Abstract—This paper presents a coupled model of fluidstructure-thermal simulation of power converter for switched reluctance motor drive. The mathematical description is made up of mass conservation equations, momentum conservation equations and energy conservation equations. The accuracy of the model is verified by comparing experimental data with simulation results derived from finite-element method. Furthermore, the analysis in the distance between the radiator and the fan, the height of the enclosure, and the air velocity of the fan is studied with the proposed model.

Index Terms—Thermal conductivity, temperature, thermal analysis, power converter.

I. INTRODUCTION

The most of the previous work on switched reluctance motor (SRM) drive are in optimization of motor made of novel iron core material [1], rotor position estimation [2], magnetic characteristics [3], motor optimal design [4], temperature rise analysis of motors [5], monitoring system for rotor eccentricity detection [6], thermal-electromagnetic analysis for driving cycles [7].

In this paper, a model of environmental effect on temperature rise of power converter for SRM drive is developed to calculate the temperature rise distribution by using finite-element method (FEM). Considering dry and moist air, different convective heat transfer coefficient, different inlet velocity, the temperature rise distribution of the power converter is simulated with the proposed model and is verified by the experimental data.

II. STRUCTURE OF POWER CONVERTER

The three-phase asymmetrical half-bridge main circuit is adopted. The power devices in main circuit include 12 power MOSFETs and 6 fast recovery diodes. The model is divided into three layers from top to bottom, such as power electronic devices, thermal insulating silicone gasket and aluminum finned radiator. The main circuit is installed in a box, and other wires inside are omitted to simplify the model, which is shown in Fig 1.

III. SIMULATION MODEL

A. Mass Conservation Equation

\[
\frac{\partial \rho}{\partial t} + \frac{\partial (\rho U)}{\partial x} + \frac{\partial (\rho V)}{\partial y} + \frac{\partial (\rho W)}{\partial z} = 0
\]  

(1)

B. Momentum Conservation Equation

\[
\frac{\partial (\rho U)}{\partial t} + \frac{\partial (\rho U^2)}{\partial x} + \frac{\partial (\rho UV)}{\partial y} + \frac{\partial (\rho UW)}{\partial z} = -\frac{\partial P}{\partial x} + \frac{\tau_{xx}}{\rho} + \frac{\tau_{yx}}{\rho} + \frac{\tau_{zx}}{\rho} + F_x
\]

(4)

\[
\frac{\partial (\rho V)}{\partial t} + \frac{\partial (\rho UV)}{\partial x} + \frac{\partial (\rho V^2)}{\partial y} + \frac{\partial (\rho VW)}{\partial z} = -\frac{\partial P}{\partial y} + \frac{\tau_{xy}}{\rho} + \frac{\tau_{yx}}{\rho} + \frac{\tau_{zy}}{\rho} + F_y
\]

(5)

\[
\frac{\partial (\rho W)}{\partial t} + \frac{\partial (\rho UW)}{\partial x} + \frac{\partial (\rho VW)}{\partial y} + \frac{\partial (\rho W^2)}{\partial z} = -\frac{\partial P}{\partial z} + \frac{\tau_{xz}}{\rho} + \frac{\tau_{zx}}{\rho} + \frac{\tau_{zz}}{\rho} + F_z
\]

(6)

where, \( \rho \) is density, \( t \) is time, \( U \) is velocity vector, \( u, v \) and \( w \) are components of the velocity vector \( U \).

C. Energy Conservation Equation

\[
\frac{\partial (\rho T)}{\partial t} + \frac{\partial (\rho U T)}{\partial x} + \frac{\partial (\rho V T)}{\partial y} + \frac{\partial (\rho W T)}{\partial z} = \frac{k}{c_p} \text{grad} T + S_T
\]

(7)

where, \( c_p \) is Specific heat capacity, \( T \) is temperature, \( k \) is the heat transfer coefficient, \( S_T \) is the heat source and the part of the mechanical energy changing into heat energy because of viscous effect.

IV. CALCULATED RESULTS AND EXPERIMENTAL VALIDATION

Fig. 2 shows the temperature contours of the power converter using a fan cooling. It is shown that the temperature of the power converter near the fan is lower than that of away from the fan. The two power MOSFETs on the left get the maximum temperature of 24.80°C. The temperature distribution of the power converter is vertically symmetric, so that it can be appropriately simplified for analysis.
V. PLACEMENT AND AIR VELOCITY

In order to enhance the heat transfer ability of power converter, the distance between the radiator and the fan, the height of the enclosure, and the air velocity of the fan, are studied by using the proposed model in this paper. The parameter symbols are illustrated in Fig. 5, while $L$ is the distance between the radiator and the fan, $h$ is the height of the enclosure.

VI. CONCLUSION

In this paper, a coupled model of fluid-structure-thermal simulation for power converter in switched reluctance motor drive has been introduced. This model can predict the temperature rise distribution in power converter by compulsive ventilation cooling, study the distance between the radiator and the fan, the height of the enclosure, and the air velocity of the fan. The accuracy of the model is verified by comparing experimental data with those resulting derived from FEM simulation.

REFERENCES