“ALPHA7 Series” Servo System: New Functions and Application Examples

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ABSTRACT

Servo systems have been increasingly used for applications in all types of industrial machinery, including semiconductor and LCD manufacturing equipment, electronic parts processing equipment, printing machines, packaging machines, and metal processing machines. To meet market demands, Fuji Electric has developed the new models of “ALPHA7 Series” that is compact and have enhanced overload capacity, as well as improved basic control performance, including the industry’s highest processing speed and high accuracy. It also comes with a new load torque monitoring function, open networks (EtherCAT), and safety functions that comply with functional safety standards. Combining it with Fuji Electric’s multivariate statistical process control (MSPC) can help users to improve safety, security and productivity.

1. Introduction

Recently, servo systems have been increasingly used for applications in all types of industrial machinery, including semiconductor and LCD manufacturing equipment, electronic parts processing equipment, printing machines, packaging machines and metal processing machines. Against this backdrop, there is a growing need not only to improve the equipment availability by increasing the speed and accuracy but also to improve productivity by preventing outflow of defective products. We have developed and released the servo system “ALPHA7 Series” that meets these needs.

2. “ALPHA7 Series” Overview

The ALPHA7 Series curbs the occurrence of defective products during processing by improving the facility operation rate with the industry’s highest level of speed and accuracy and by using a load torque monitoring function that utilizes sensing technology. Furthermore, enhanced overload capacity has been achieved as well as size reduction. It also features support for open networks (EtherCAT*1) and safety functions that comply with functional safety standards (such as STO SIL3).

Figure 1 shows the appearance and Table 1, the product specifications of the ALPHA7 Series.

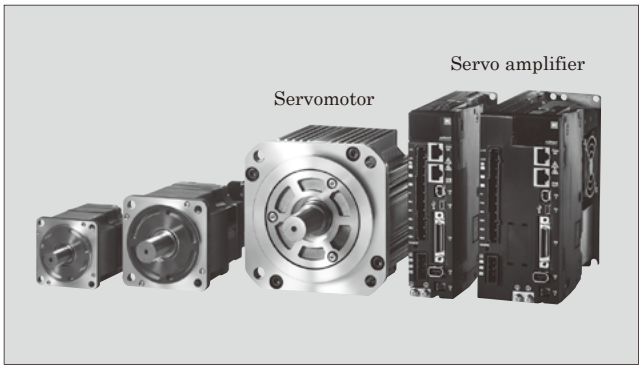

Fig.1 “ALPHA7 Series”

Table 1 Product specifications

Item	Specification
Command interface	High-speed serial bus (SX bus communication), pulse, analog, MODBUS**1, EtherCAT**2
Control mode	Position control, speed control, torque control
Capacity	0.05 to 5.0 kW
Main power supply	200 to 240 V AC
Frequency response	3,200 Hz
Feedback	24-bit serial encoder (incremental or absolute)

**1 MODBUS is a trademark or registered trademark of Schneider Automation, Inc.
**2 EtherCAT is a trademark or registered trademark of Beckhoff Automation GmbH.

3. Features of “ALPHA7 Series”

3.1 Industry’s highest level of size reduction

Both servomotors and servo amplifiers have been made more compact than conventional products. Three types of servomotors, GYS, GYB and GYG for different inertia zones, are available for the ALPHA7 Series. Figure 2 shows a comparison of the 0.2-kW GYB motor with the conventional product. GYB and GYG are among the smallest in the industry, reducing

* Power Electronics Systems Industry Business Group, Fuji Electric Co., Ltd.

*1 EtherCAT is a trademark or registered trademark of Beckhoff Automation GmbH.

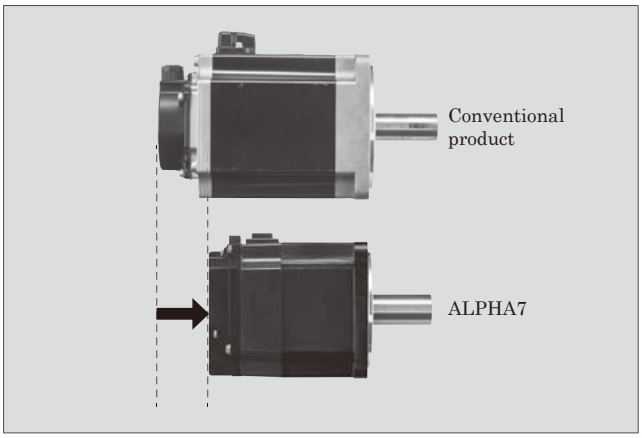

Fig.2 Servomotor size reduction

the total length of the motor by approximately 13% to 19% from the conventional models. The servo amplifiers can be mounted close together in the same way as the conventional products. In addition, by reducing the width by approximately 6% to 27% from conventional products, the mounting area has been reduced by up to 12%, which further contributes to size reduction of mechanical devices.

3.2 EtherCAT support

Along with the progress of the Internet of Things (IoT), industrial networks are migrating from field buses based on RS-485 to industrial Ethernet*2 capable of transmitting and receiving more information at a higher speed. In the field of factory automation (FA), in particular, EtherCAT, which features excellent real-time and synchronization performance, is attracting attention. The ALPHA7 Series now has a new addition to the line-up: the "ALPHA7 VC Type" equipped with EtherCAT. Table 2 shows the major specifications. It is expected to be used in fields where high-speed, multi-axis synchronous control is required, such as semiconductor manufacturing equipment.

3.3 Higher speed and higher accuracy

The ALPHA7 series has improved the frequency response from the conventional 1,500 Hz to 3,200 Hz by further improving the control algorithm developed

Table 2 "ALPHA7 VC Type" product specifications

Item	Specification
Baud rate	100 Mbits/s
Device profile	CoE*
Supported control mode	pp, pv, hm, csp, csv, cst
Synchronous mode	DC (synchronous), SM2 (synchronous), FreeRUN (asynchronous)
Minimum cycle time	125 μs

*CoE: CAN Application Protocol over EtherCAT

*2: Ethernet is a trademark or registered trademark of FUJIFILM Business Innovation Corp.

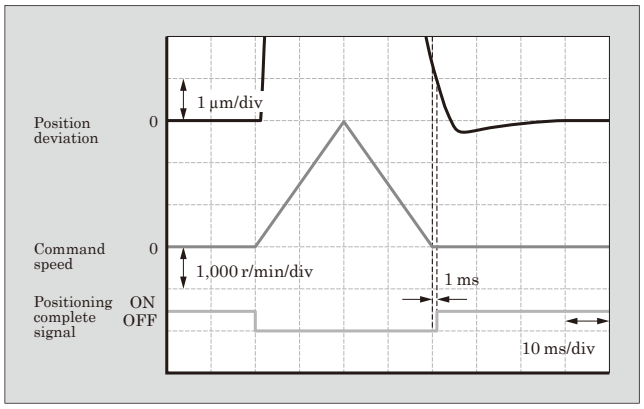

Fig.3 Positioning operation waveforms

with conventional servo systems. In addition, the employment of a high-resolution 24-bit serial encoder in all servomotors has achieved 16 times higher-accuracy positioning operation than that of conventional products. Figure 3 shows an example of waveforms during positioning control. Conventional products required a delay from a command (positioning setting time) of a few milliseconds, which has been improved with the ALPHA7 Series to approximately 1 ms. This facilitates improvement of mechanical performance of semiconductor manufacturing and other equipment requiring short takt time and high accuracy.

3.4 Improved overload capacity

The magnetic structure of the magnet inside the servomotor has been optimized to achieve a smaller size and higher torque than in the past. Furthermore, the latest power semiconductors have been used for the servo amplifiers to optimize the thermal cooling structure, which has reduced temperature rise of the main circuit, achieving the maximum torque of 350% (see Fig. 4).

3.5 Improved safety

The ALPHA7 Series is equipped with a safe torque off (STO) function conforming to the functional safety standards IEC 61800-5-2 / IEC 61508 (SIL3) and ISO

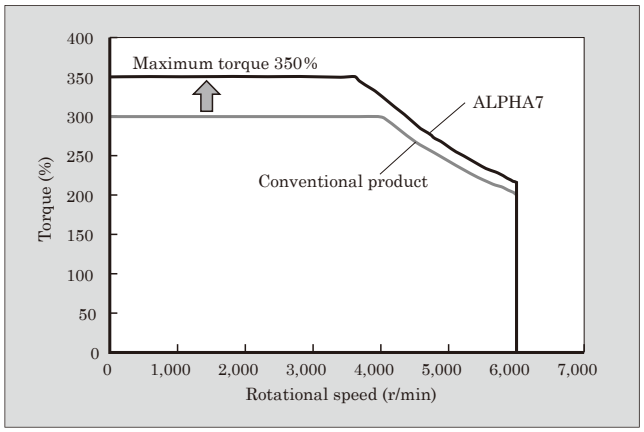

Fig.4 Speed torque characteristics

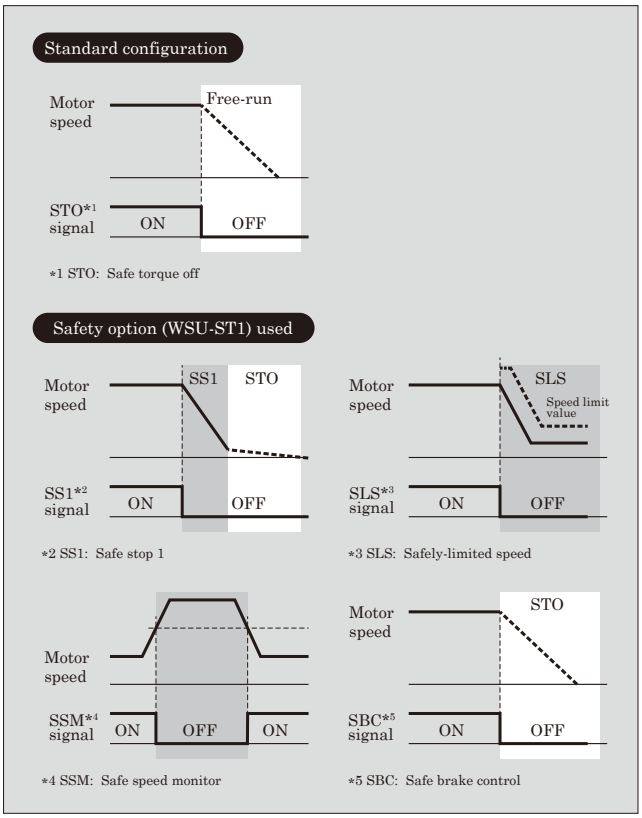

Fig.5 Safety function

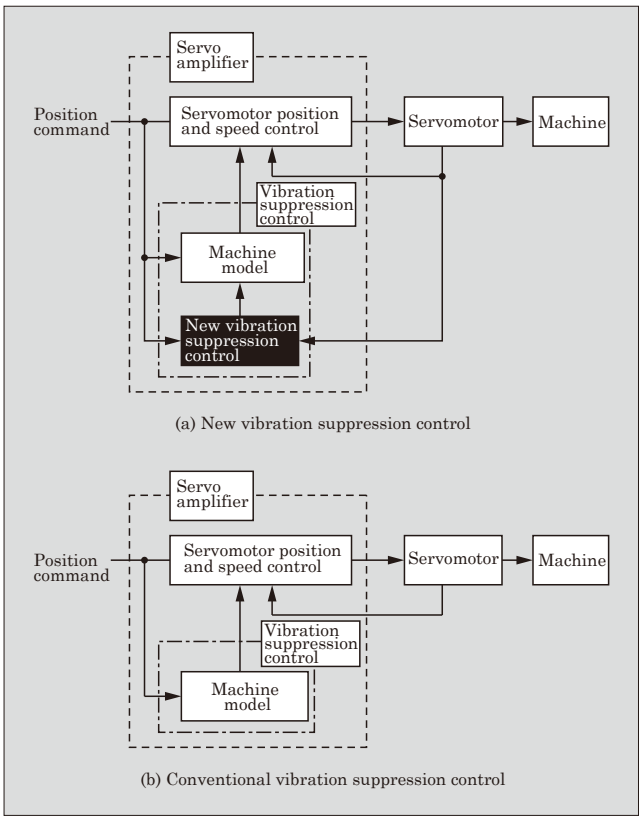

Fig.6 Comparison between block diagrams of new and conventional vibration suppression control

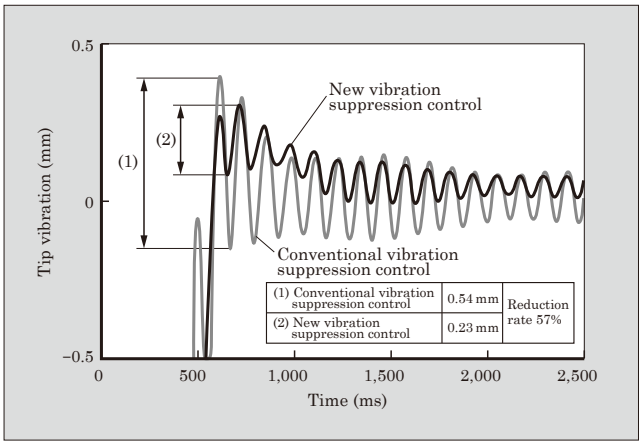

Fig.7 Comparison between waveforms of new and conventional vibration suppression control

13849-1 (PL-e) as a standard feature. This has eliminated the need for redundant removal circuits (e.g. two magnetic contactors) of the main circuit of the conventional models. Furthermore, combining the ALPHA7 Series motor with the safety option (WSU-ST1) has enabled the setting of five types of safety functions including SS1, SLS, SSM and SBC (SIL2, PL-d) as shown in Fig. 5. The user can easily set the required type for each mechanical device.

3.6 New vibration suppression control system

In an elastic structure such as a robot arm, vibration at the tip of a workpiece can be suppressed by conventional vibration suppression control. However, vibration may remain due to slight displacement because the vibration is controlled only by position information from a machine model.

The ALPHA7 Series adopts the method of vibration suppression control to suppress this vibration, as shown in Fig. 6. This method has been enhanced by adding a configuration for applying correction to the configuration of the conventional product from the residual vibration components appearing in the position feedback information from the encoder mounted on the servomotor. As a result, vibration has been reduced by 57% compared with the conventional system (see Fig. 7).

3.7 Full-closed control system

Generally, as shown in Fig. 8, there are roughly two types of positioning control for machinery and equipment: semi-closed control and full-closed control.

Semi-closed control controls the machine position by positioning the servomotor though feedback control using the information from the encoder mounted on the servomotor. Therefore, errors in the transmission mechanism (such as ball screws and gears) from the motor to the machine cannot be controlled.

Full-closed control uses an external encoder to detect the machine position for controlling the servomotor, which provides the capability of high-accuracy positioning. Accordingly, when positioning not affected

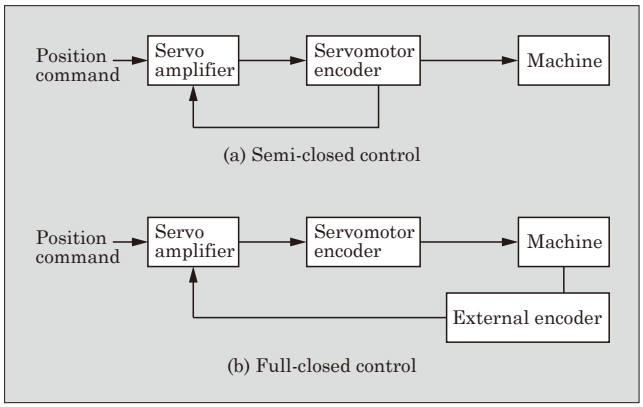

Fig.8 Comparison between block diagrams of semi-closed and full-closed control

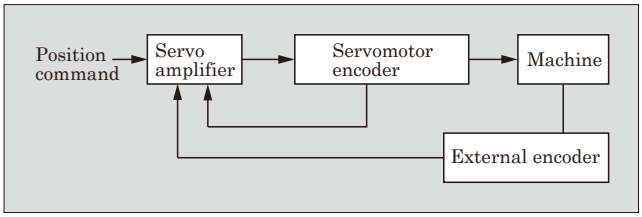

Fig.9 Block diagram of full-closed control of "ALPHA7 Series"

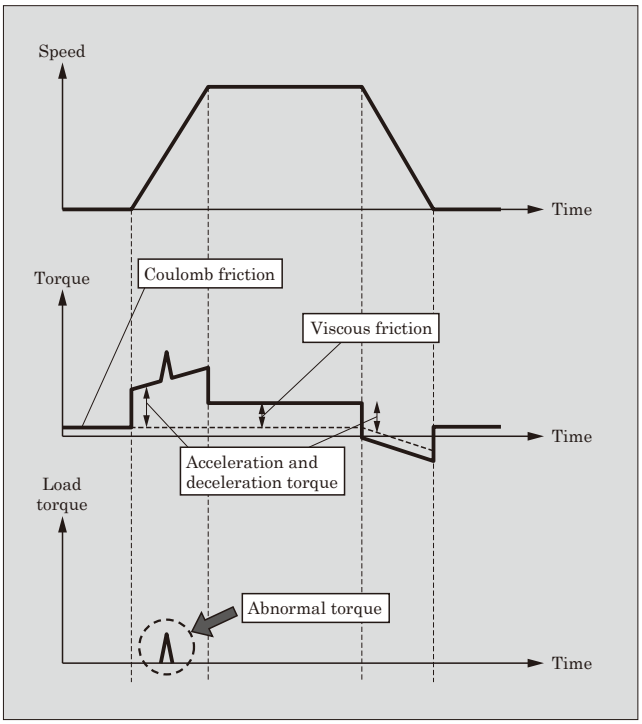

Fig.10 Speed, motor torque and load torque waveforms

by machine deflection or distortion is required, full-closed control is adopted.

However, an external encoder is more significantly affected by vibration resulting from mechanical resonance than the encoder of the servomotor. Therefore, in high-takt operation likely to generate mechanical resonance, full-closed control only by the detected value of the external encoder may lead to failure to increase the control gain, which can poses a problem of inability to provide sufficient performance such as the setting time. Accordingly, with the ALPHA7 Series, both the feedback from the external encoder and that from the servomotor encoder are used for position control, as shown in Fig. 9. The detected value of the servomotor encoder is used to reduce the influence of mechanical resonance and the external encoder is used for final positioning. This has led to the achievement of high-speed and high-accuracy positioning operation. The full-closed control provided for the ALPHA7 Series is expected to be utilized in the semiconductor manufacturing equipment and other industries where high-speed, high-accuracy positioning is required.

3.8 Load torque monitoring function

Due to the demand for improvement of the quality of processed products, machine manufacturers that produce equipment for bagging food, such as packaging machines, are making special efforts to detect abnormalities during processing by using sensors and other devices.

For example, when the command torque is used to detect any foreign matter caught in the sealed part of the bagging film, detection is not possible if the component of the acceleration and deceleration torque is larger than the component of the load torque at the time of the actual occurrence of a caught foreign matter.

The ALPHA7 Series is capable of detecting an abnormal torque by extracting load torque that does not include acceleration and deceleration torque, friction or gravitational torque from the command torque, which is monitored.

Possible applications are as follows.

(a) Detection of any dust stuck, foreign matter caught and defect in the mechanism
(b) Detection of rubbing and collision with another mechanism due to misconfiguration
(c) Detection of defective crimping of a harness processing machine
(d) Detection of any foreign matter caught in the sealing section of a packaging machine

This function is provided individually as requested.

4. Examples of Application of "ALPHA7 Series"

4.1 Interference detection using load torque monitoring function

Use of the load torque monitoring function of the ALPHA7 Series enables interference detection, in which disturbance to the device, such as a collision to the machine end, is detected with the servo amplifier to mitigate the impact at the time of the collision to the machine (see Fig. 11).

With this load torque monitoring function, the servo amplifier alone can perform the process of detecting a torque abnormality for protective operation,

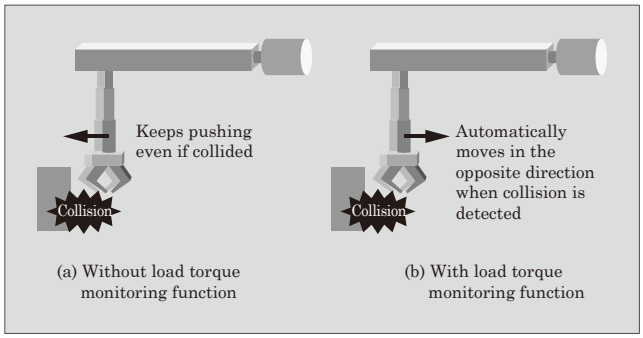

Fig.11 Interference detection by load torque monitoring function

which was conventionally achieved with a upper-level controller.

4.2 Abnormality detection and diagnosis system combining MSPC

This subsection presents an example of application to press equipment.

Conventionally, a foreign matter was detected by providing a sensor for detecting the load right under the press axis to see the difference of the load.

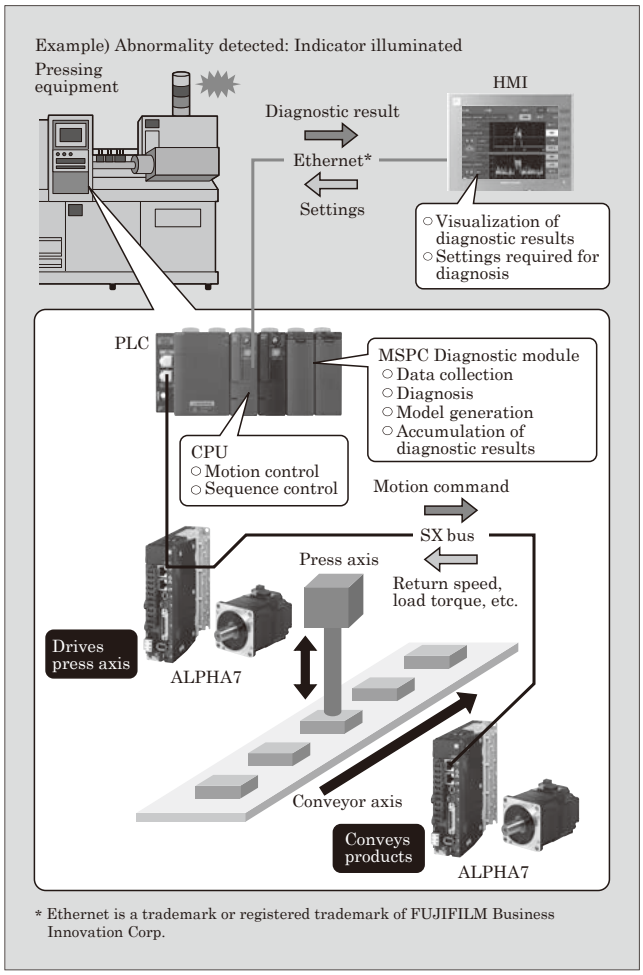

Fig.12 Abnormality detection and diagnosis system combining MSPC

We have now combined the ALPHA7 Series equipped with the load torque monitoring function and a diagnostic module equipped with the multivariate statistical process control (MSPC) diagnosis function to construct an abnormality detection system for processed products without an external sensor, as shown in Fig. 12.

MSPC diagnosis is an abnormality detection technique in which a diagnosis model is created based on a large number of normal data and data deviated from the diagnosis model are evaluated as errors using two statistics: Q-statistic (deviation from the correlation) and T^2-statistic (deviation from the mean).

For a press axis for harness processing as shown in Fig. 12, the MSPC diagnostic module mounted on the programmable logic controller (PLC) can be used for diagnosis based on the data from the servo, which enables monitoring for any increase in the Q-statistic to detect abnormality, as shown in Fig. 14.

In addition, using the load torque monitor function together with the MSPC provides the capability, in the case of press equipment, of detection of abnormalities such as any foreign matter mixed in during processing or a change in the thickness of the product.

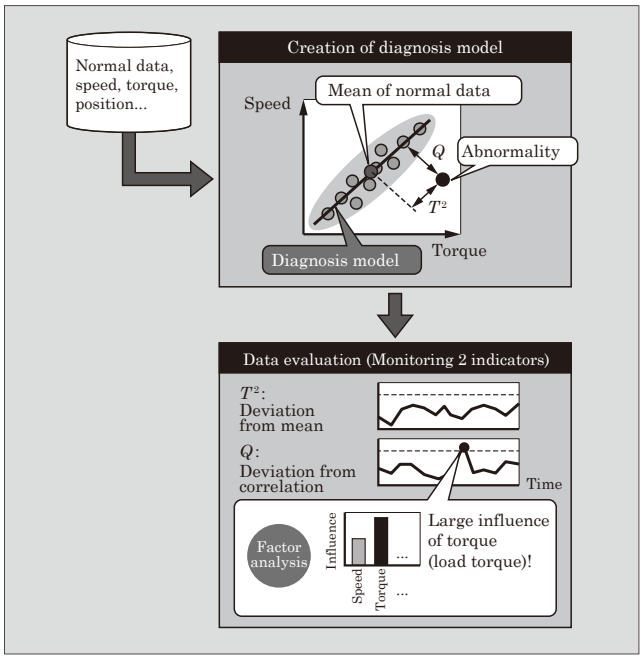

Fig.13 MSPC diagnostic method

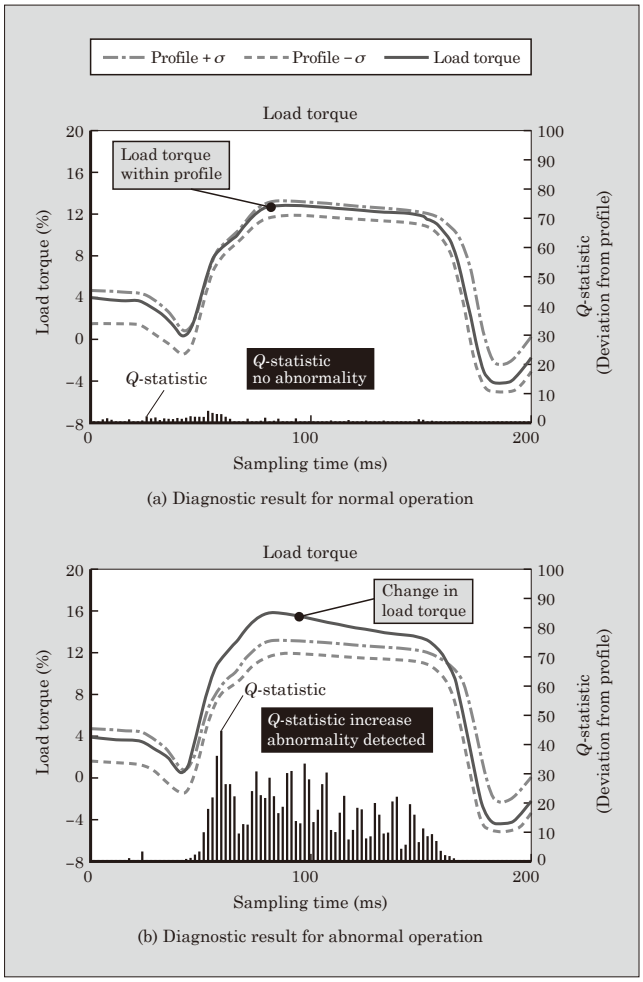

Fig.14 Results of MSPC diagnosis for normal and abnormal data

5. Postscript

This paper has described the new functions and application examples of the servo system "ALPHA7 Series." Furthermore, combining with Fuji Electric's MSPC diagnostic module improves system performance, which contributes to the user's safety and security and improved production capacity.

In the future, we intend to expand the line-up to meet the needs for capacity expansion and servo amplifiers for linear and DD motors.

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