

# NEW SERIES OF ES MOTOR

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## 1. FOREWORD

The need for improvement of the machining cycle or machining accuracy and other high speed and high accuracy is becoming steadily stronger in various industrial machinery fields with the change of the economic environment. The demand for an AC servomotor with superior performance is expanding noticeably in response to this. However, whereas the AC servomotor has high performance, it also has disadvantages such as it is difficult to use, it is expensive, motor mounting dimensions are special, etc.

The applications of the general-purpose inverter, PS motor, DC motor, and other general-purpose variable speed motor are limited from the standpoint of response, variable speed range, maintainability, and other characteristics.

In this market trend, in 1988 Fuji Electric introduced the ES motor as a revolutionary product incorporating the ease of use and economy, which are features of the general-purpose inverter, and utilizing the excellent performances of the AC servo. This motor is widely used and highly evaluated.

On the other hand, market needs are steadily becoming more diverse. To meet these market needs, Fuji Electric

has developed and serialized an "advanced functions series" and a new "standard series" with more compact controller with a wider capacity range, improved functions, and a range of applications expanded tremendously by installation of option cards.

These new series are outlined below.

## 2. ES MOTOR

The origin of the name is Easy and Economy Servo Motor. It is a product in which ease of use and economy were pursued exhaustively.

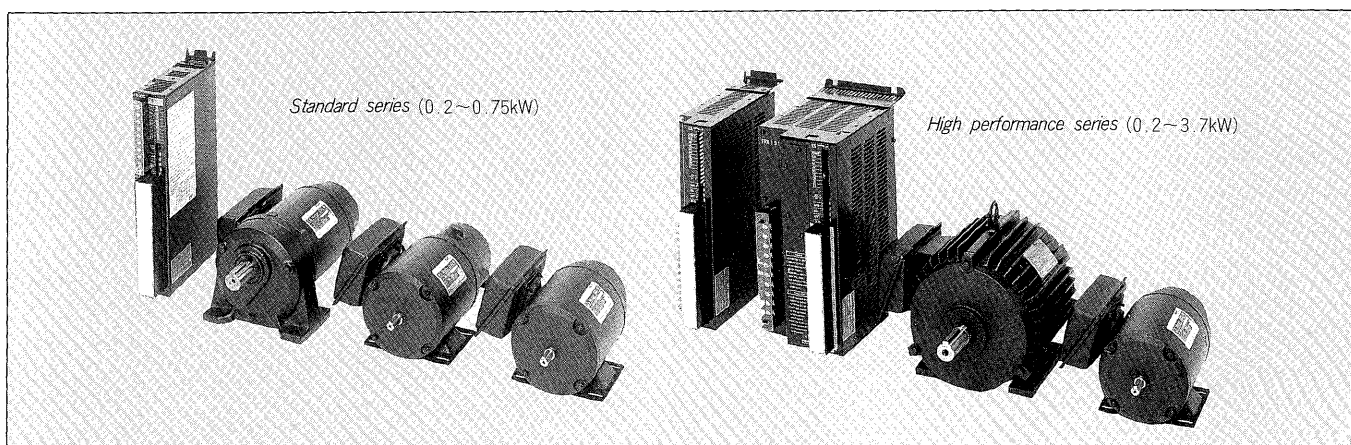
The capacity range is seven models from 200W to 3.7kW. Flange mounting, gear, brake, etc. are provided based on the leg mounting shown in *Fig. 1* so that it can meet diverse customer needs.

The ES motor is a permanent magnet synchronous motor with a permanent magnetic as the rotor and the armature winding as the stator, the same as an AC servomotor. Its torque and speed are controlled the same as a DC motor by an encoder with pole position sensor.

### 2.1 Appearance

Replacement with a variable speed motor for general

*Fig. 1* ES motor standard and high performance



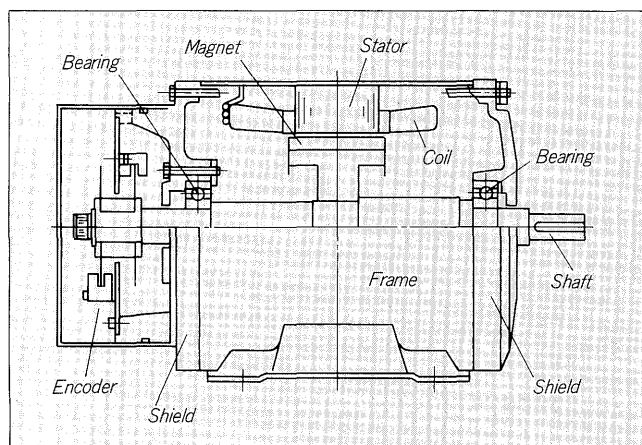
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Table 1 ES motor specifications

| Model                                 |                               | GRK1200M   | GRK1400M              | GRK1750M            | GRK1151A              | GRK1221A              | GRK1301A             | GRK1371A                            |
|---------------------------------------|-------------------------------|--|-----------------------|---------------------|-----------------------|-----------------------|----------------------|-------------------------------------|
| Item                                  |                               |  |                       |                     |                       |                       |                      |                                     |
| Rated output (kW)                     |                               | 0.2  | 0.4                   | 0.75                | 1.5                   | 2.2                   | 3                    | 3.7                                 |
| Rated torque (kgf·cm)                 |                               | 9.74   | 19.5                  | 36.5                | 73                    | 107                   | 146                  | 180                                 |
| Rated revolution (rpm)                |                               | 2,000  |                       |                     |                       |                       |                      |                                     |
| Maximum revolution (rpm)              |                               | 2,500  |                       |                     |                       |                       |                      |                                     |
| Instantaneous maximum torque (kgf·cm) |                               | 14.6   | 29.3                  | 54.8                | 110                   | 161                   | 219                  | 270                                 |
| Rotor inertia                         | $GD^2$ (kgf·cm <sup>2</sup> ) | 27.4   | 45.1                  | 86.2                | 210                   | 279                   | 510                  |                                     |
|                                       | $J_M$ (kg·cm·s <sup>2</sup> ) | $7 \times 10^{-3}$                                 | $11.5 \times 10^{-3}$ | $22 \times 10^{-3}$ | $53.5 \times 10^{-3}$ | $71.3 \times 10^{-3}$ | $130 \times 10^{-3}$ |                                     |
| Rated current (A)                     |                               | 1.2  | 2.3                   | 4                   | 8.6                   | 13                    | 17.2                 | 21                                  |
| Maximum current (A)                   |                               | 2  | 3.6                   | 6                   | 13                    | 19.5                  | 25.8                 | 31.5                                |
| Insulation                            |                               | Class B  |                       |                     |                       |                       |                      |                                     |
| Rating                                |                               | Continuous   |                       |                     |                       |                       |                      |                                     |
| Protection ventilation system         |                               | Totally enclosed, self-cooling (JP44)              |                       |                     |                       |                       |                      | Totally enclosed, separate cooling* |
| Terminals                             | Motor                         | Terminal box (with terminal board)                 |                       |                     |                       |                       |                      |                                     |
|                                       | Detector                      | Terminal box (with terminal board)                 |                       |                     |                       |                       |                      |                                     |
| Overheat protection                   |                               | Thermistor (leads are led into motor terminal box) |                       |                     |                       |                       |                      |                                     |
| Mounting method                       |                               | Legs attached                                      |                       |                     |                       |                       |                      |                                     |
| Shaft end                             |                               | Straight shaft key equipped                        |                       |                     |                       |                       |                      |                                     |
| Color of finish                       |                               | N1.2 (delustered)                                  |                       |                     |                       |                       |                      |                                     |
| Detector                              |                               | Encoder 1,000p/r                                   |                       |                     |                       |                       |                      |                                     |
| Vibration                             |                               | V5 or less   |                       |                     |                       |                       |                      |                                     |
| Altitude of installed location        |                               | 1,000m or less                                     |                       |                     |                       |                       |                      |                                     |
| Operating temperature range           |                               | -10~+40°C, 90% RH or less (non-condensing)         |                       |                     |                       |                       |                      |                                     |
| Vibration resistance                  |                               | 0.5G or less                                       |                       |                     |                       |                       |                      |                                     |
| Weight (kg)                           |                               | 6.3  | 8.4                   | 14.2                | 24                    | 30                    | 43                   | 45                                  |

\*Cooling fan motor: 1φ 200V 50/60Hz input 12/11W

Fig. 2 ES motor construction sectional view



industry was taken into account and the mounting dimensions were made to conform to the same IEC Standard as AC motors.

## 2.2 Specifications

The specifications of the ES motor are shown in Table 1.

## 2.3 Construction and features

The 200 to 750W models have a sheet-steel frame and the 1.5kW and larger models have a cast iron frame. The construction sectional view is shown in Fig. 2.

The stator can be wound and inserted automatically, the same as general-purpose AC motor and low price was realized by the mass production effect.

As for the rotor, the inertia was made small by assembling a cylindrical permanent magnet at the outside edge and the rotor was made a special shape to raise its response. A ferrite cylindrical permanent magnet was used and skew magnetization of the rotor was made possible and the cogging torque was reduced.

The detector is an optical encoder. The output signal of this detector is open collector. The detector is provided with pole position detection and speed detection.

For the model with brake, a hold brake is installed at the back of the motor and a separate power module is added.

The model with gear can correspond to high frequency operation with AGMA-CLASSII, no backlash and is completely equipped for leg mounting and flange mounting. It is grease lubricated with long-life grease and the mounting direction is unrestricted.

**Table 2 ES controller specifications**

(a) Standard series

| Item                   |  | Specification  |         |         |
|------------------------|--|--|---------|---------|
| Controller type        |  | FRK200C  | FRK400C | FRK750C |
| Control specifications | Applicable motor output (kW)           | 0.2  | 0.4     | 0.75    |
|                        | Rated current (A)                      | 1.2  | 2.3     | 4       |
|                        | Maximum output current (A)             | 2  | 3.6     | 6       |
|                        | Number of phases                       | 1φ, 3φ   |         | 3φ      |
|                        | Frequency                              | 50/60Hz ±3Hz   |         |         |
|                        | Voltage                                | 200~230V ±10%  |         |         |
|                        | Main circuit system                    | Transistor bridge  |         |         |
|                        | Control system                         | Rectangular-wave PWM control   |         |         |
|                        | Speed command voltage                  | ±8V/2000rpm; viewed from output shaft direction + forward rotation (counterclockwise) – reverse rotation (clockwise)   |         |         |
|                        | Speed detection method                 | Encoder (1000p/r)  |         |         |
| Control accuracy       | Speed control range                    | (1 : 200) 10~2000rpm   |         |         |
|                        | Load variation                         | At 0~100%/10rpm or less (0.5% or less)   |         |         |
|                        | Power supply variation                 | At ±10%/1rpm or less (0.05% or less)   |         |         |
|                        | Temperature variation                  | 25°C ±5°C/4rpm or less (0.2% or less)  |         |         |
|                        | Maximum load inertia                   | $GD^2_L$ (kgf·cm <sup>2</sup> )  | 274     | 451     |
|                        |  | $J_L$ (kg·cm·s <sup>2</sup> )  | 0.07    | 0.115   |
|                        |  |  |         | 862     |
|                        |  |  |         | 0.22    |
|                        | Speed command power supply             | ±10V/30mA (max)  |         |         |
|                        | Soft start/stop                        | Soft/quick selection by means of external contact signal; setting time 0.1~5 secs (start/stop simultaneously adjusted)   |         |         |
| Incorporated functions | Rotating direction changeover          | Changeover between (+) forward ↔ (+) reverse by internal selector switch   |         |         |
|                        | Rotating speed monitor                 | 7V/±2500rpm, max 4mA*  |         |         |
|                        | Torque monitor                         | +6V/150% torque max. 4mA*  |         |         |
|                        | Protective functions ( ) : LED display | Overvoltage (OV), overcurrent (OC), motor overheat (MH), controller overheat (AH), motor lock (ML): at 60 sec/150%, detecting encoder trouble (ET), overspeed (OS), regenerative resistor overheat (RH); motor comes to free run stop when trouble detected. |         |         |
|                        | Internal regeneration processing       | YES  |         |         |
|                        | Indication                             | POWER (power on, G), RUN (speed setting on, G), various faulty indications (R), as follows:<br>(1) OV (2) OC (3) MH (4) AH (5) ML (6) ET (7) OS (8) RH   |         |         |
|                        | G: Green R: Red                        |  |         |         |
|                        | External output signal                 | (1) Alarm output: open at fault, contact capacity AC 220V, 3A<br>(2) Zero speed detection: open collector, closed at detection, contact capacity AC 220V, 3A   |         |         |
|                        | Structure                              | Rack mounted type, self-cooled   |         |         |
|                        | Installation location                  | Indoor/altitude 1000m or less; should be free from direct sunlight, dust, oil mist, corrosive gas  |         |         |
| Operating environment  | Temperature                            | -10~55°C (storage temperature -20~85°C)  |         |         |
|                        | Humidity                               | 90% RH or less (non-condensing)  |         |         |
|                        | Vibration/shock resistance             | 0.5G/2G (should be no resonance)   |         |         |
|                        | Weight (kg)                            | 2.5  |         |         |

\*Value obtained when using 7kΩ internal resistance monitor.

### 3. CONTROLLER

The specifications of the ES controller are shown in Table 2. It consists of 10 models in two series, standard series and advanced functions series.

The standard series is limited to the low capacity range and was developed for minimum dimensions. On the other hand, the advanced functions series is equipped with a posi-

(b) High performance series

| Item                          |  |  |  | Specification                          |       |       |       |       |                               |       |
|-------------------------------|--|--|--|--|-------|-------|-------|-------|-------------------------------|-------|
| Controller type               |  |  |  |  |       |       |       |       |                               |       |
| Control specifications        | Output   | Applicable motor output (kW)   |  | 0.2                                    | 0.4   | 0.75  | 1.5   | 2.2   | 3                             | 3.7   |
|                               |  | Rated current (A)  |  | 1.2                                    | 2.3   | 4     | 8.6   | 13    | 17.2                          | 21    |
|                               |  | Maximum output current (A)   |  | 2                                      | 3.6   | 6     | 13    | 19.5  | 25.8                          | 31.5  |
|                               |  | Number of phases   |  | 1φ, 3φ                                 |       | 3φ    |       |       |                               |       |
|                               |  | Frequency  |  | 50/60Hz ±3Hz                           |       |       |       |       |                               |       |
|                               | Input power supply                                 | Voltage  |  | 200~230V ±10%                          |       |       |       |       |                               |       |
|                               |  | Main circuit system  |  | Transistor bridge                      |       |       |       |       |                               |       |
|                               | Control system                                     |  | Rectangular-wave PWM control   |  |       |       |       |       |                               |       |
|                               | Speed command voltage                              |  | ±8V/2000rpm; viewed from output shaft direction + forward rotation (counterclockwise) – reverse rotation (clockwise)   |  |       |       |       |       |                               |       |
|                               | Speed detection method                             |  | Encoder (1000p/r)  |  |       |       |       |       |                               |       |
|                               | Speed control range                                |  | (1 : 200) 10~2000rpm   |  |       |       |       |       |                               |       |
|                               | Control accuracy                                   | Load variation   |  | At 0~100%/10rpm or less (0.5% or less) |       |       |       |       |                               |       |
|                               |  | Power supply variation   |  | At ±10%/1rpm or less (0.05% or less)   |       |       |       |       |                               |       |
|                               |  | Temperature variation  |  | 25°C ±5°C/4rpm or less (0.2% or less)  |       |       |       |       |                               |       |
|                               |  | Maximum load inertia   | $GD^2_L$ (kgf·cm <sup>2</sup> )  | 274                                    | 451   | 862   | 2,100 | 2,790 | 5,100                         | 5,100 |
| $J_L$ (kg·cm·s <sup>2</sup> ) | 0.07   |  | 0.115  | 0.22                                   | 0.535 | 0.713 | 1.3   | 1.3   |                               |       |
| Incorporated functions        | Speed command power supply                         |  | ±10V/30mA (max)  |  |       |       |       |       |                               |       |
|                               | Soft start/stop                                    |  | Soft/quick selection by means of external contact signal; setting time 0.1~5 secs (start/stop simultaneously adjusted)   |  |       |       |       |       |                               |       |
|                               | Rotating direction changeover                      |  | Changeover between (+) forward ↔ (+) reverse by internal selector switch   |  |       |       |       |       |                               |       |
|                               | Rotating speed monitor                             |  | 7V/±2500rpm, max 4mA*  |  |       |       |       |       |                               |       |
|                               | Torque monitor                                     |  | +6V/150% torque max. 4mA*  |  |       |       |       |       |                               |       |
|                               | Protective functions ( ) : LED display             |  | Overvoltage (OV), overcurrent (OC), motor overheat (MH), controller overheat (AH), motor lock (ML): at 60 sec/150%, detecting encoder trouble (ET), overspeed (OS), regenerative resistor overheat (RH); motor comes to free run stop when trouble detected. |  |       |       |       |       |                               |       |
|                               | Internal regeneration processing                   |  | YES  |  |       |       |       |       |                               |       |
|                               | External regenerative discharge resistor provision |  | Connectable at option (internal connector)   |  |       |       |       |       |                               |       |
|                               | Indication   |  | POWER (power on, G), RUN (speed setting on, G), various faulty indications (R), as follows:<br>(1) OV (2) OC (3) MH (4) AH (5) ML (6) ET (7) OS (8) RH   |  |       |       |       |       |                               |       |
|                               | G: Green R: Red                                    |  |  |  |       |       |       |       |                               |       |
|                               | Position pulse output                              | Output mode  | Output signal A phase, B phase: 1000p/r, Z phase: 1 p/r open collector output (max.: 16mA, 24V)  |  |       |       |       |       |                               |       |
| Pulse frequency division      |  | 1/n (n = 1~16)   |  |  |       |       |       |       |                               |       |
| External output signal        |  | (1) Alarm output: open at fault, contact capacity AC 220V, 3A<br>(2) Zero speed detection: open collector, closed at detection, contact capacity AC 220V, 3A |  |  |       |       |       |       |                               |       |
| Structure                     |  | Rack mounted type, self-cooled   |  |  |       |       |       |       | Rack mounted type, air-cooled |       |
| Operating environment         | Installation location                              |  | Indoor/altitude 1000m or less; should be free from direct sunlight, dust, oil mist, corrosive gas.   |  |       |       |       |       |                               |       |
|                               | Temperature  |  | -10~55°C (storage temperature -20~85°C)  |  |       |       |       |       |                               |       |
|                               | Humidity   |  | 90% RH or less (non-condensing)  |  |       |       |       |       |                               |       |
|                               | Vibration/shock resistance                         |  | 0.5G/2G (should be no resonance)   |  |       |       |       |       |                               |       |
| Options                       | Internal mounting<br>Option card 1 only mountable  |  | (1) Current limiting card (2) Multistep speed card (3) Digital interface card (4) Pole lock card (5) Pulse frequency dividing card (6) Cable extending card (7) Servo lock card  |  |       |       |       |       |                               |       |
|                               | External mounting                                  |  | External regenerative discharge resistor unit  |  |       |       |       |       |                               |       |
| Weight (kg)                   |  | 3.5  |  |  | 6.1   |       | 8     | 8.2   |                               |       |

Fig. 3 ES controller basic block diagram

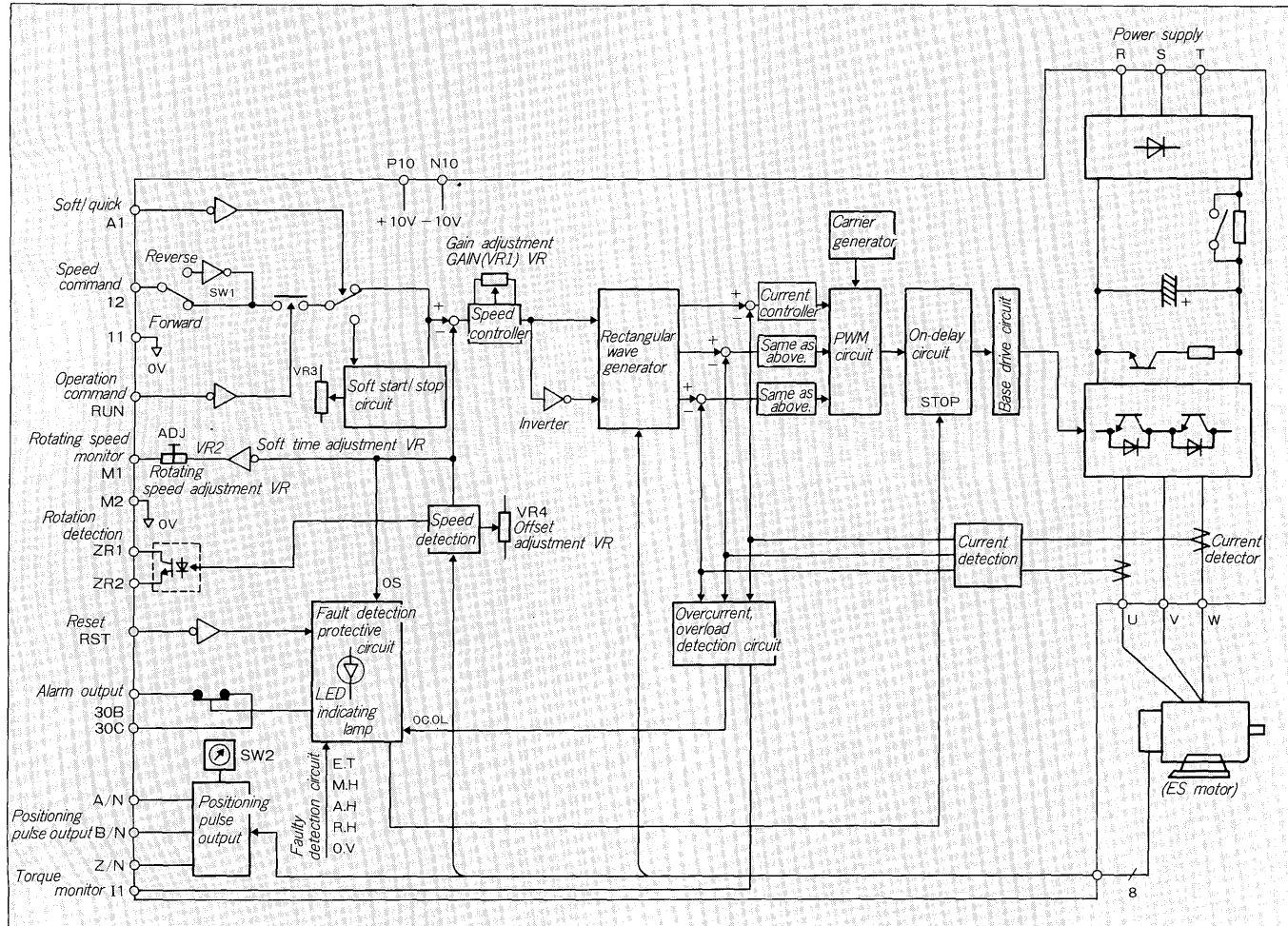
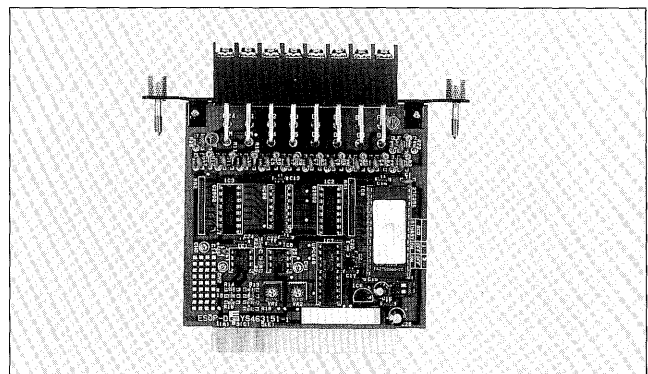


Fig. 4 Option card example



tioning pulse output and its peripheral functions. Its functions can be diversified to torque limiting, digital speed setting, etc. by installing option cards.

### 3.1 Circuit composition

The ES control function block diagram composition is shown in Fig. 3. The internal composition is almost the same as that of the F series AC servoamp (FRE type).

### 3.2 Features

This motor is a motor which takes advantages of the features of the AC servomotor and incorporates the economy and ease of use of the general-purpose variable speed motor. Therefore, measures and innovations for functions improvement were added to the controller. Typical examples are shown below.

- (1) Connection and inspection were made easier by using a terminal board system.
- (2) Size was reduced considerably by using surface mounting PC boards.
- (3) Seven option cards were serialized for advanced function series use. An example is shown in Fig. 4. The

kinds of cards are listed below.

- (a) Multistep speed card
- (b) Current limiting card
- (c) Pulse frequency dividing card
- (d) Digital interface card
- (e) Pole lock card
- (f) Servo lock card
- (g) Cable extending card

Fig. 5 Torque-speed characteristic

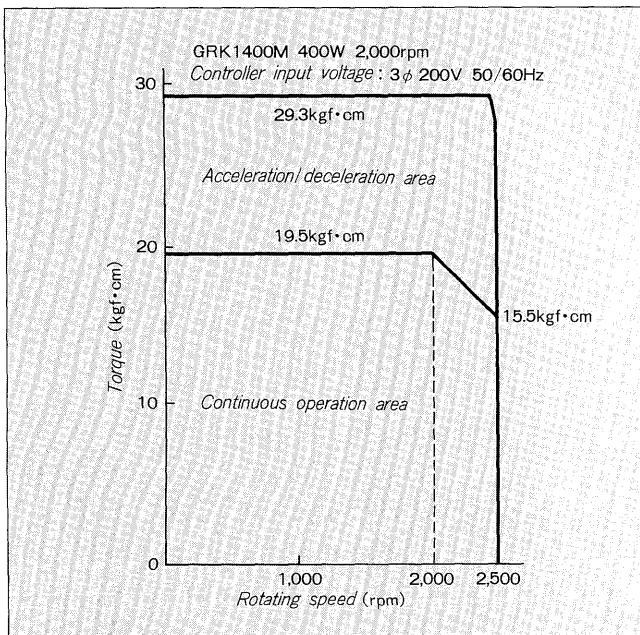
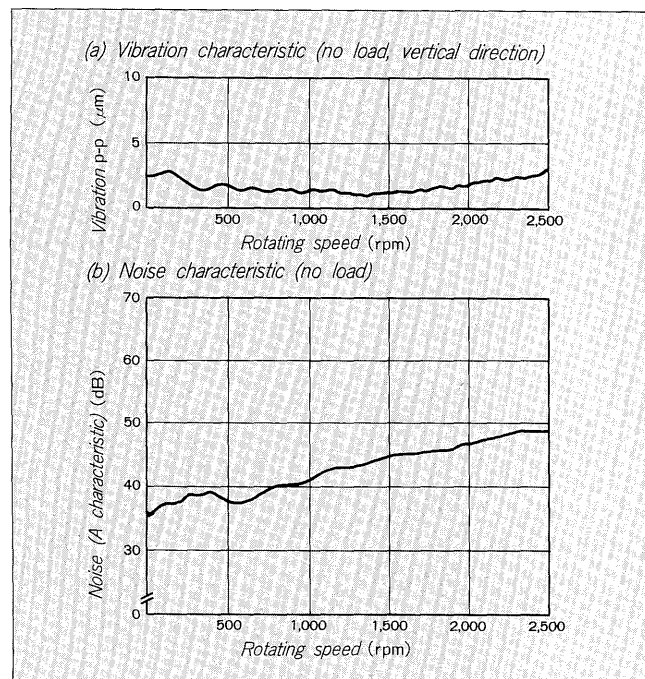


Fig. 6 Vibration and noise characteristics

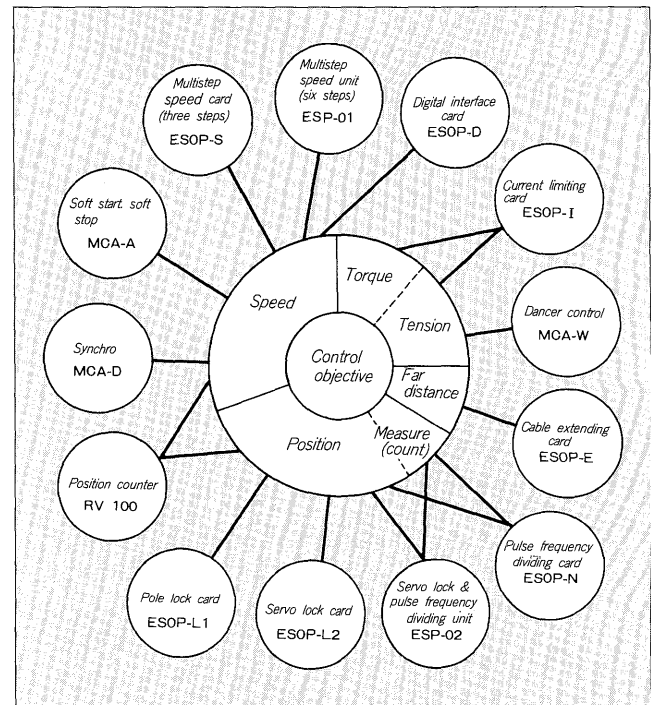


#### 4. COMBINATION PERFORMANCE AND CHARACTERISTICS

The following performances and characteristics are obtained by combining the motor and controller.

- (1) Frequency response is about 50Hz.  
The frequency response of an AC servomotor is about 100Hz. This combination has a performance near this.
- (2) Rotation irregularity is 2% or less at 100rpm point.  
This is the same characteristic as an AC servomotor.

Fig. 7 Composition of peripheral functions group



- (3) Torque of 150% can be output over the rated or less entire speed control range.

The basic characteristic is shown in Fig. 5.

- (4) Holding torque can be generated even at zero speed. Driftless holding is possible by using an option card (servo lock, pole lock card).
- (5) Low vibration and low noise.

Almost the same characteristic as the following AC servomotor is obtained over the entire rotating speed range.

- (a) Vibration: All models V5 or less
- (b) Noise: 750W or less 50dB (A) or less  
1.5kW or more 60dB (A) or less

The characteristics are shown in Fig. 6.

#### 5. PERIPHERAL DEVICES

To pull out the various functions and characteristics of the ES motor, peripheral devices corresponding to the application were provided. The composition of peripheral devices ground corresponding to the control objectives is shown in Fig. 7.

#### 6. CONCLUSION

The development aims, features, and specifications of the ES motor were outlined. We are confident that the ES motor, which has the features of an ordinary general-purpose variable speed motor and a servomotor, will amply satisfy in applications where there is a strong desire for high cost-performance.

The market demand for variable speed equipment is forecast to become more diversified and we will make efforts to further brush up and add to this series.