COMPUTATIONAL ANALYSIS OF THREE DIMENSIONAL STEADY STATE HEAT CONDUCTION IN THE ROTOR OF AN INDUCTION MOTOR BY FINITE ELEMENT METHOD

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Abstract — In developing electric motors in general and induction motors in particular temperature limits is a key factor affecting the efficiency of the overall design. Since conventional loading of induction motors is often expensive, the estimation of temperature rise by tools of mathematical modeling becomes increasingly important. Excepting for providing a more accurate representation of the problem, the proposed model can also reduce computing costs. The paper develops a three-dimensional steady state thermal model in polar coordinates using finite element formulation and arch shaped elements. A temperature-time method is employed to evaluate the distribution of loss in various parts of the machine. Using these loss distributions as an input for finite element analysis, more accurate temperature distributions can be obtained. The model is applied to predict the temperature rise in the rotor of a squirrel cage 7.5 kW totally enclosed fan-cooled induction motor. The temperature distribution has been determined considering convection from the outer air gap surface and annular end surface for both totally enclosed and semi enclosed structures. Finally the temperatures obtained by this three-dimensional analysis have been compared with the approximate temperatures obtained by two-dimensional analysis.

Keywords — FEM; Induction Motor; Thermal Analysis; Design Performance.

I. INTRODUCTION

Considering the extended use of squirrel cage induction machine in industrial or domestic applications both as motor and generator, the improvement of the energy efficiency of this electromechanical energy converter represents a continuous challenge for the design engineers, any achievements in this area meaning important energy savings for the world economy. Thus to design a reliable and economical motor, accurate prediction of temperature distribution within the motor and effective use of the coolant for carrying away the heat generated in the iron and copper are important to designers (Griffith et al., 1986).

Traditionally, thermal studies of electrical machines have been carried out by analytical techniques, or by thermal network method (Rosenberry, 1955; Okoro, 2005). These techniques are useful when approximations to thermal circuit parameters and geometry are accepted. Numerical techniques based on either finite difference method (Richert, 1969; Tindall and Brankin, 1988) or finite element methods (Demoulia et al., 2008; Armor, 1980; Sarkar, 1997; Armor and Chari, 1976; Hwang and Pan, 1988; Lin and Arkkio, 2008; Nerg, 2006; Huebner et al., 1995) are more suitable for analysis of complex system. Rajagopal et al. (1994, 1998) have carried out two-dimensional steady state and transient thermal analysis of TEFC machines using FEM. Compared to the finite difference method finite element method can easily handle complicated boundary configurations and discontinuities in material properties.

The finite element method is first introduced for the steady state thermal analysis of the stator cores of large turbine-generators by Armor and Chari (1976). However, their works are restricted to core packages far from the ends and they do not consider the influence of the stator coil heat. Armor (1980) employed arch-shaped finite elements to solve the transient heat flow in the rotor of large turbine-generators. Sarkar (1997) also described a method based on arch-shaped finite elements with explicitly derived solution matrices for determining the thermal field of induction motors.

In this paper, the finite element method is used for predicting the temperature distribution in the rotor of an induction motor using arch-shaped finite elements with explicitly derived solution matrices. A 128 element three-dimensional slice of armature iron, together with copper winding bounded by planes at mid-slot, mid-tooth and mid package are used for solution to a steady state heating problem, and this defines the scope of this technique. The model is applied to one squirrel cage TEFC machine of 7.5 KW and the temperatures obtained are found to be within the permissible limit in terms of overall temperature rise computed from the resulting loss density distribution.

II. POLYPHASE INDUCTION MOTOR MODEL AND BOUNDARY CONDITIONS

The details of the induction motor are shown in Fig. 1. In this analysis, the 3-dimensional slice of armature iron and winding chosen for modeling the problem and the geometry is bounded by planes passing through the mid-tooth, the mid-slot and the mid-package centre. This is shown in Fig. 2, taken from the shaded region A of Fig. 1. The temperature distribution is assumed symmetrical...