cu1} = 3.25°C$;
- the core temperature: $\theta_{miez} = 127°C$;
- the winding in slots temperature: $\theta_{Cu1} = 130.34°C$.

6. Conclusions

In this simple approximation defining thermal conduction, convection, and radiation, and of the equivalent circuit becomes a rather simple task.

However, it is not at all simple to calculate the temperature distribution.

A numerical approach is the best solution in the thermal calculation of the asynchronous machine modeled as a multiphase system.

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