6ステップインバータ駆動誘導機の振動・トルクリップルの実験的検討

Experimental Study on Vibration and Torque Ripple of 6-Step Inverter Fed Induction Motor

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1. Introduction

Inverter fed induction motor drives have been widely utilized in various industrial applications. According to the prevalence of them, many problems with respect to the electrical and mechanical phenomena have occurred. One of them is mechanical vibration of the machine for the low switching frequency operation, which is the object of this study. In this paper, the authors discuss the mechanical vibration of the induction motor which is caused by the torque ripple and/or the stator flux ripple in the motor.

2. Experimental System

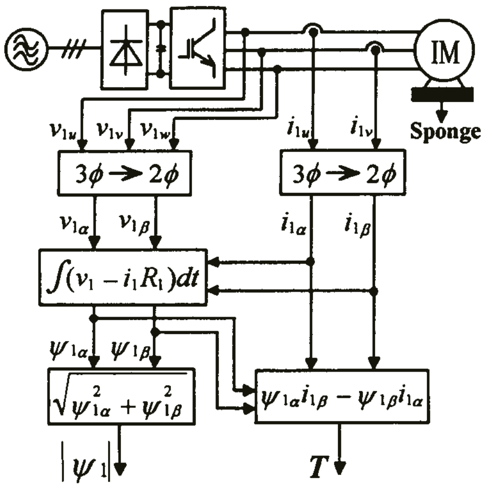

Fig. 1 Experimental system configuration

As shown in Fig. 1, the tested motor - 2.2[kW] 3-phase squirrel-cage type induction motor - is placed on the sponge to reduce the reaction from the rigid ground. The motor is controlled by 3-phase 6-step inverter of which operating frequency is 10[Hz]. The inverter output is composed of 6 different basic steps (101, 100, 110, 010, 011, 001) in one cycle. Therefore, the torque and stator flux of the motor contain the ripples of 60[Hz] components for the most part. The torque and stator flux are calculated from 2-phase stator's voltage and current in the stator reference frame, i.e., α-β coordinates. Accompanied with torque and flux, the mechanical vibration of the motor is also detected. In order to detect the vibration, the acceleration sensor is implemented. Harmonic components of the torque ripple, flux ripple and vibration are measured by the FFT analyzer which indicates these amplitudes in volt unit. The sensor can detect the vibration only in the vertical direction in the unit of times of gravitation. The positions of the sensor are studied to detect the vibration waveforms as correctly as possible. In order to accomplish this purpose, the sensor is attached to the stator at six different places as shown in Fig. 2. Then the torque, flux and vibration of the motor are observed for several dc-link voltage levels.

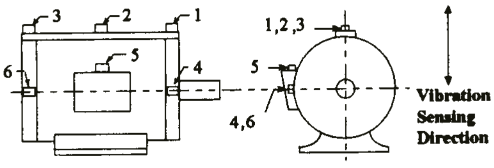

Fig. 2 Positions of the acceleration sensor

3. Results and Data Analysis

Mechanical vibration waveforms from the sensor at the six positions were obtained with the estimated torque and flux. Figure 3A and 3B show the waveforms of the vibration, torque ripple, and flux ripple. The simulated waveforms of the torque and flux are shown in Fig. 3C. From Fig. 3A, it is found that the vibration at position 2 (also 1 and 3) does not have any close relation with both torque and flux ripples. On the other hand, the vibration at position 5 (also 4 and 6) expresses the effect of either torque or flux ripple.

The 60[Hz] components of the torque and flux ripples are plotted against dc-link voltage as shown in Fig. 4A and 4B. The experimental results of vibration at positions 1 to 3 and 4 to 6 are plotted as shown in Fig. 4C and 4D. Referring to the dc-link voltage, the torque and vibration ripples can be written as second order polynomial functions, while the stator flux ripple can be written as a first order polynomial function

As shown in Fig. 4, the vibrations at positions 1 to 3 were not varied with the dc-link voltage. In addition, it was found that the vibrations at these positions were very small. From the results of six positions, the vibrations at positions 4 to 6 which are tangential to the rotation indicate the highest values. From Fig. 5, the coefficient of the correlation at position 5 was about 0.9995, while at positions 1 to 3 were about 0.662, and at positions 4 and 6 were about 0.99. Therefore it can be stated that the position 5 is the best place to detect the vibration and to estimate the pulsating torque without any calculation circuits.

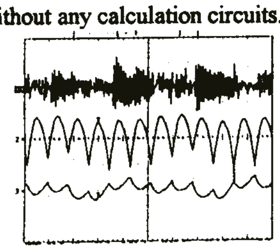

Fig. 3A Experimental result : sensor at position 2

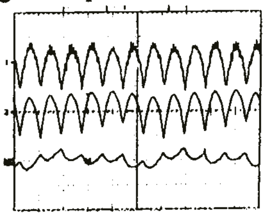

Fig. 3B Experimental result : sensor at position 5

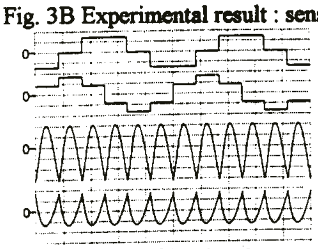

Fig. 3C. Simulated torque and flux

Fig. 3 Waveforms of torque, flux and vibration at operating frequency of 10[Hz]

4. Conclusion

The relation between the vibration and, torque and flux ripples was examined by using the acceleration sensor on the basis of numerical data analysis. As a result, the pulsating torque of the operated motor could cause the motor vibration. Moreover, the vibration should be detected at positions tangential to the rotation, which give the best correlation.

Reference

[1] M. Ishida, S. Higuchi and T. Hori, " Reduction of Mechanical Vibration of Induction Motor with Pulsating Torque Load by Repetitive Control Using Acceleration Sensor ", IPEC-Yokohama '95, pp. 1151-1156

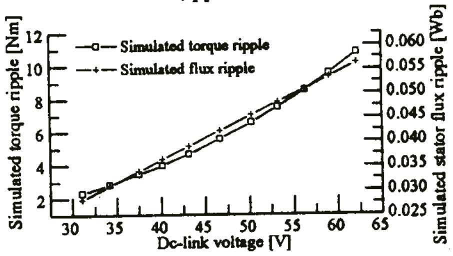

Fig. 4A Simulated torque and flux ripples

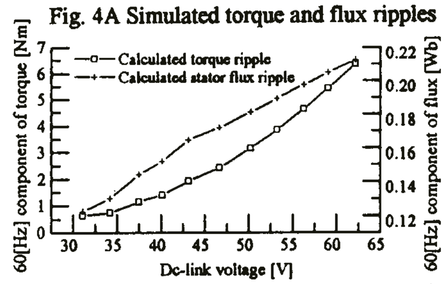

Fig. 4B Experimental torque and flux ripples

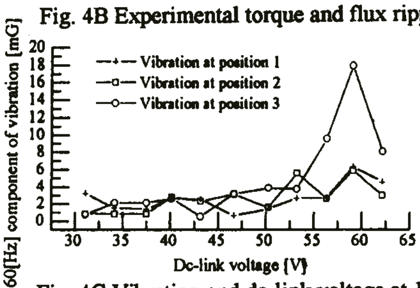

Fig. 4C Vibration and dc-link voltage at 1,2,3

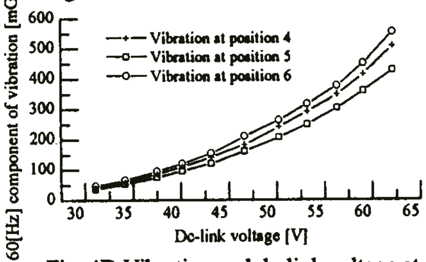

Fig. 4D Vibration and dc-link voltage at 4,5,6

Fig. 4 Vibration, torque and flux characteristics

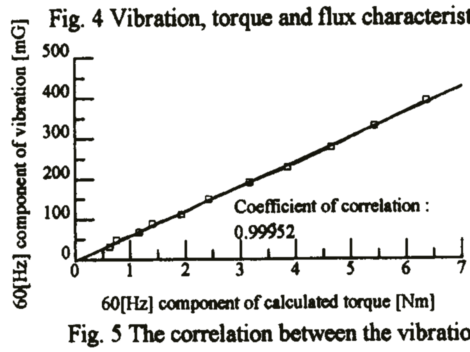

Fig. 5 The correlation between the vibration at position 5 and experimental torque