

FRENIC5000MS5 for Machine Tool Spindle Drives

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1. Introduction

In AC spindle drive systems for machine tools, operation such as frequent acceleration and deceleration, operation with low rotation ripple and low vibration, as well as various control functions including spindle positioning control, are generally required. Fuji Electric has responded to market requirements for spindle drive systems through the introduction of the torque vector control type FRENIC5000M3 series, suitable for driving the main spindle of lathe type machine tools, and the high performance vector control type FRENIC5000V3 series, suitable for machining centers.

In recent years, however, along with requirements for space-saving in the installation of the machine tool itself, there have been demands for further downsizing of the spindle drive system. Synchronized operation control are also required to handle combined machining that utilizes multiple spindles. Further, it is also becoming necessary to comply with various regulations represented by the EC machinery directive. To meet these requirements Fuji Electric has developed the new FRENIC5000MS5 series. A summary of which is presented below.

2. Features of the New Series

The FRENIC5000MS5 series has the following features as a spindle drive system for machine tools.

2.1 Separated construction for the converter and inverter

An external view of the FRENIC5000MS5 series is shown in Fig. 1. The drive unit (inverter circuit part) is on the left, and on its front panel can be seen the display and connectors for input/output signals. On the right is the converter unit (rectifier circuit and smoothing ripple-free circuit). Both units are mounted side-by-side and connected by bar wiring to the DC bus of the main circuits.

There are two drive units in this series, the “FRENIC5000M5 series” mainly for the spindle drive of lathes and the “FRENIC5000V5 series” having a high performance vector control that is suitable for

Fig.1 External view of FRENIC5000MS5



machining centers. There are also two series of converter units, the “dynamic braking type converter unit” and the “regenerative braking converter unit”, which make various combined applications possible.

Because a single converter unit can drive several drive units, it is easy to construct multi-drive systems consisting of a main spindle, sub-spindles and tool spindles. With this method, because braking energy is used for driving other spindles via the DC bus, the system operates with higher efficiency than a system having an inverter and converter for every spindle.

2.2 Standard specification complies with EC directive

The EC directive (low voltage directive) is adopted as the standard specification for all types of drive units, converter units and motors including options, making the products suitable for the international machine tool market.

The control input/output signals to/from the drive unit can be switched for compatibility with either a sink input or source input, allowing interchangeability among conventional model types.

2.3 Improvement of basic functions

Figure 2 shows a block diagram of the control

circuit of the FRENIC5000M5 series. For PWM control and digital AVR control which require high speed calculations, control circuits are constructed from newly developed ASIC. Torque vector control is processed by the software, together with other sequential operations and calculating operations.

Through utilization of this new control method, the accuracy of torque limiting characteristics has increased, response to impact loads and acceleration/deceleration performance have also improved, and rotation ripple has been suppressed to a large extent.

2.4 Downsizing

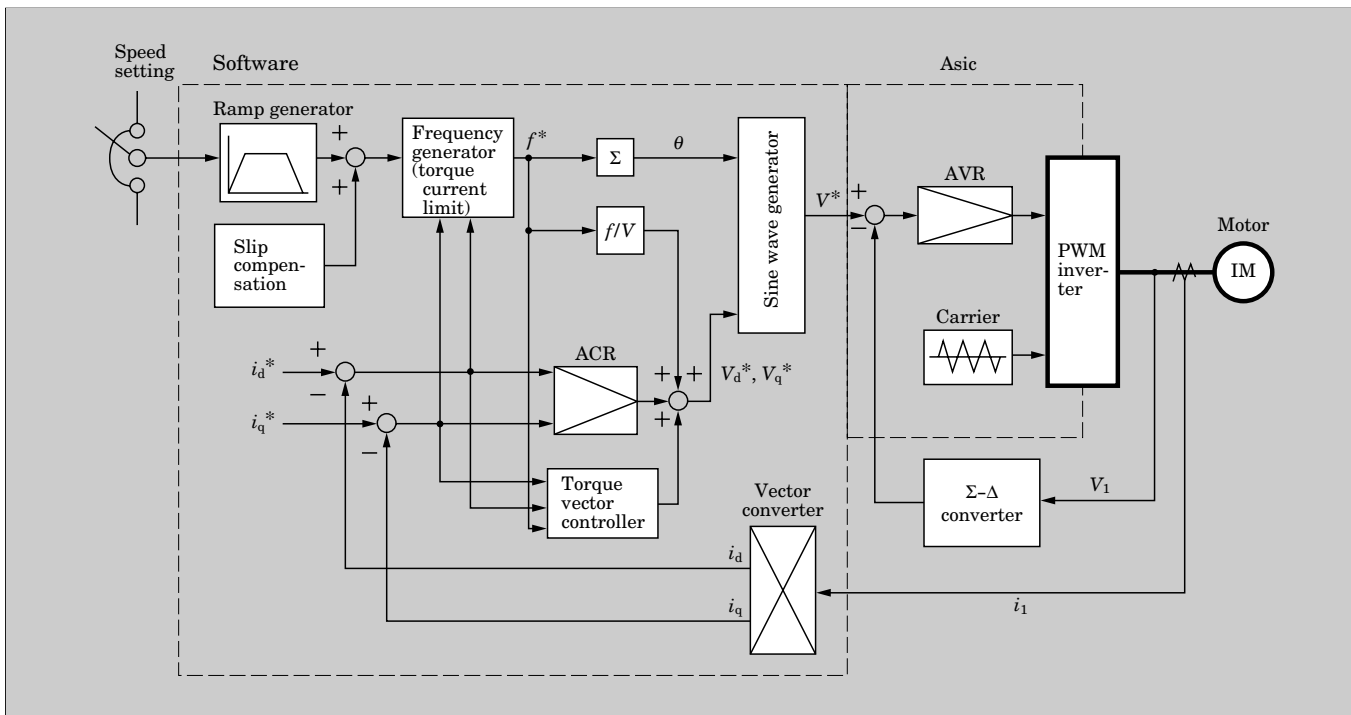
By applying a newly developed ASIC and by reconstructing the cooling elements with heat pipe type cooling fins, the control circuit has been downsized and the installation space reduced by 60% compared with conventional products.

In addition, by standardizing the height and the length of mounting surfaces for all model types, all units can be mounted side-by-side and thus the space occupied by the spindle drive unit can be greatly reduced.

2.5 Integrating and reducing the option cards

Some of the control functions of several options (synchronized operation, pulse-encoder type orientation, switching of the motor windings, etc.) have been moved to the main control P.C.B. This has reduced the load of additional boards and integrated the more than 10 conventional options into 4 types of options. These options are applicable and common to both the FRENIC5000M5 and FRENIC5000V5 series.

Fig.2 Block diagram of control circuit of FRENIC5000M5



3. Operating Characteristics

A typical example of operating characteristics of the torque control type FRENIC5000M5, a member of the FRENIC5000MS5 series, is introduced below.

3.1 Torque limiting characteristics

Figure 3 shows a typical example of the torque limiting characteristics measured at 11/7.5kW. It can be seen that the maximum torque of 120% is secured over the entire range.

3.2 Acceleration and deceleration characteristics

Figure 4 shows an oscillogram of acceleration and deceleration operation. This operating characteristic is for a motor having a capacity of 11/7.5kW combined with an inertia load of 0.4 kg·m².

Compared with the conventional FRENIC5000M3 series, a time reduction of about 10% has been achieved, resulting in acceleration and deceleration characteristics comparable with those of the conventional vector controlled FRENIC5000V3 series. Both the acceleration time and deceleration time satisfy the theoretical values calculated at the maximum torque of 120%.

3.3 Rotation ripple characteristics

Figure 5 shows a measurement of the rotation ripple for operation of a single 7.5/5.5kW motor. As a reference, operation data for drive units of the conventional FRENIC5000M3 and FRENIC5000V3 series are shown on the same graph. A large improvement has

Fig.3 Torque limiting characteristics

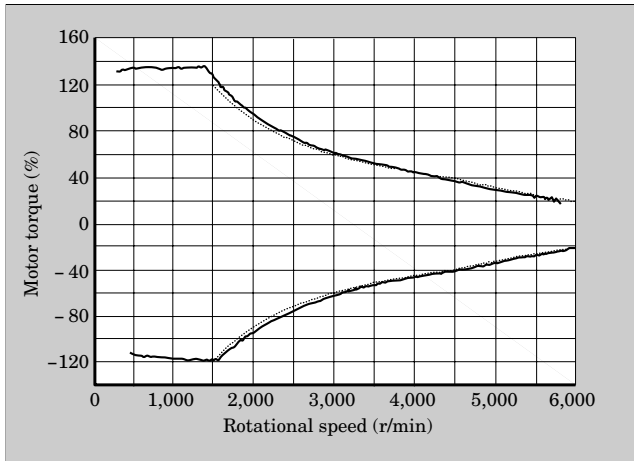
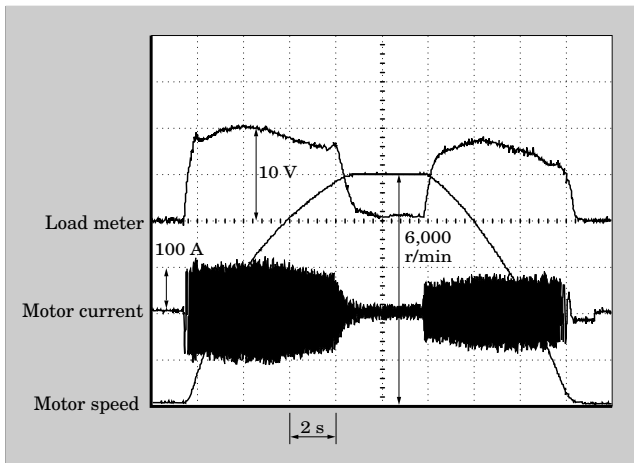


Fig.4 Acceleration and deceleration characteristics (11/7.5kW, Inertia load 0.4kg-m²)



been realized compared with the FRENIC5000M3 series.

3.4 Orientation control characteristics

Figure 6 shows an example of the operating characteristic of high-precision multi-point orientation control. The oscillogram shows operation of one revolution of positioning control from a stopped condition at 0° to 360°. The time required until output of the completion signal is reduced by approximately 20% compared with that of the conventional FRENIC5000 M3 series.

To improve performance of the FRENIC5000MS5 series, the creeping speed has been increased, and an algorithm has been implemented to generate a speed pattern for deceleration within a minimal time from the creeping speed to approximately the final stop position.

3.5 Easy setup and simple display

To realize user-friendly operation of the FRENIC 5000MS5, software for the loader that runs on Windows 95^(*) on a personal computer has been developed

Fig.5 Comparison of rotation ripple (7.5/5.5kW single motor operation)

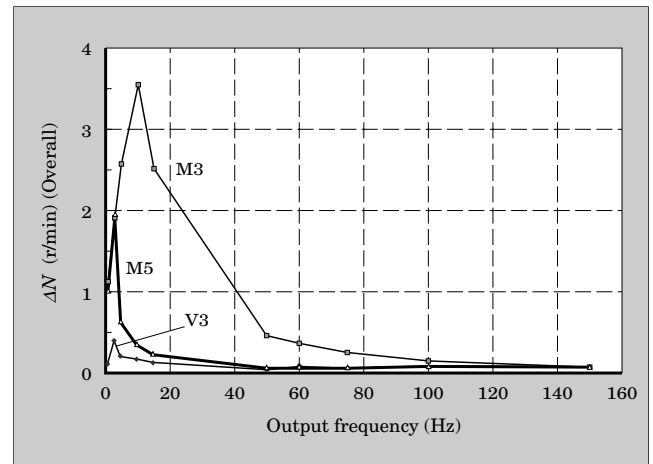


Fig.6 Orientation control characteristics

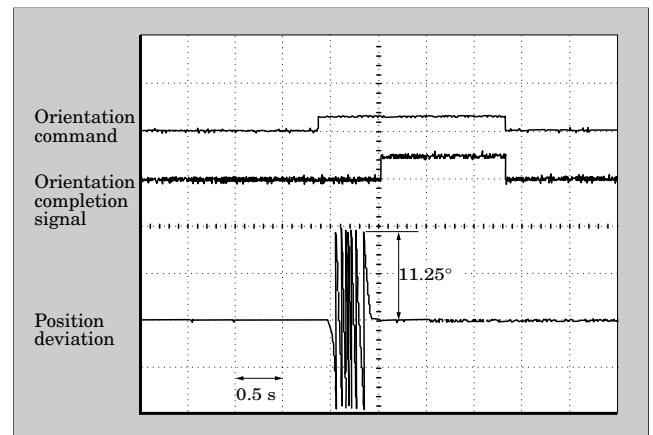
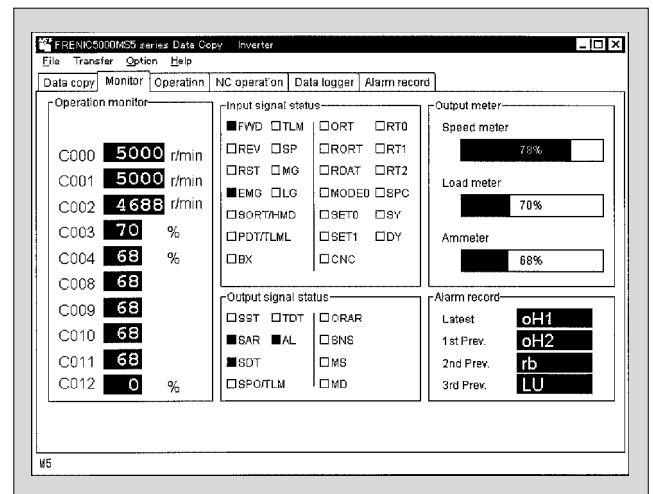


Fig.7 Example of the monitoring display screen



for the loader.

To make setup and adjustment at the installation site easier, this software for the loader is equipped

* Windows 95 : A trademark of Microsoft Corp., USA

with a function to collectively set standard setting values prepared in accordance with machine types, a function to read and copy the set values of other machines, a function for monitoring various operating conditions, and an operation function by which the drive unit can be test-operated by settings on the loader side.

Figure 7 shows a display of the monitoring operation as an example display screen during operation of the personal computer. In this example, the left column (Operation monitor) indicates such items as the rotation speed of the motors and spindles, the upper middle section (Input signal status) indicates the existence of digital input signals, the lower middle section (Output signal status) indicates the existence of digital output signals, the upper right section (Output meter) shows the scale of the analog output

and the lower right section (Alarm record) shows the history of the past four trips.

4. Conclusion

A summary of the FRENIC5000MS5 series including its options has been presented above. By separating the drive unit and converter unit, this series has been made compatible with a wide range of machine tools. To extend its application range further, Fuji Electric will continue to improve the product series and to develop products having enriched systems. Furthermore, we will increase efforts to equip our product series of spindle drive units with sufficient functions and performance to meet the needs of the still evolving and developing machine tool market.





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