Characteristics of the Two-phase Induction Motor By the Inverter Fed Control

Byoung-Yull Yang† and Byung-Il Kwon*

Abstract - The single phase induction motor has been commonly applied to small-sized electrical appliances because of its low cost, but it has low efficiency and large torque ripple, and it is incapable of speed control. However, two-phase induction motors have small torque ripple, high efficiency and variable speed control, because they are inverter fed. In this paper, the dynamic characteristics of the two-phase induction motor, such as the torque ripple, current and speed, are analyzed by using the time-stepping finite element method, and compared with the cage-type single phase induction motor.

Keywords: Single phase induction motor, torque ripple, two phase induction motor

1. Introduction

The single-phase induction motor is one of the most widely used types of AC machines. The single-phase induction motor has an advantage of low cost and it is easy to apply in mass productions. Unfortunately, it has several disadvantages such as low efficiency, large torque ripple, and difficulty of controlling motor speed. However, motor speed control is one of the highest featured demands by industries. The commercial usages of single-phase induction motors are various such as for fans, pumps, washers, refrigerators, dryers, treadmills, professional hand tools for automobile accessories, wheelchairs, velocity control for packaging and food processors. Due to the difficulties involved in speed control, single-phase induction motors have been replaced with a two-phase induction motor. The capacitor ensures a "separate" voltage supply for the auxiliary winding, so that the motor can operate as a two-phase induction motor. The optimum capacitance value, in order to achieve a circular rotating flux of high efficiency, depends on the rotor speed. The capacitor value must be determined exactly to satisfy the starting condition (high starting torque and low starting current) [1-6].

Two-phase induction motors contain an inverter and have the same stator and rotor shapes as single-phase induction motors, but they are distinguished from each other by the driving method. The two-phase induction motor starts and rotates by the inverter fed control to achieve different voltages in the main winding and the auxiliary winding.

Even though the three-phase induction motor has the advantages of high efficiency, low torque ripple, and easy control, the two-phase induction motor uses a low cost inverter fed control compared to the three-phase induction motor. The common three-phase motor is the Brushless DC motor.

This paper compares two-phase induction motors with single-phase motors and analyzes the torque characteristic, current, and speed curve for these two types of motors, using the finite element method program.

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2. Modeling

In the single-phase induction motor the main winding and the auxiliary winding have different specifications. Also, it has different types of starting and running capacitors so as to maximize starting torque, and minimize the operating speed pulsation and torque ripple.

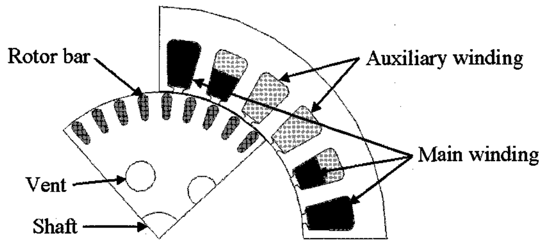
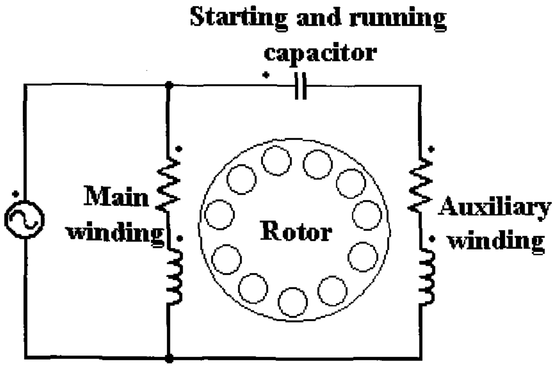


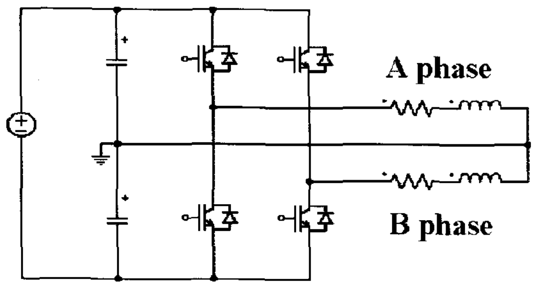
Fig. 1 Shape of the single-phase induction motor

The single-phase induction motor [220 V] that is studied in this paper is used in laundry machines. Since this motor performs frequent forward and backward running, the main winding and the auxiliary winding require the same coil specification in order to match the current and the torque characteristics. The capacitor's capacity is 14[μF] and it is used for the running and starting purposes. In addition, the coil resistance specifications of the main winding and the auxiliary winding are 14.5[Ω] each.

The two-phase induction motor has the same torque, rotor size, and stator core as the single-phase induction motor. However, the two-phase induction motor runs by the PWM inverter fed control, thus the voltage, which supplies the main winding and the auxiliary winding, has a 90° phase difference. As a result, the starting torque generates a steady state with negligible ripples. The voltage is 110[V] and the resistance of each coil is 5.08[Ω]. Fig. 1 shows the shape of the single-phase induction motor.



(a) Circuit of the single phase induction motor



(b) Circuit of the two phase induction motor

Fig. 2 Shape of the single-phase induction motor

Table 1 Specifications of the single and two-phase induction motor

		Single	Two
	Frequency	60	
	Rated torque	1.617	
	Rated speed	1690	
	Core type	S60	
Stator	Winding [Turns/slot]	118	72
	No. of slots	24	24
	Thickness [mm]	47.5	47.5
	Input voltage [V]	220	110
	Resistance [Ω]	14.5	5.08
	Capacitance [μF]	14	-
Rotor	Air gap	0.25	0.25
	No. of rotor bars	36	36

Fig. 2(a) shows circuits of the single-phase induction motor and Fig. 2(b) shows circuits of the A & B phase in the two-phase induction motor.

As it is indicated in the figures, the direct current link capacitor is maintaining half of the maximum voltage, 110[V] in both A and B phases. When supplying half of the DC voltage in each phase directly, there is an arbitrary grounding between the A phase and the B phase by disconnecting the middle of the A phase and the B phase. Table 1 offers specifications of single and two-phase induction motors.

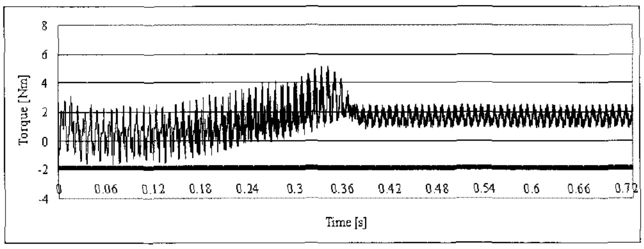
3. Result of Special Quality Analysis

3.1 Result of the characteristic in the load

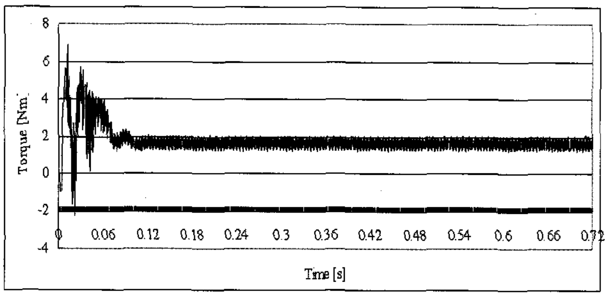
Fig. 3 represents the torque characteristic curve of single-phase and two-phase induction motors.

As shown in Fig. 3(a) and (b), torque pulsation of starting and running of the two-phase induction motor is smaller than those of the single-phase induction motor. In addition, it takes a shorter time until they reach steady state. Generally, the single-phase induction motor attaches PTC in the starting and running capacitors. However, the motor that is used in this paper is a laundry machine type single-phase induction motor, which only utilizes one large-capacity capacitor. These types of motors have the characteristic of a large phase angle difference between the main winding and the auxiliary winding. Therefore, the two-phase induction motor that controls the phase angle (90 degree) without the starting capacitor has small torque.

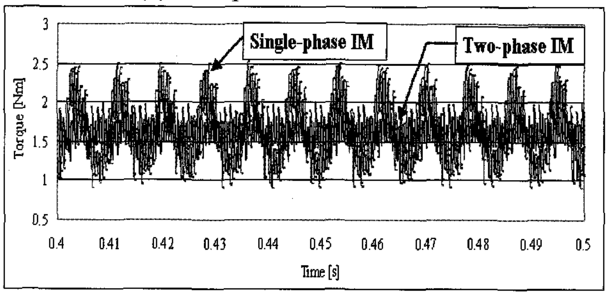
Fig. 3(c) and (d) describe details of magnitude of torque ripple between the single-phase induction motor and the two-phase induction motor during normal operation and also describe details of magnitude of the fast fourier transform (FFT) curve. At the FFT curve, peek value of the single-phase induction motor is shown at the 3rd and 26th harmonics and peek value of the two-phase induction motor is shown at the 25th harmonic, and the average value of the two-phase induction motor is 0.201[mNm] and the average value of the single-phase induction motor is 0.462[mNm]. Therefore the PWM inverter fed control reduces the torque ripple by 56%.



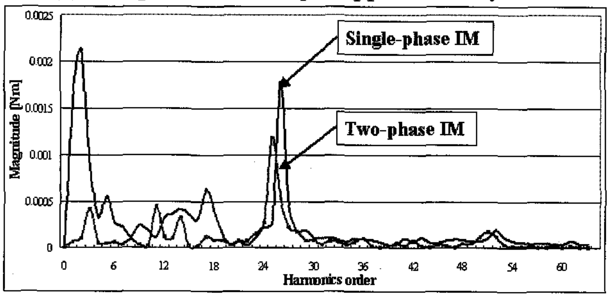
(a) Single-phase induction motor



(b) Two-phase induction motor



(c) Comparison the torque ripple in steady state



(d) Fast Fourier transform curve of the torque ripple

Fig. 3 Torque characteristic curve (Load: 1.617[N·m])

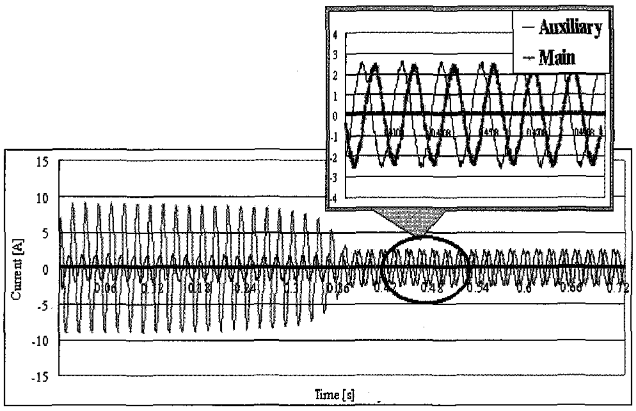
Fig. 4 presents the current characteristic curves of the single-phase induction motor and the two-phase induction motor.

Because the motor has the largest resistance impedance, inductance at the starting region in Fig. 4(a) has a similar amount of input voltage divided by coil resistance value during the running. However, the current in the auxiliary winding is 5 times higher than the main winding current because of the inverse of the coil resistance and capacitance.

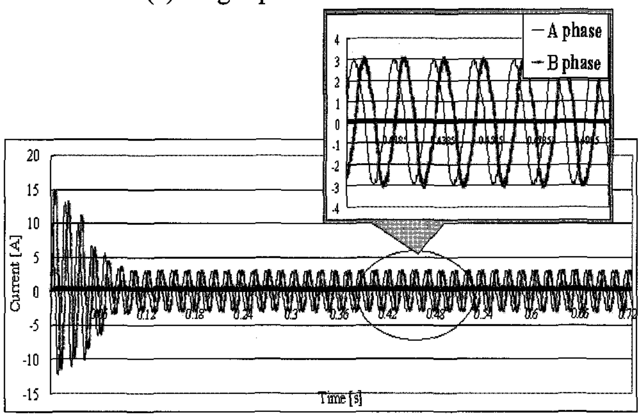
Because the two-phase induction motor has the same resistance at A phase and at B phase, in Fig. 4(b), the A phase current and the B phase current have similar characteristic curves.

During normal operation, the currents of the single-phase induction motor and the two-phase induction motor are 1.6[A] and 2.05[A] each. The input voltage of each coil in the two-phase induction motor is $0.5V_{ac}$, so that the impedance of the motor in the coil is decreased and the current is amplified in each phase.

Fig. 5 represents the speed characteristics of the single and the two phase induction motors. The two-phase induction motor arrived at a steady state more rapidly than the single-phase induction motor.

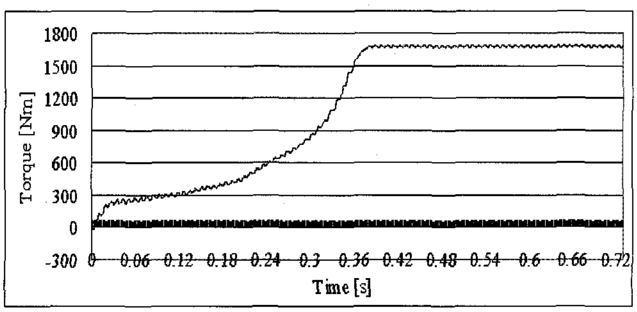


(a) Single-phase induction motor

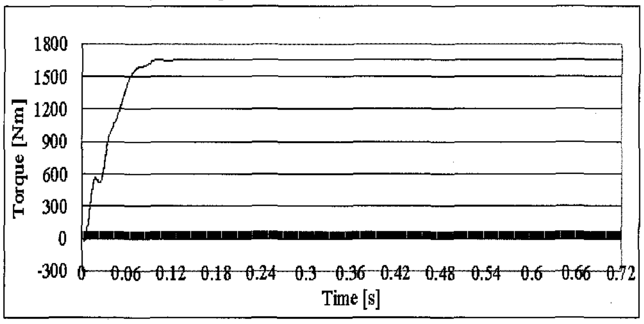


(b) Two-phase induction motor

Fig. 4. Current characteristic curve (Load: 1.617[N·m])



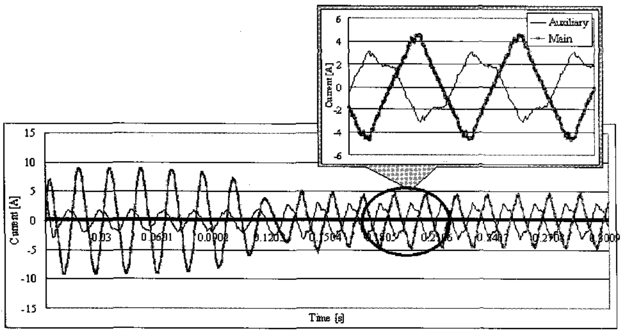
(a) Single-phase induction motor



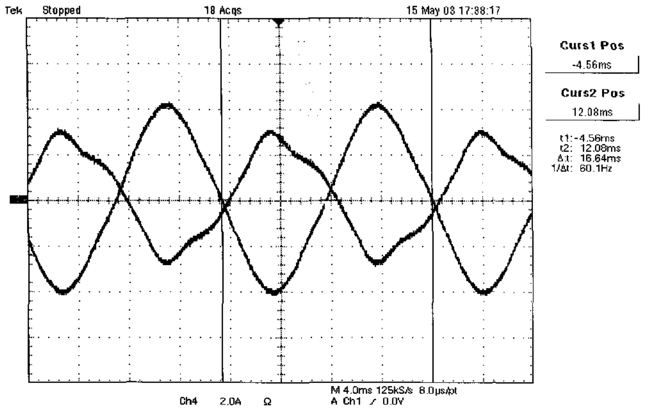
(b) Two-phase induction motor

Fig. 5 Current characteristic curve (Load: 1.617[Nm])

3.2 Result of the characteristic during No-Load

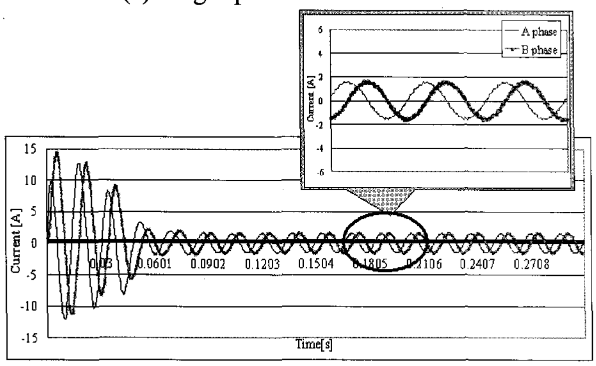


(i) simulation result

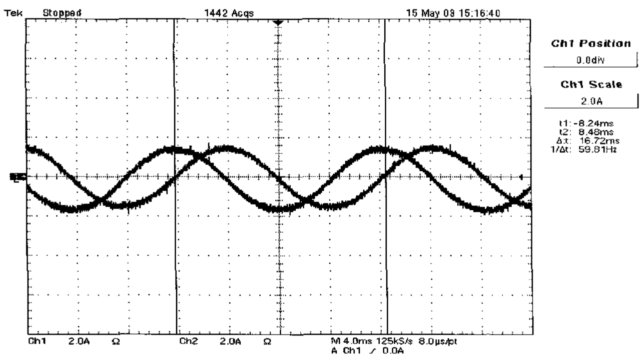


(ii) experiment result

(a) Single-phase induction motor



(i) simulation result



(ii) experiment result

(b) Two-phase induction motor

Fig. 6 Current characteristic curve (No-load)

Fig. 6 shows the current wave-shapes of a single-phase and two-phase induction motor during no-load. The peak values of the current of the main winding and auxiliary winding have 5% differences between the experimental and the simulation result.

Also, Fig. 6(a) indicates the possibility of minor error. These errors might be caused by not considering the skew of the aluminum bar during analysis.

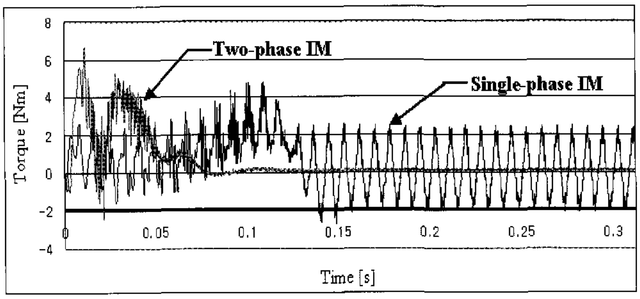


Fig. 7 Torque characteristic curve

In addition, the two-phase induction motor has a smaller torque ripple than the single-phase induction motor. It reaches a steady state in shorter time due to large torque during initial operation, as illustrated in Fig. 7.

4. Conclusion

This paper compared a two-phase induction motor with a single-phase induction motor under load and non-load conditions. The two-phase induction motor has many advantages compared to the single-phase induction motor, such as the torque ripple, the response speed and the consumption of electric power. The torque ripple is reduced by 56%, and electric power is reduced by 30%.

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