3-D non-linear eddy current analysis using the time-periodic finite element method

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3-D NON-LINEAR EDDY CURRENT ANALYSIS
USING THE TIME-PERIODIC FINITE ELEMENT METHOD

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INTRODUCTION

When periodic fields are analyzed taking into account eddy current and terminal voltage[1] by using the so-called step-by-step method[2], a number of iterations are necessary until periodic solutions can be obtained. As the method needs much CPU time, it is not practical to apply it to the non-linear analysis of such periodic fields. The improved 2-D finite element method for such analysis has been already developed[3]. The improved method is called the "time-periodic finite element method", in which vector potentials in half a period are calculated at the same time by using the relationship between the vector potentials at the time t and t+T/2 (T:period) of the periodic waveform. The introduction of such a method in 3-D magnetic field analysis is especially important in order to reduce the CPU time.

In this paper, the method is expanded to 3-D analysis of magnetic fields with eddy currents using the $A-\phi$ method. The finite element formulation of the expanded method is described, and it is shown that the CPU time can be reduced to, for example, about 1/3 of the conventional step-by-step method.

METHOD OF ANALYSIS

When the waveform of a vector potential is symmetrical and periodic with time as shown in Fig.1, the following relationship is hold between vector potentials A^t and $A^{t+T/2}$:

$$A^t=-A^{t+T/2} \tag{1}$$

By solving simultaneously the Rayleigh-Ritz matrix equations at respective steps in half a period taking into account the relationship of Eq.(1), vector potentials in half a period can be calculated at the same time.

AN EXAMPLE OF APPLICATION

The currents in the primary and the secondary windings of a loaded transformer shown in Fig.2 are analyzed. The core is made of non-oriented silicon steel M-15. The effective voltage and the frequency of the power source are 200V and 50Hz respectively. The numbers of turns of the primary and the secondary windings are both equal to 120. The load is pure resistance, and its value is equal to 20Ω.

Figure 3(a) shows the current waveforms obtained by the step-by-step method. Iterations should be carried out for 3 periods in order to get the periodic waveform. Figure 3(b) shows the current waveforms obtained by the time-periodic method. The CPU time can be reduced to about 1/3 of the conventional step-by-step method as shown in Table 1.

REFERENCES

[1] T.Nakata, N.Takahashi, K.Fujiwara and A.Ahagon : IEEE Trans. on Magnetics, MAG-24, 5 (1988).
[2] T.Nakata and Y.Kawase : Journal of IEE, Japan, 104-B, 6, 380 (1984).
[3] T.Nakata, N.Takahashi and Y.Kawase : Proceedings of International Symposium on Electromagnetic Fields in Electrical Engineering, 89 (1985).

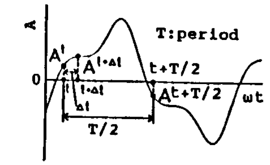


Fig.1 Periodic waveform.

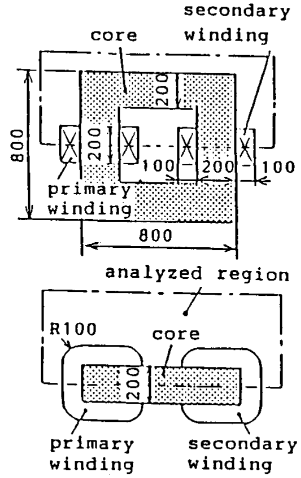
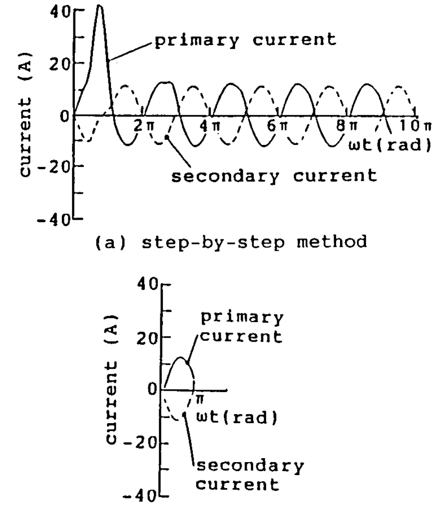


Fig.2 Analyzed model.



(a) step-by-step method

(b) time-periodic method

Fig.3 Current waveforms.

Table 1 Comparison of CPU time

method	CPU time (sec)
step-by-step method	298
time-periodic method	103