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メタデータ	言語: eng
	出版者:
	公開日: 2017-10-03
	キーワード (Ja):
	キーワード (En):
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	所属:
URL	http://hdl.handle.net/2297/48314

NEW HIGH-SPEED INDUCTION MOTOR DRIVEN BY A COMMERCIAL SOURCE

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Abstract - This paper described the structure and characteristics of a new high-speed induction motor. The motor has the magnetic combination of an induction motor and a magnetic frequency tripler and is called a "hybrid motor". When the three-phase to two-phase type tripler we proposed is adopted, this rotating-field type hybrid motor can be constructed. The motor has remarkable starting torque and operates near synchronous speed (10800rpm) by only an application of a 60 Hz commercial source. It is noted that the motor has no semiconductor device and a brushless structure.

INTRODUCTION

The authors have developed the magnetic frequency multiplier(frequency tripler) for the application of high-speed motor operation. Since both the magnetic tripler and the motor have each magnetic circuit, the magnetic combination can simplify the structure. In the previous paper [1], we reported the high-speed induction motor of a single phase and call it "hybrid motor". But the single-phase induction motor has one unavoidable defect, that is, starting torque. In order to remove it, we propose the rotating-field type hybrid induction motor and discuss the characteristics.
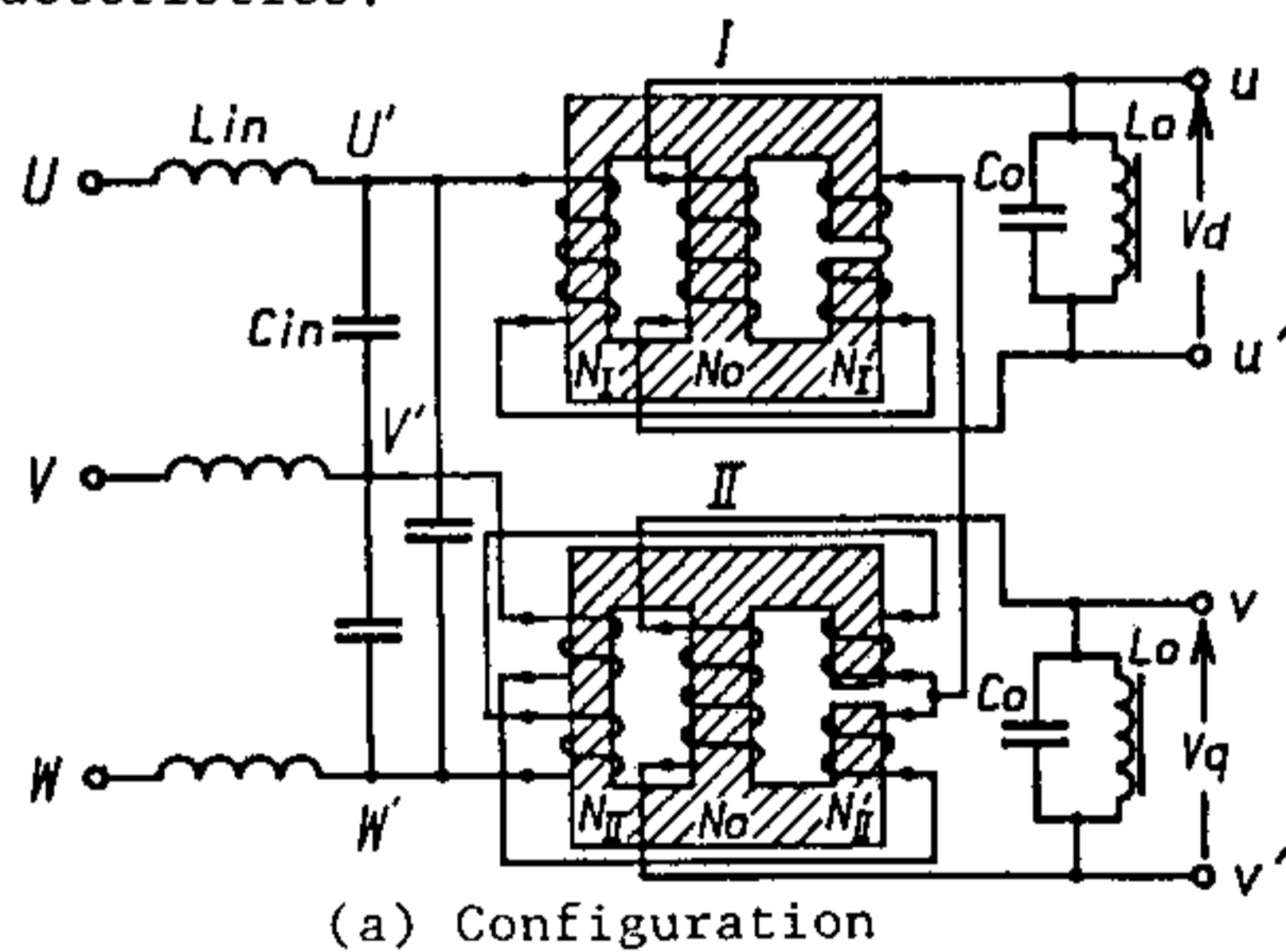
(a) Configuration
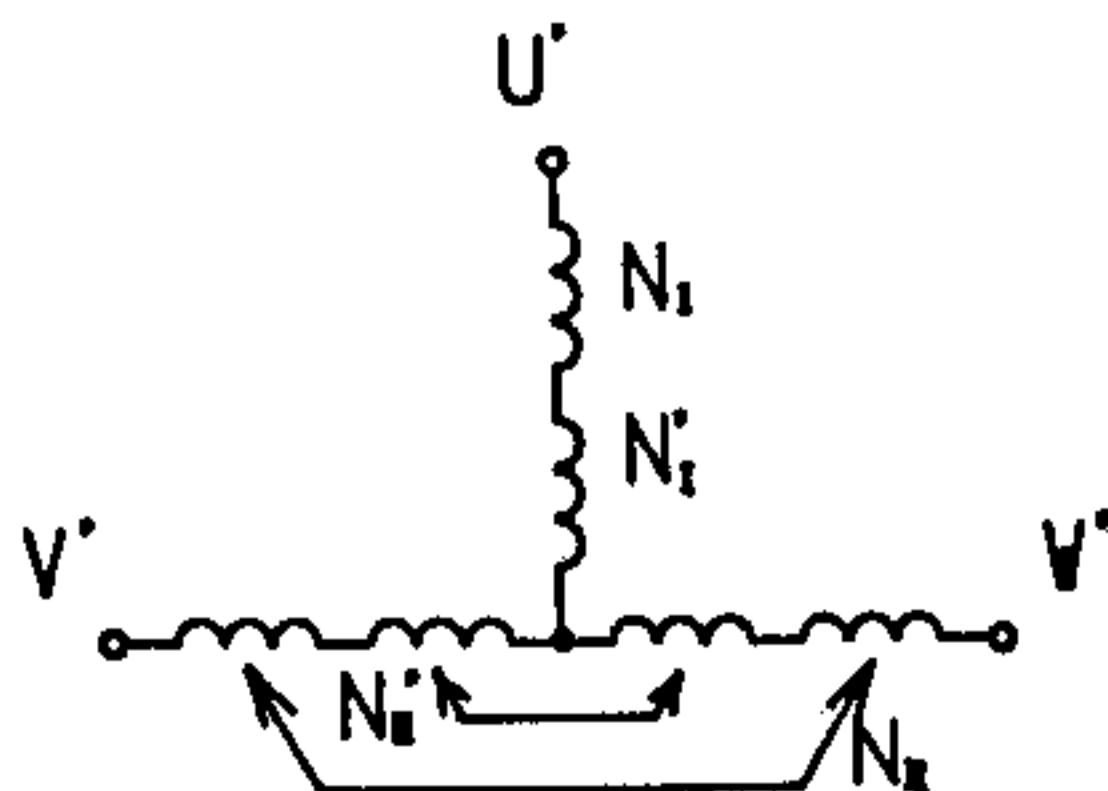
(b) Scott-connection in the primary windings

Fig.1 Three-phase to two-phase magnetic tripler

STRUCTURE OF ROTATING-FIELD TYPE HYBRID INDUCTION MOTOR

(1) Three-phase to two-phase tripler

Figure 1(b) shows the three-phase to two-phase magnetic frequency tripler. In this configuration, two single-phase triplers(I, II) composed of 3-legged cores are connected in Scott-connection(Fig.1(b)). The circuit(Lin-Cin) improves the power factor and expands the range of a operating input voltage. The parallel resonant circuit(Lo-Co) enhances the third harmonic voltage. The characteristics of the single-phase tripler are described in the literatures.[2,3] The two-phase input voltages shifted at 90 degree are applied to two triplers. The output voltage of one tripler is given as,

$$V_d(t) = \sum_{n=1}^{\infty} V_{2n-1}\sin\{(2n-1)\omega t + \theta_{2n-1}\} \quad \ldots(1)$$

where n, θ_{2n-1} and V_{2n-1} are integer, phase difference and peak value of each harmonic respectively. As two triplers have the same structures, the output voltage of the other is expressed as,

$$V_q\{t+(\pi/2\omega)\} = \sum_{n=1}^{\infty} V_{2n-1}\sin\{(2n-1)\omega t+(2n-1)\pi/2+\theta_{2n-1}\} \quad \ldots(2)$$

Therefore, two third harmonic components of output voltages (Vd, Vq) have the phase difference of 270 degree as a two-phase source. The phase sequence of a three-times frequency voltage rotates reversely against a fundamental frequency voltage.

(2) Structure of a new hybrid induction motor

The structure and dimensions of the hybrid induction motor made are shown in Fig.2. The new induction motor has the magnetic combination of an induction motor and a magnetic frequency tripler in structure. The motor has two pairs of magnetic frequency multipliers (I, II) in four magnetic poles as shown in Fig.2(a). In each pole, the middle leg has a air-gap and the legs at both sides operate in magnetic saturation. The symmetrical configuration offers the stout structure. In operation, the magnetic poles(I, II) correspond to the triplers(I, II) in Fig.1. But comparing the flux paths, the third harmonic flux generated at the poles flows through the rotor and the yoke in the motor.

Figure 2(b) shows the connection diagram between two poles. The coils at two poles are connected in the Scott-connection and the relations between numbers of turns at each coil are expressed as,

$$N_I = \sqrt{3}/2 N_{II}, \quad N_I' = \sqrt{3}/2 N_{II}' \quad \ldots(3)$$

The capacitor Co is connected to the coil Nc. The reactor Lo in Fig.1 corresponds with that
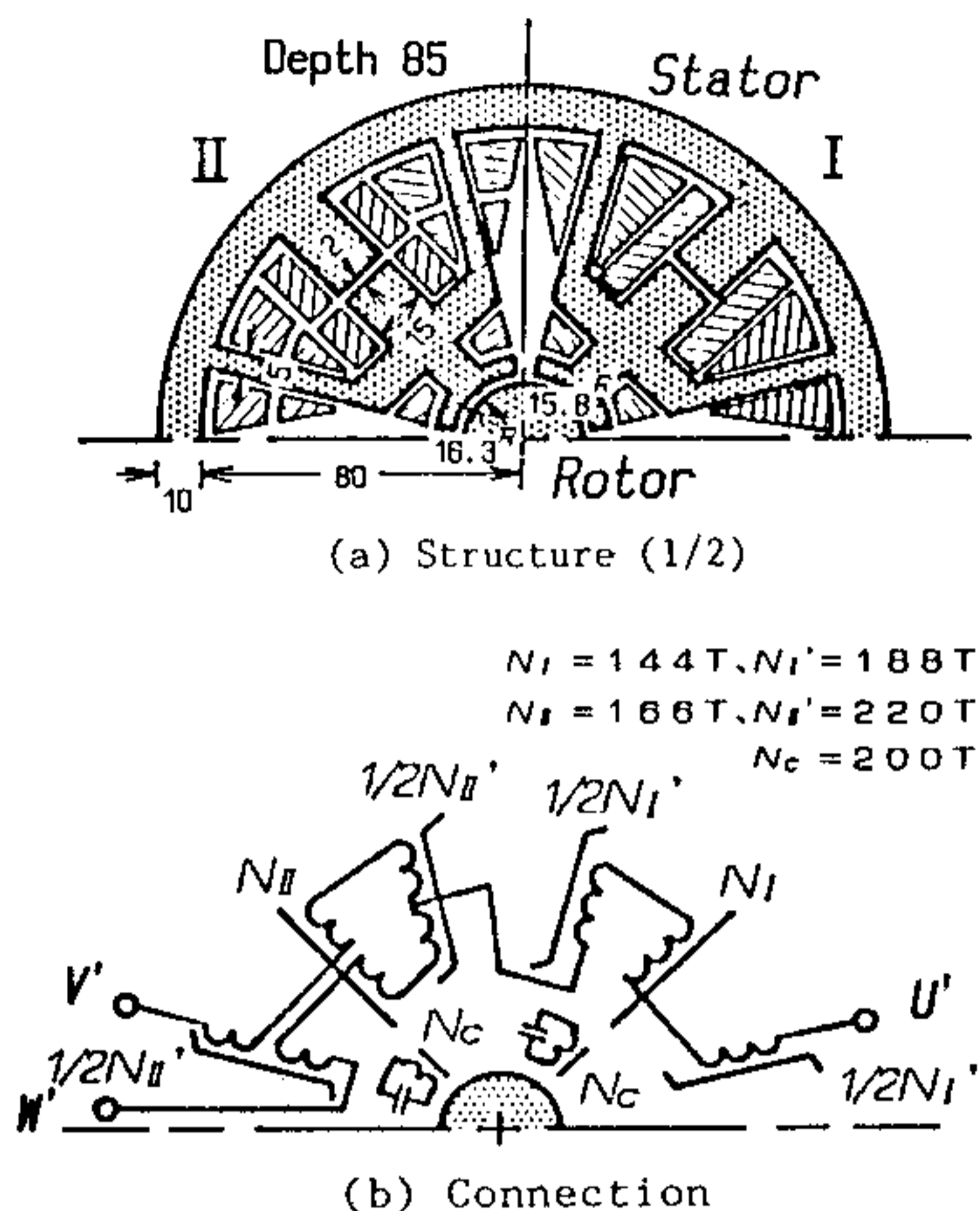
Depth 85   Stator

II   I

Rotor

(a) Structure (1/2)

$N_I = 144T, N_I' = 188T$
$N_{II} = 166T, N_{II}' = 220T$
$N_c = 200T$

(b) Connection
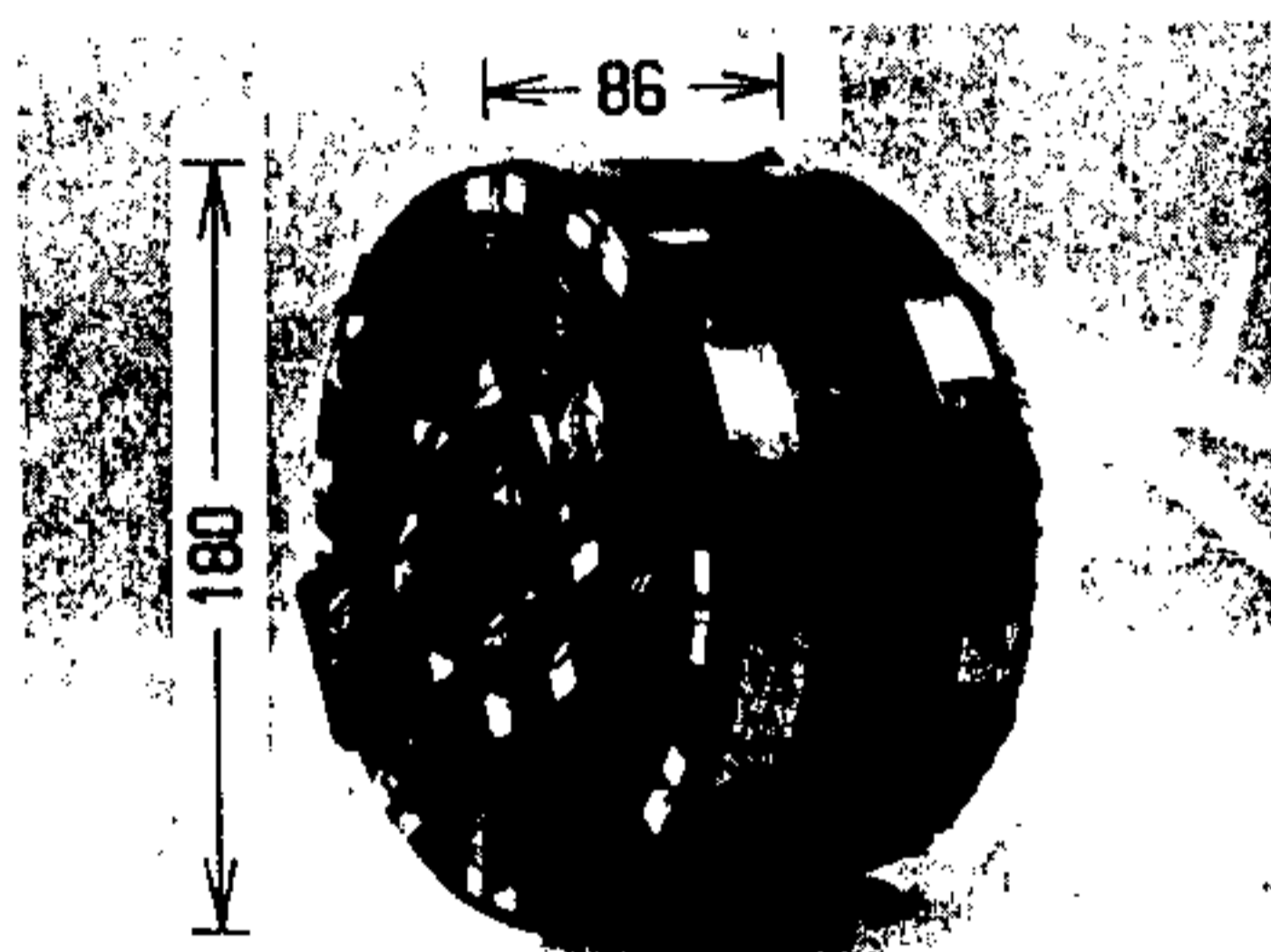
Fig.2 High-speed hybrid two-phase induction
motor

Fig.3 Photograph of a new motor

based upon the gap between a stator and a
rotor. The resonance(Co-Lo) enhances the three-
times frequency flux through the rotor and the
pole. The circuit(Lin-Cin) is separately
connected to terminals(U', V', W').
' The photograph of the tested motor is
shown in Fig.3. The stator is made of 0.35mm
silicon steel. The rotor is the conventional
squirrel-cage type for commercial frequency.

CHARACTERISTICS OF A HYBRID INDUCTION MOTOR

(1) Characteristics

When a 60Hz commercial source is applied
to the hybrid motor and the rotor is locked,
the characteristics as triplers are measured at
the coil Nc. Figure 4 shows the frequency
components of voltages as a function of an
input voltage. For simplicity, the circuit
(Lin-Cin) is removed. As the legs in the pole
are saturated with increasing input voltage,
the harmonics are generated and the Lo-Co
resonant circuit enhances the third harmonic
component. However, a fundamental and other
harmonic voltages can not be suppressed.
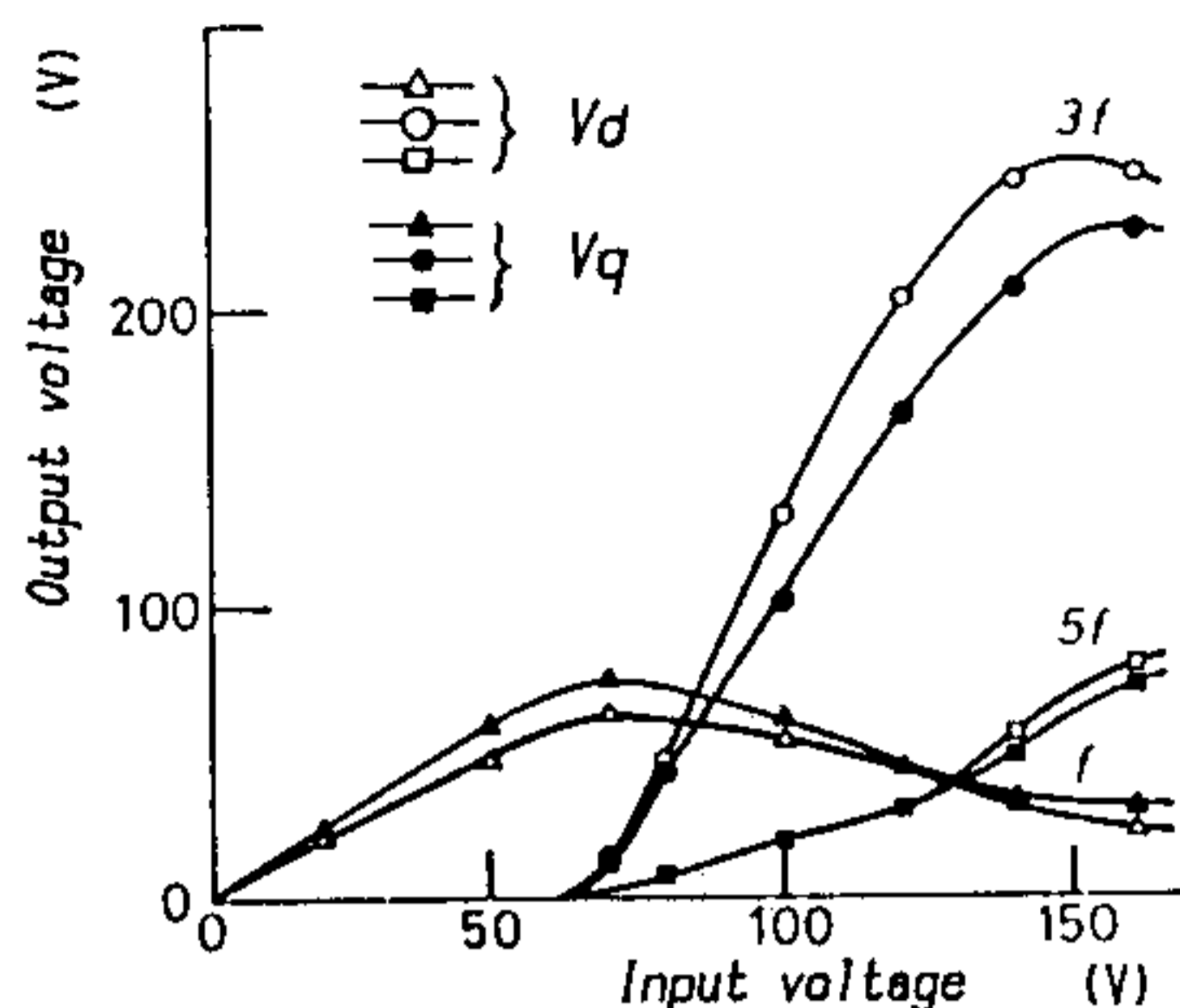Figure 5 shows the Lissajous'figure of voltages

Fig.4 Frequency components of the output
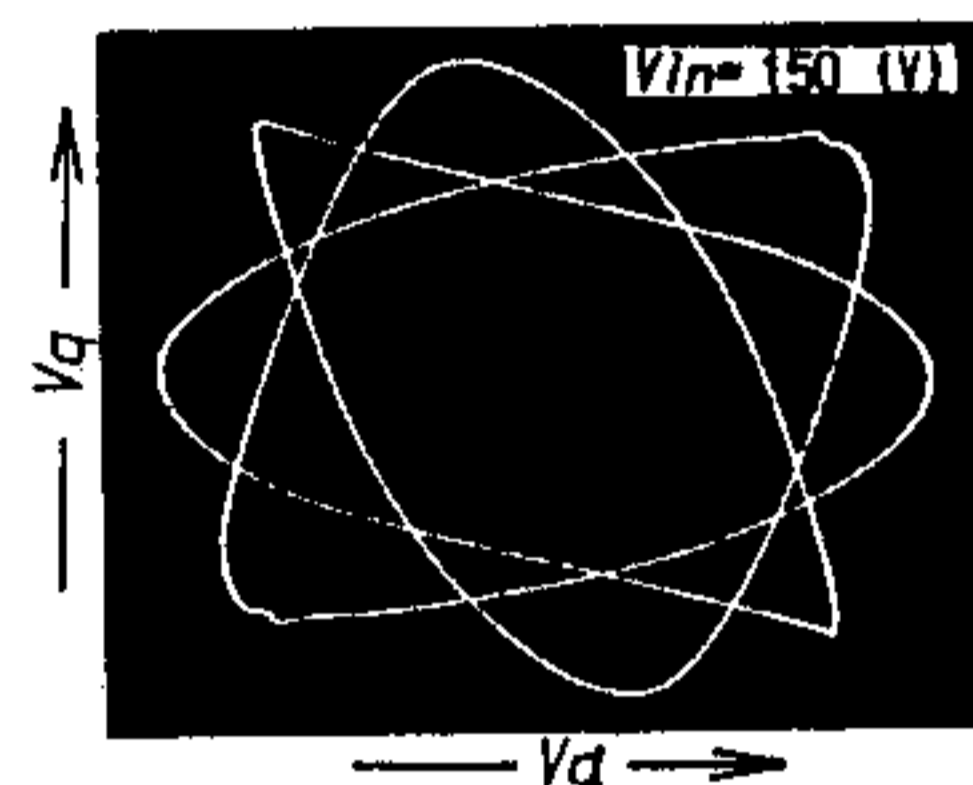voltages at the windings Nc as a
function of an input voltage

Fig.5 Lissajous'figure of output
voltages V_d, V_q

Vd and Vq. The fundamental component mainly
disturbs the waveform of third harmonic
voltages.
Figure 6 shows the relation between an
input voltage and a rotational speed. As an
input voltage is low (Vin<120V), the
fundamental component of the flux at the poles
is major and the rotor rotates near the
3600rpm. As an input voltage increases more
than 120V, the third component produces a high-
speed rotation near 10800rpm. The negative
value of the rotational speed indicates the
reverse of the rotation direction.
Figure 7 shows the torque-speed
characteristics. As the results, the curve is
similar to one of a three-phase induction
motor. The starting torque of the hybrid motor
is remarkably increased in comparison with the
former. The fundamental component decreases the
torque near a rotational speed of 3600rpm. The
maximum mechanical output and efficiency are
158W , 12.5%.

(2) Analysis of the torque-speed curve

To examine the basic characteristics of
the hybrid motor, the equivalent circuit for
the third harmonic component is introduced.
Figure 8 shows the basic equivalent circuit for
each pole of the two-phase motor. The right-
side circuit is for the tripler on the magnetic
pole. The equivalent circuit of the rotor is
similar to the conventional one. The value s
indicates the slip of rotor.
Figure 9 shows the characteristics of
third harmonic as a function of a resonant
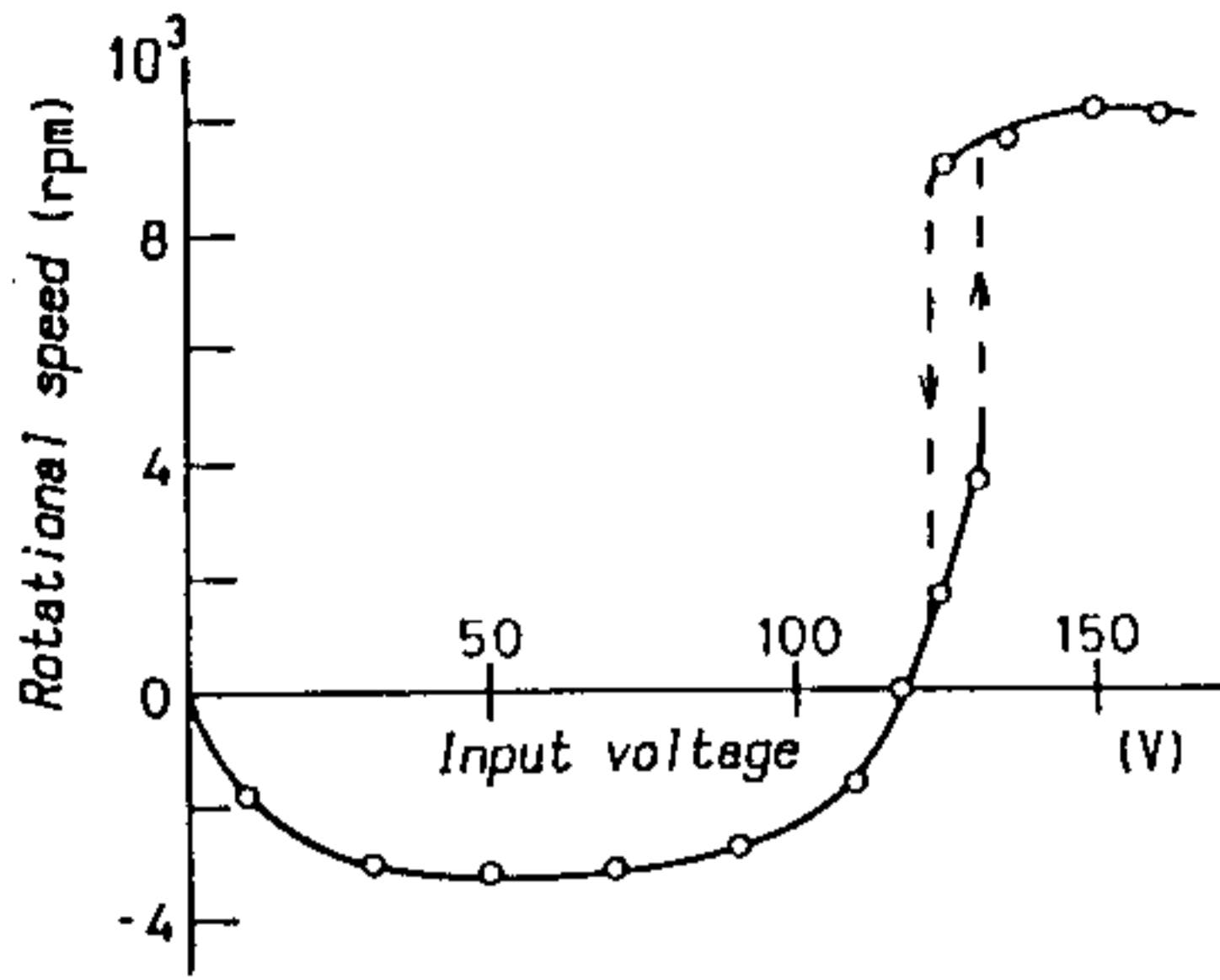capacitor on the lock test(slip s=0). The same
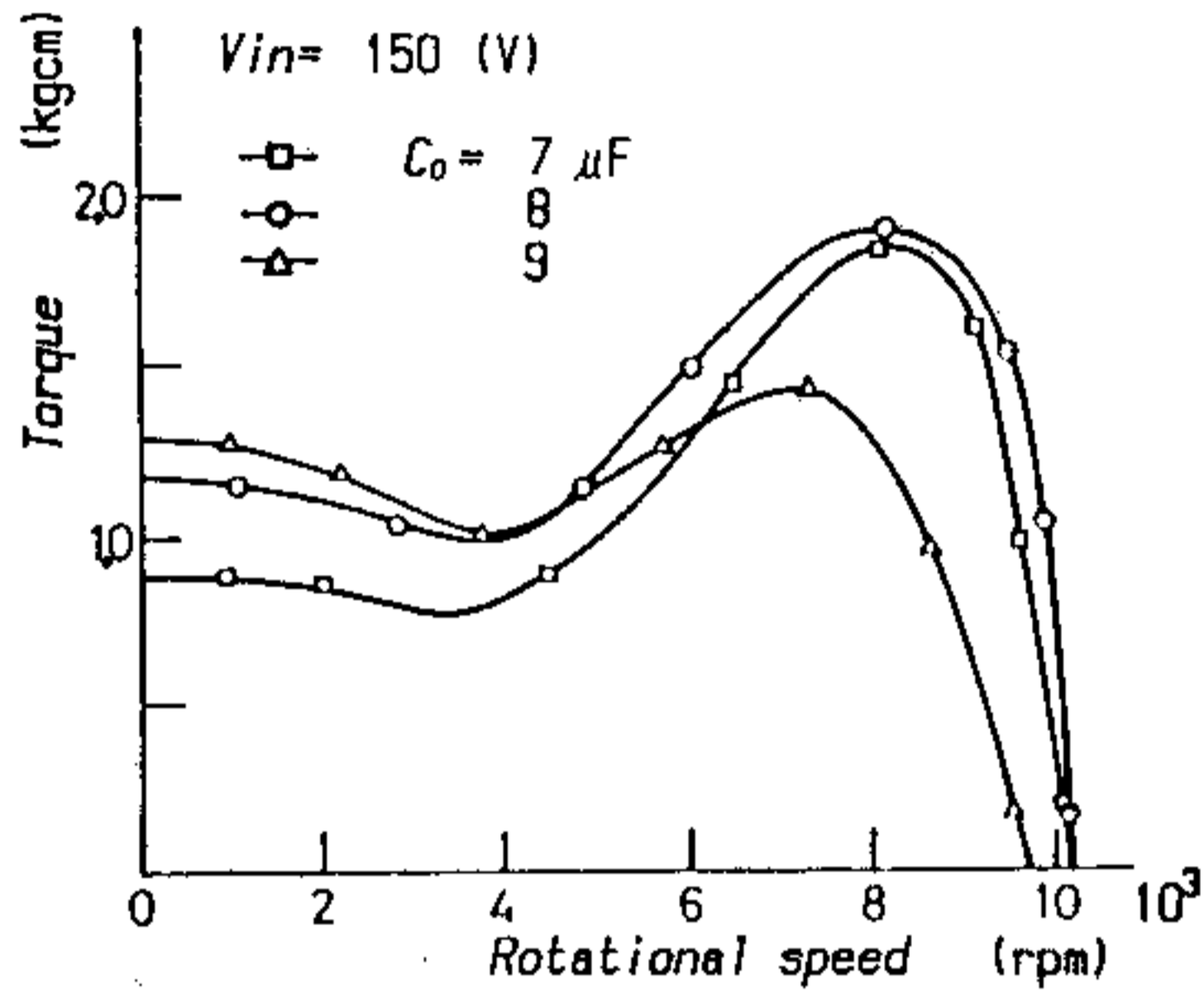
Fig.6 Rotational speed vs. input voltage

Fig.7 Torque-speed characteristics

Fig.8 Equivalent circuit of the motor for third harmonic

Fig.9 Third harmonic of output voltages as a function of resonant capacitor Co

Fig.10 Torque-speed curve calculated at the equivalent circuit

characteristic is measured on the no-load test(slip s=0). As the results, values of the elements are obtained as,

$$J = 0.9 \text{ A},$$
$$g_o = 1.5 * 10^{-3} \text{S}, \quad b_o = 8.65 * 10^{-3} \text{S}, \quad ...(4)$$
$$r_2 = 285 \ \Omega, \quad x_2 = 320 \ \Omega$$

where each value is converted on the winding Nc.

Figure 10 shows the torque-speed curve calculated on the equivalent circuit. The curve corresponds to the experimental characteristics shown in Fig.7. Comparing two curves, the characteristics are similar each other on a high-speed operation but the decrease of the torque is remarkable below the rotational speed 8000 rpm. The fundamental component distinctly decreases the torque. It is important to reduce the fundamental component of flux for the improvement of a torque characteristic.

CONCLUSIONS

The new high-speed motor with the combination of a magnetic frequency tripler and an induction motor has been proposed. The motor has the high-speed operation and the high starting torque by supplying only the 60Hz commercial source.

Compared with a conventional high-speed motor, the motor has the defects to improved. But as the motor has no semiconductor device and the brushless structure, it may be possible to apply it to the high-speed motor under a bad environment.
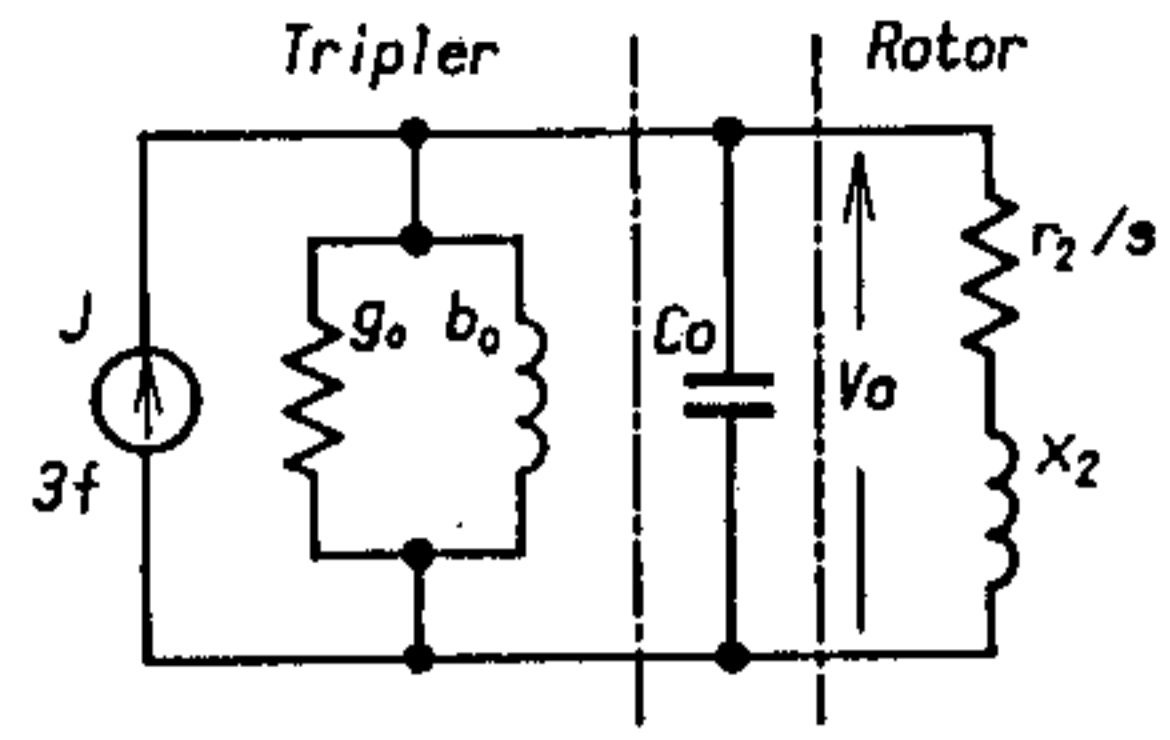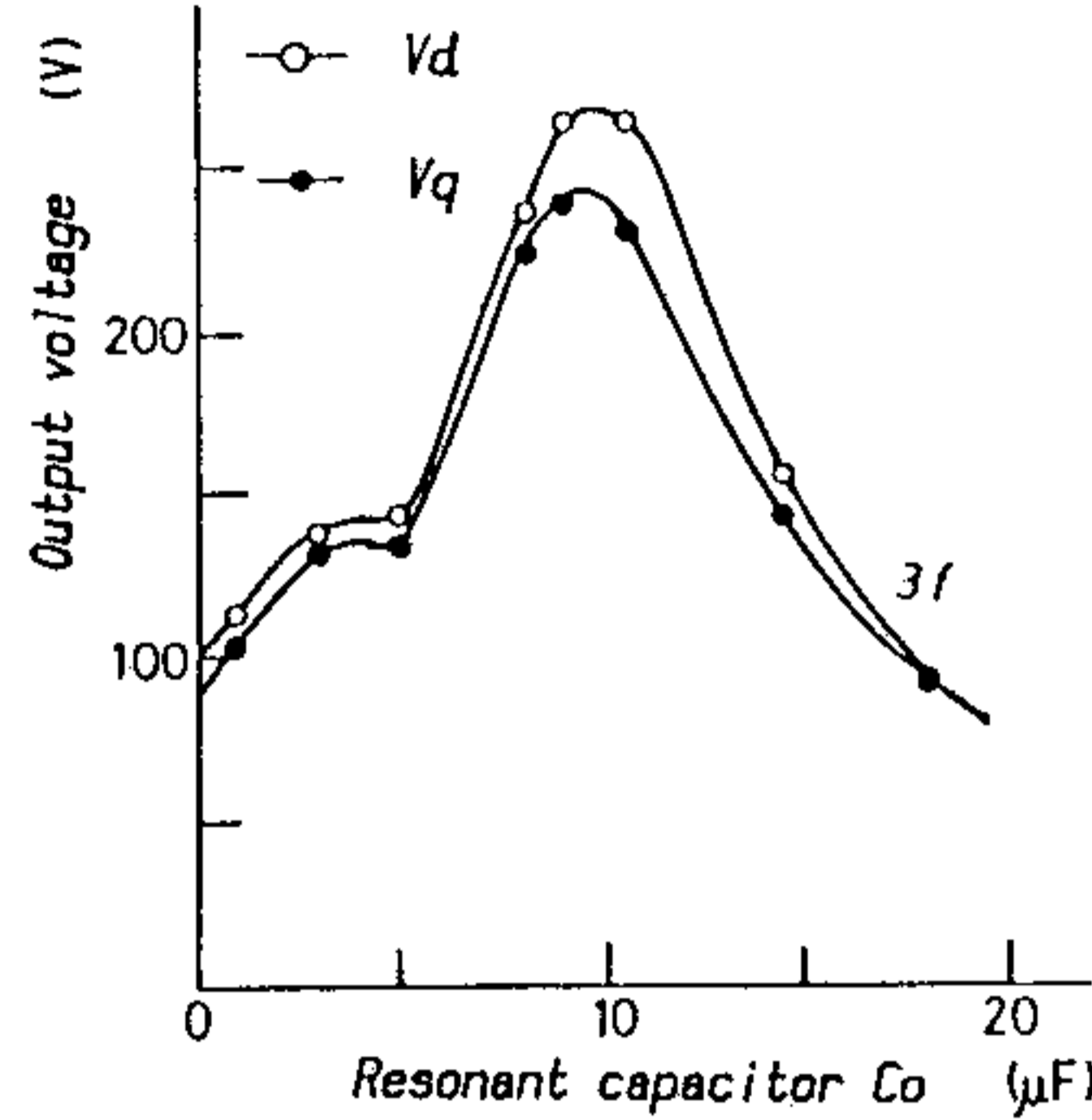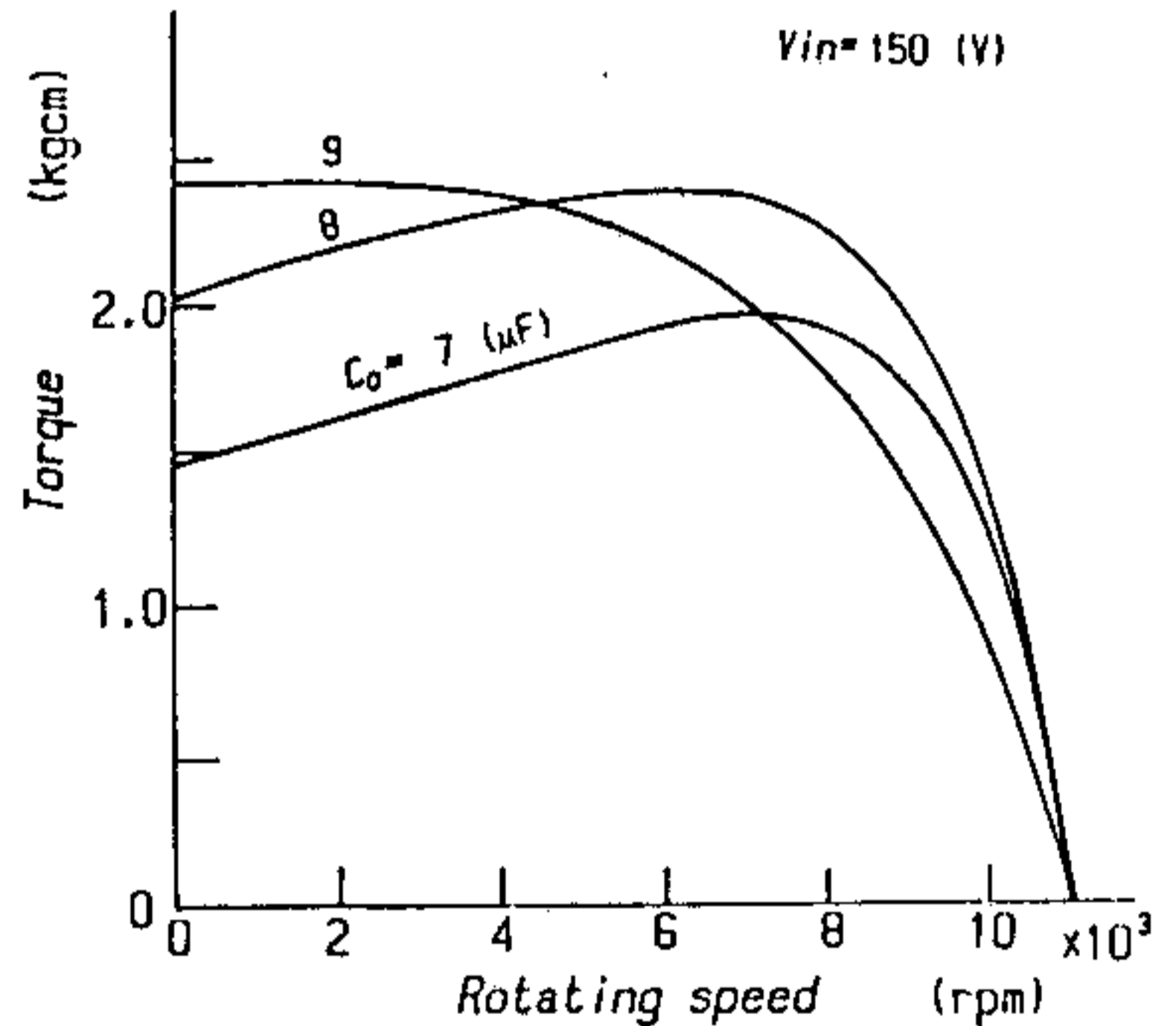
REFERENCES

[1] S.Yamada, A.Takeuchi, T.Sudani, K.Bessho ; "High-speed AC Motor Including the Function of a Magnetic Frequency Tripler", IEEE Trans. Magnetics, Vol.MAG-22, No.5, 967-989, '84.

[2] K.Bessho,S.Yamada,T.Sudani,Y.Kanamaru;"Some Experiments and Considerations on the Behavior of a New Magnetic Frequency Tripler with Bridge-connected Reactor Circuit", IEEE Trans. Magnetics, Vol.MAG-12, No.6, 829-831, '76.

[3] T.Sudani, S.Yamada, K.Bessho: "Numerical Analysis of a New Magnetic Frequency Tripler with Series-connected Reactors", IEEE Trans. Magnetics, Vol.MAG-15, No.6, 1788-1790, '79.