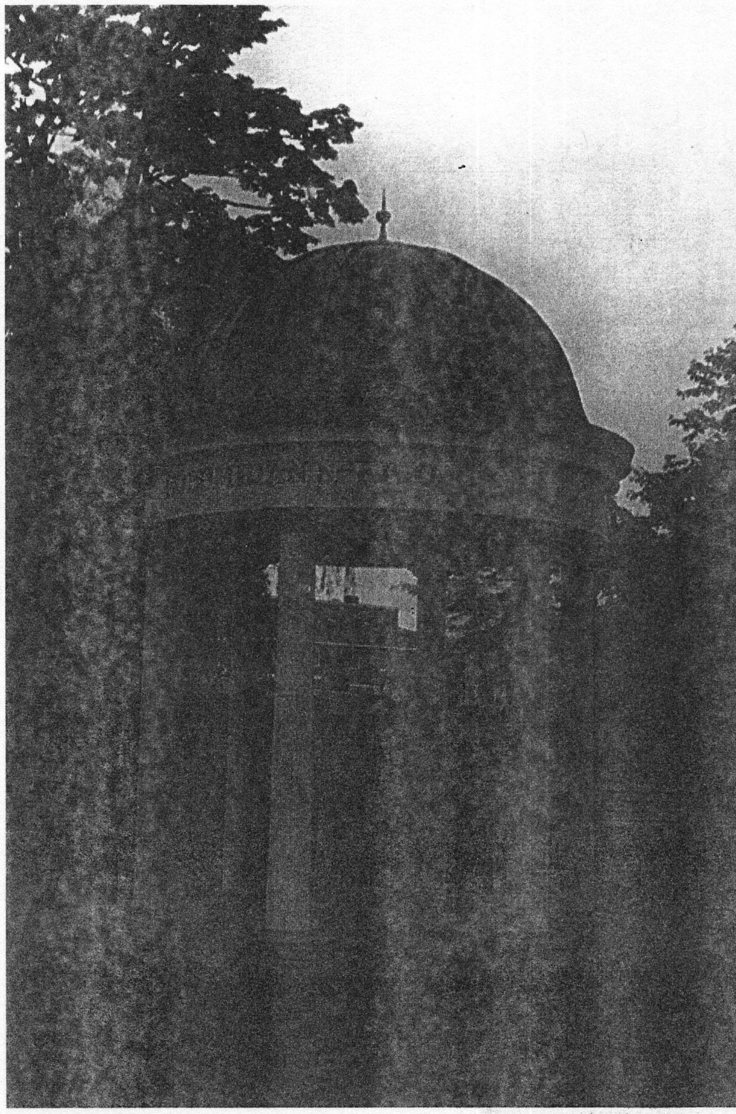

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Loss Distribution of 3-phase Induction Motor with PWM Inverter Drive

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Abstract — **This paper presents the analysis of loss distribution in 3-phase induction motor using PWM (Pulse-Width Modulated) inverter drive. The analysis is based on the time-stepping finite element method. The loss of induction motor is separated into mechanical loss, conductor loss, and iron loss. The iron loss is evaluated by the frequency analysis of flux density using DFT (Discrete Fourier Transforms) and the data of iron loss curves. The iron loss curve data is provided by manufacturing company. In order to calculate loss distribution of PWM inverter fed, voltage profiles are performed. The result is compared with the sinusoidal drive loss distribution. The validity of this method is verified by the comparison of the estimated values with measured one.**

Introduction

In recent years, PWM inverter drive is mainly used as the input of motor rather than sinusoidal voltage. The average voltage of the inverter output is equal to that of sinusoidal input, but it causes current ripple. And the high frequency current ripple decreases the motor performance [1]. The iron loss and conductor loss are changed in PWM waveforms. There is a need for the quantitative analysis, because it leads to improvement of motor performance. In traditional ac machine theory, the core loss is viewed as being caused mainly by the fundamental frequency variation of the magnetic field, which is not sufficiently accurate. Nick Stranges, Raymond D. Findly studied the method for predicting rotational iron losses in three phase induction motor stators [2].

In this paper, the loss distribution of induction motor is calculated considering the various frequency PWM methods. The analysis is based on the time stepping FEM (Finite Element Method). The voltage of inverter output is described according to time, and transient FEM is performed, where the time is changed on the each analysis step. And the simulation results, which are the iron loss, conductor loss, and the current, are compared with test result.

Analysis Model and Methods

The 3-pahse Induction Motor

The stator has 48 slots and the rotor is consisted of 40 conductor bars. Fig. 1. show the quarter cross-section of the induction motor and Table I describes main specification of the motor. In order to compare sinusoidal voltage with PWM inverter output voltage, voltage profiles are shown in Fig. 2. Sinusoidal frequency is 60 [Hz], and PWM frequency is variable from 2-12 [kHz].

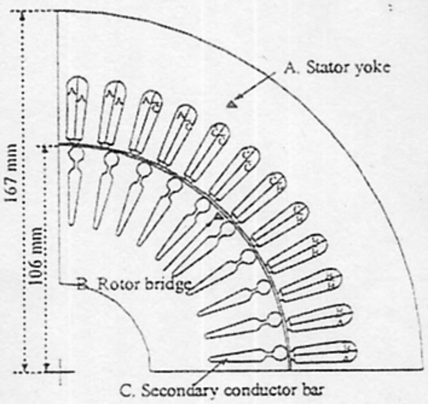

Fig. 1. Analysis model

Table I. Specifications of the induction motor

Specification	Value
Input voltage	380 (line-to-line)
Rated Output	35 (kW)
Frequency	60(Hz)

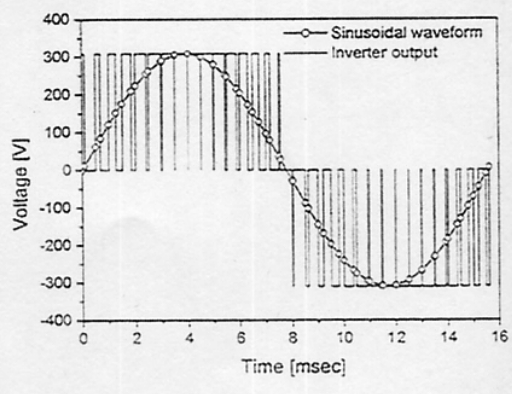

Fig. 2. The voltage profile when PWM frequency is 2 [kHz], sinusoidal frequency is 60 [Hz]

Analysis Methods

The loss of induction motor is separated into mechanical loss, conductor loss and iron loss. The mechanical loss is ignored in simulation. The conductor loss is separated into the primary winding conductor loss and secondary winding eddy current conductor loss. It is possible to calculate the conductor loss with FEA result, and the method is described in this paper. Iron losse is divided into the histerisis loss and eddy current loss. It is difficult to estimate the eddy current loss of iron. In this paper, iron loss is calculated by the freuqency analysis of flux density using DFT and iron loss data sheet [3]. The iron loss sheet is provided by core manufacturer company. Flux density of iron core is analyzed by each element harmonic component, and iron loss is calculated by the harmonic component of each element considering the magnitude of flux density and frequency. The proposed method is shown in Fig. 3.

ANALYSIS RESULTS AND CONCLUSION

Table II shows the loss distribution according to drive method. The sinusoidal current and PWM inverter drive current are shown in Fig. 4. The effect of PWM inverter is high frequency current. That current increases the conduction loss, and iron loss. When driving with PWM inverter, iron loss and conductor loss are greater than sinusoidal voltage. The flux density waveforms of elements in stator yoke and rotor bridge are shown in Fig. 5.

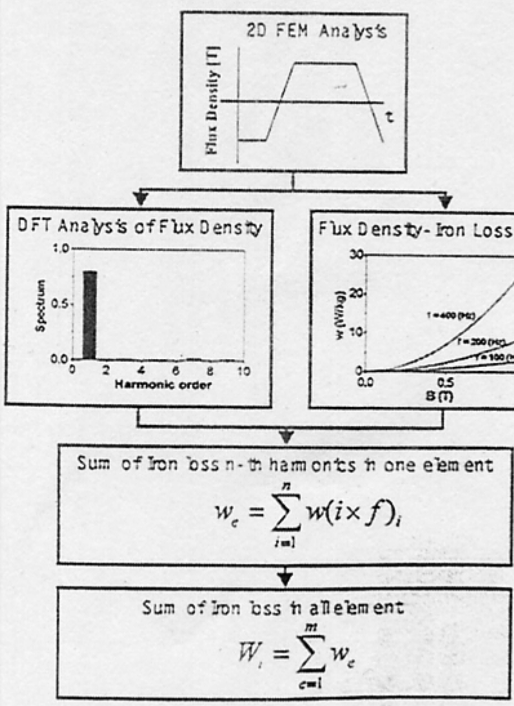

Fig. 3. Flow chart of iron loss computation

This paper presents the loss distribution of 3-phase induction motor comparing PWM inverter and sinusoidal drive. The proposed analysis method and experimental result will be reported in extend paper in detail. And the proposed method is expected that can be applied to other motors.

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Table II. Loss distributions

Power & Loss	Sinewave	PWM (8kHz)
Input power	43163	38135
Primary conductor loss	1190	988
Secondary conductor loss	637	818
Iron loss	640	882
Output power	39640	34391
Efficiency	91.37 %	90.60 %

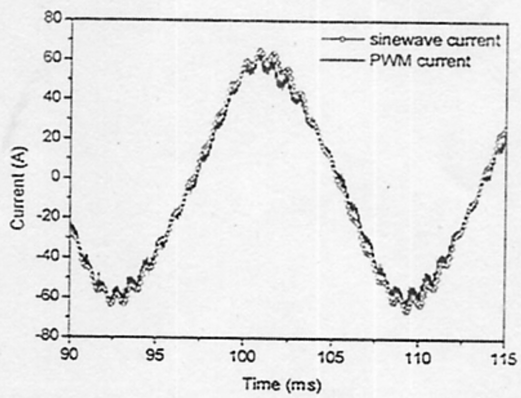

Fig. 4. Current display according to voltage profiles.

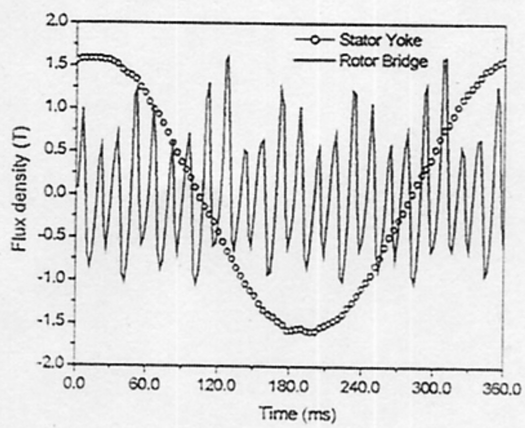

Fig. 5. The flux density waveforms of the stator yoke and the rotor bridge.

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