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AC SPINDLE DRIVE SYSTEM FOR MACHINE TOOL FRENIC 5000V2/VH2

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1 FOREWORD

As spindle driving unit of NC machine tools, up to now, the spindle drive has been DC spindle drive system, which was a combination of completely laminated stator type DC motor with small-sized and high-performance thyristor Leonard equipment, improving in large scale the functionality and performance of the machine. But later, together with the development of FMS and FA systems, the improvement of performance of machine tools continued and, as the result, still higher performance and freedom from maintenance and higher speed were demanded for spindle drive system. In response to this demand, Fuji Electric has produced and commercialized the AC Spindle Drive System that is a combination of cage rotor type induction motor and vector-controlled transistor inverter.

This AC Spindle Drive System has an equal or more rapid response than that of DC Leonard equipment and answering the demand of the market, Fuji Electric has come to enlarge their capacities and heighten their speed and serialized the products. In the following, characteristics, specifications and performance of the AC Spindle Drive System of FRENIC 5000V2/VH2 Series.

2 SPECIFICATIONS AND FEATURES

Fig. 1 shows an outer view of FRENIC 5000V2/VH2, and *Table 1*, standard specifications. The features of the series are as follows:

(1) Wide adjusting speed control

Standard output range of the 5000V2 series is from 3.7 to 45 kW, and 2.2 to 5.5 kW for 5000 VH2 series, so that the machines can be applied for various range of spindle driving.

(2) Wide speed changing range

The field-weakening control range for 5000V2 is 1:4 and for 5000VH2, it is still further expanded to 1:8, so that the speed-changing mechanism on the machine spindle side can be far more simplified.

(3) Small torque ripple

By high-speed PWM control and sinusoidal wave current control, sinusoidal-wave current having little ripple is supplied to the spindle motor, torque ripple that constitutes a cause of gear noise and vibration is extremely few.

(4) Use of specially designed motor

The spindle motors are designed to reduce noise and vibration and, at the same time, by adopting unique cooling mechanism, temperature rise in the shaft end and flange is suppressed.

Fig. 1 FRENIC 5000V2/VH2 AC spindle drive system

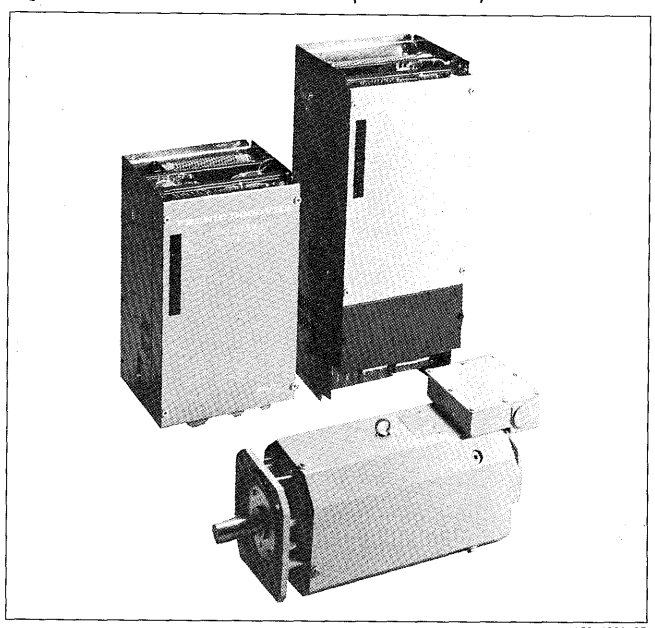

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Fig. 2 Composition of magnetic sensor system orientation

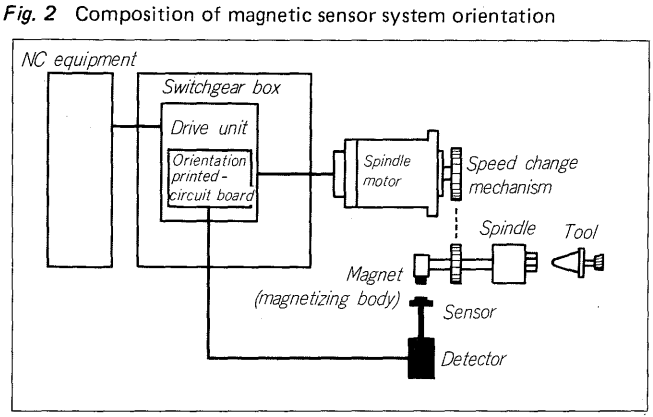


Table 1. Standard specifications

Series name		FRENIC 5000V2										FRENIC 5000VH2		
System name FSD-		5A	7A	11A	15A	18A	25A	30A	37A	45A	55A	3 AH	5 AH	7 AH
AC spindle motor	Continuous rating output (kW)	3.7	5.5	7.5	11	15	18.5	22	30	37	45	2.2	3.7	5.5
	30-min. rating 50% ED output (kW)	5.5	7.5	11	15	18.5	25	30	37	45	55	3.7	5.5	7.5
	Fundamental speed (rpm)	1,500						1,200		1,000		1,500		
	Maximum speed (rpm)	6,000						4,800		4,000		12,000		
	Model MPF	1114	1116	1134	1136	1138	1168	1186	1188	1208	1224	2114	2116	2118
	Continuous rating torque (kg·m)	2.40	3.57	4.87	7.14	9.74	12.0	17.9	24.4	36.0	32.8	1.43	2.40	3.57
	GD^2 (kg·m²)	0.10	0.14	0.18	0.24	0.30	0.43	0.83	1.02	2.08	3.04	0.040	0.055	0.070
	Approximate weight (kg)	65	75	100	110	130	165	245	325	400	440	55	65	75
	Cooling fan capacity	1 φ, 50 W		1 φ, 100 W				3 φ, 50/80 W		3 φ, 80/120 W		1 φ, 50 W		
	Vibration	V5		V10								V5		
	Noise	75 dB(A)		80 dB(A)								75 dB(A)		
	Overload capacity	30 min. 50% ED, 120% of rated value, one minute												
	Mounting system	Foot mounting type (F11, F12), Flange type (L51, L52)										Flange type (L51, L52)		
	Color of paint	Munsell N5												
	Accessories	Forced cooling fan, pulse generator, thermistor.												
	Installing place	Indoors, altitude: 1,000 m or less												
	Ambient temperature and humidity	−10 to +40 °C, 20 ~ 90% RH (No condensation allowed)												
Drive unit	Model FSD-	5AR-22	7AR-22	11AR-22	15AR-22	18AR-22	25AR-22	30AR-22	37AR-22	45AR-22	55AR-22	3AH-22	5AH-22	7AH-22
	Power source capacity (kVA)	9	12	17	22	28	37	45	55	67	82	6	9	12
	Power supply	3 φ, 200/220 · 230 V±10%, 50/60 Hz + 2 Hz ~ −3 Hz												
	Generated heat value (W)	340	420	530	750	1,000	1,300	1,600	2,100	2,500	3,000	200	340	420
	Approximate weight (kg)	28	28	40	40	60	60	80	80	140	140	28	28	40
	Main circuit system	Transistor system sinusoidal-wave PWM type VVVF inverter												
	Control system	Trans-vector control												
	Drive system	Reversible 4-quadrant operation												
	Braking system	Regenerative braking												
	Speed control range	45~6,000 rpm						36~4,800 rpm		30~4,000 rpm		90~12,000 rpm		
	Speed control precision	Maximum speed ±0.5% (condition: load variable, 10~100%; power supply variable, ±10%; ambient temperature, 0~40° C)												
	Speed command input	Analog: 10 V/maximum speed, Digital: 12 bits binary or BCD 2 digits												
	Accelerating/decelerating system	Current limiting acceleration/deceleration												
	Color of paint	Munsell N1.2 semi-gloss (Cover: Munsell 1 PB5/1.3 leather satin)												
	Option	Soft start/soft stop function, D/A converter element, electric orientation												
	Installing place	Indoors, altitude: 1,000 m or less												
	Ambient temperature and humidity	0 ~ +55°C, 20 ~ 90% RH (no condensation allowed)												

(5) Regenerative braking

For both 5000V2 and 5000VH2 series, a power supply regenerative braking is adopted for all their models, so that an energy-saving operation with highly frequent acceleration and deceleration as well as reversible operation are made possible.

(6) Abundant interfaces

Abundant functions that can sufficiently cope with all the requirements of NC machine tools, such as various types of speed detector (speed zero, designed speed attained, and voluntary speed), speed indicator, load meter, torque limiter, over-ride input, etc.

(7) Orientation (Option)

A "magnetic sensor system orientation unit" for automatic tool change (ATC) at the machining center is available. By mounting a magnetizing body and magnetic sensor to the spindle, stop precision within ±0.1 ° can be obtained. *Fig. 2* shows the composition of this system.

Also, a "pulse encoder system orientation unit" is available for work changing operation in the lathe, and for

angle indexing control of the spindle at the time of secondary transformation. This is made possible by attaching a pulse encoder to the spindle, and with which stopping precision within ±0.2° can be obtained. Furthermore, it enables multi-point stop control that stops at the stopping positions successively.

3 SPINDLE MOTOR AND CIRCUIT COMPOSITION

3.1 Spindle motor

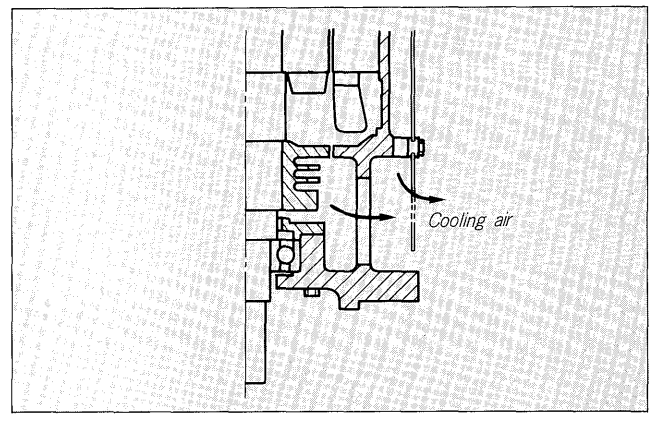
In order that it can cope with high-speed operations, working precision, mounting precision and balance precision are designed and constructed with high precision. In an example of 5000VH2 that uses a speed as high as 12,000 rpm, the manufacturing reference is as follows: spindle deviation, 0.01 mm or less; flange surface deviation, 0.03 mm or less; offset of the flange faucet, 0.03 mm or less; rotor balance, G1.0 class.

For suppressing temperature rise of the spindle end and flange mounting surface, the structure is designed in due consideration of suppression of heat transfer and cooling. *Fig. 3* shows a sectional view of the flange structure of the spindle motor for 5000VH2. By turning the cooling fins mounted to the drived shaft, shaft cooling is obtained by its fanning effect.

3.2 Circuit composition

Fig. 4 shows the circuit composition of this drive system.

Fig. 3 Structure of spindle motor cooling mechanism (FRENIC 5000VH2)



(1) Main circuit

Power supply side converter consists of diode rectifier supplying power during the driving operation, and transistor inverter that regenerates braking power in AC power supply. As braking duty has a capacity of disposing 20% ED, frequently alternating accelerating/decelerating operations are possible.

Motor side converter is a conventional type voltage PWM inverter. It is PWM-controlled with high carrier frequency for higher speed of control response and for reducing electro-magnetic noise.

(2) Control circuit and protective circuit

Vector control system by current model is adopted for

Fig. 4 Circuit composition

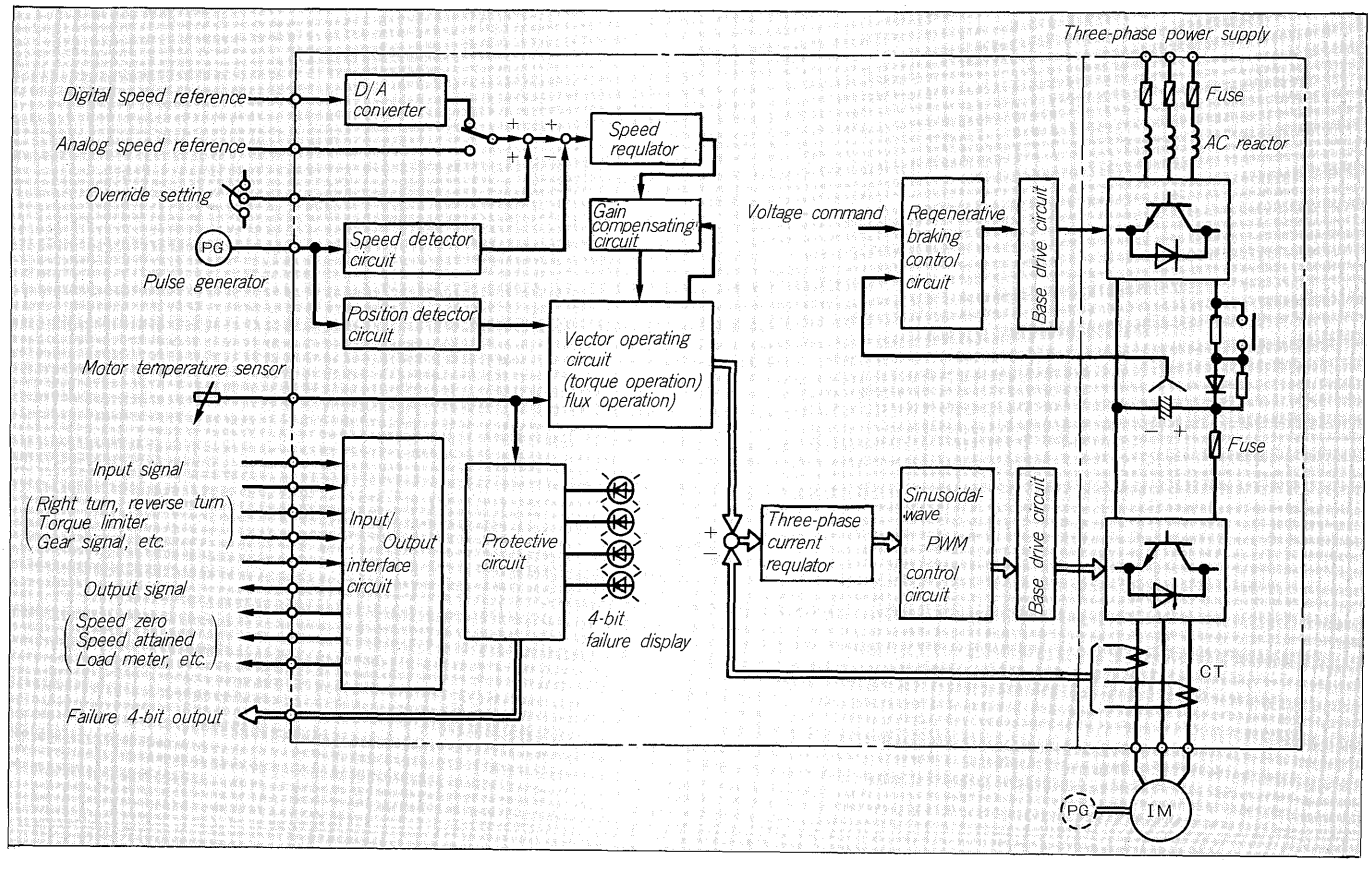


Fig. 5 Accelerating/decelerating characteristics (Load GD^2 = 5 x Motor GD^2)

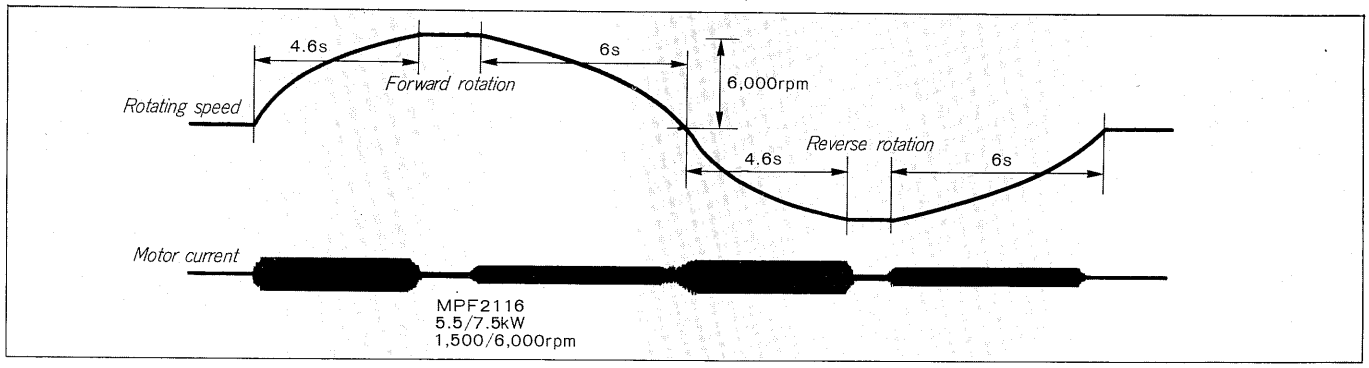


Fig. 6 Operating waveform of magnetic sensor system orientation

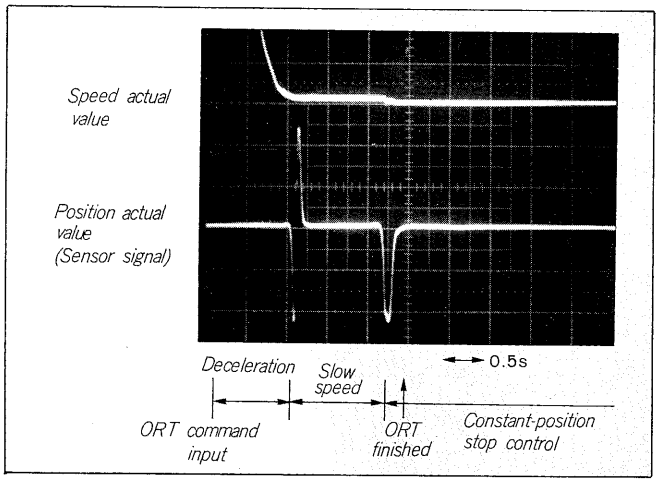
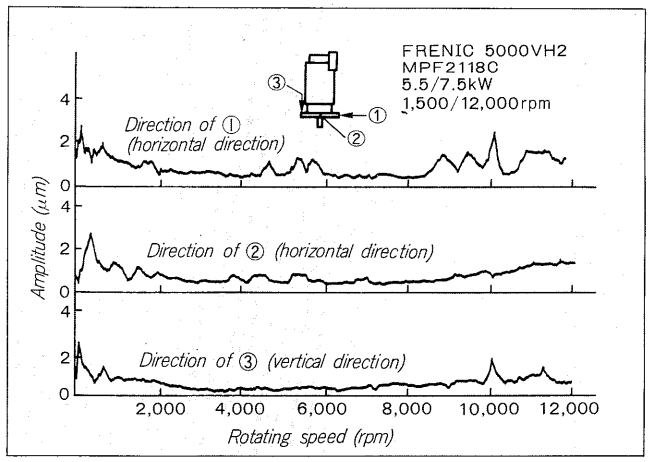


Fig. 7 Vibrating characteristics of spindle motor



all the control range. In order to avoid an influence from temperature change of the secondary winding resistance, by carrying out compensation of control constant through temperature detection by a thermistor, a vector operation of high precision is effectuated.

The protective circuit is provided with protective function against 13 items as overcurrent, overvoltage, motor overheat, etc. and the content of failure is indicated individually by means of 4-bit code signal of LED and further the code signal can be sent to NC equipment to display the content of the failure and measures that should be taken up on CRT.

The interface is all wired with connectors and all input and output circuits are concentrated in the connector of the main body.

4 OPERATING CHARACTERISTICS

Fig. 5 shows accelerating/decelerating characteristics during advancing and reverse operations. It shows a smooth operation without an overshoot nor undershoot. *Fig. 6* shows an operating waveform of magnetic sensor type orientation. The upper curve shows the speed spindle and the lower curve, a position signal by magnetic sensor. When an orientation command is received, the motor decelerates until the slow speed without modifying the turning direction. When stop position is detected during the slow speed operation, the motor speed command is switched over to the output side of the position adjusting device. By this operation, a locating braking operation is carried and the motor comes to a constant position stop. *Fig. 6* aims at the center of position signal as the goal, and attains a smooth stopping operation without overpassing nor vibrations.

Fig. 7 shows the results of vibration measurement of 5000VH2 spindle motor. It represents a vibration value smaller than 3 μm over a whole range up to 12,000 rpm.

5 SUMMARY

We have introduced in this report the actual situation of a high-performance AC spindle drive system FRENIC 5000V2/VH2 in which vector control is adopted.

For machine tools, except for those of large-capacity range, AC drive systems seem to have established themselves as a main stream, but still, there are other new movements with further development taking advantage of features of AC drive system, such as high-speed driving and variable speed driving in a wide range abbridging mechanical speed changing mechanism.

Fuji Electric, in due consideration of adopting new systems, is endeavoring for developing a higher technological drive system besides these standard types of machines that have been introduced in this report, for coping with the new market demands.