Analysis of Eddy Current in an Asymmetrical Conductor using the New 3-D Equivalent Magnetic Circuit Network Method

Jin Hur, Hamid A. Toliyat, Jung-Pyo Hong [°] and Dong-Seok Hyun [#]

Dept of Electrical Engineering, Texas A&M University, College Station, TX, 77843-3128, USA

E-mail: hjemcn@ee.tamu.edu

[°] Dept. of Electrical Engineering, Changwon National University, Kyungnam, 641-773, Korea

[#] Dept. of Electrical Engineering, Hanyang University, Seoul, 133-791, Korea

Abstract — The 3-D eddy current fields in asymmetrical conductor with a hole of benchmark model are analyzed by using new time stepping 3-D numerical analysis method. The method is capable of modeling the eddy current and analyzing the characteristics by using only scalar potential at each node in three dimensions. The calculated values of magnetic flux density are compared with the measured values, and the results indicate that the proposed method is valid.

I. INTRODUCTION

Most papers concerning the calculation of 3-D eddy current problems are using a combination of a vector potential and a scalar potential to solve the electromagnetic field in conduction region [1]. This paper proposes a new time harmonic equivalent magnetic circuit network (EMCN) method, which can analyze the eddy current in 3 dimensions using only scalar potential. Additional variables like electric vector potential are not needed to be introduced in the method. The proposed method is a numerical analysis method based on the magnetic equivalent circuit. In this method, the analysis model is divided into hexahedral elements like 3-D FEM and then equivalent magnetic network is constructed by connecting the center of each element. Also, the magnetomotive forces (MMF) due to the induced currents are shown as passive sources in the network. Therefore, by using only scalar potential at each node, it is possible to model induction motor and analyze its characteristics in 3-dimensions.

II. MODELING OF EDDY CURRENT

In order to analyze eddy current using EMCN method, the induced current due to the electromagnetive force (EMF) is expressed as MMF with a passive source in the conventional network. From Faraday law the induced current density can be written as follow:

$$\nabla \times \vec{J}_e = -\sigma \, d\vec{B}/dt \qquad (1)$$

Here, the induced current component of each direction in the conducting region may be expressed as the time-changing magnetic flux linked by the region using the Taylor series.

The governing equation plus the induced current term is as follow:

$$\oint H \cdot dl = \int \vec{J}_F \cdot ds + \int \vec{J}_e \cdot ds \qquad (2)$$

where, $\vec{J}_F$ is input current density and $\vec{J}_e$ is eddy current density. From (1) and (2), we can obtain following relation using the time harmonics form.

$$\phi' R_N = F'_N \qquad (3)$$

where, $R_N = (R_m + R_{IND})$, $F'_N = (F_S + F_{IND})$. R_m and F_S are the reluctance and the MMF due to the input current and R_{IND} and F_{IND} are the added reluctance and the induced MMF due to the eddy current. Therefore, we can get the new reluctance and MMF with the induced current included. We then can solve the network using the fact that the magnetic flux has to be continuous at all nodes.

III. RESULTS AND DISCUSSION

In this paper, in order to verify the effectiveness and accuracy of the proposed method, the eddy current fields in an asymmetrical conductor with a hole is analyzed. Figuare 1 shows the analysis model. The calculated value compared with FE analysis result and mesured value are shown Fig.2. The EMCN result show a good agreement with FE and measured values results.

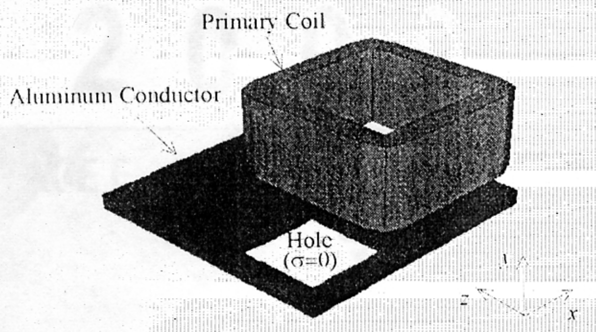

Fig.1. Analysis model.

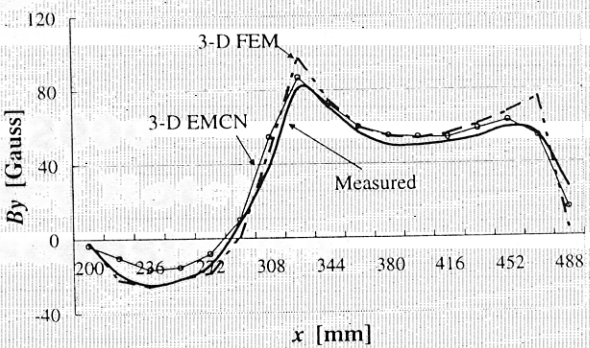

Fig.2. Comparison between EMCN, FE and measured results

VI. REFERENCE

[1] S. R. Hoole, *Finite Elements Electromagnetics and Design*, Elsevier Press 1995.

[2] Li Lin and C. Xiang, "Analysis of 3D Nonlinear Eddy Current Problem Using the Field Variables H and E Directly", *IEEE Trans. on Magnetics*, Vol. 33, No. 2, pp. 1179-1184, Mar. 1997.

DIGESTS OF THE 9th

BIENNIAL IEEE CONFERENCE ON ELECTROMAGNETIC FIELD COMPUTATION - CEFC-2000

June 4-7, 2000
Hyatt Regency Hotel
Milwaukee, Wisconsin USA

Jointly Sponsored by
IEEE- Magnetics Society, IEEE-Milwaukee Section,
IEEE-Miami Section and Marquette University