Servo Systems Evolving in Line with Market Changes

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1. Introduction

Presently, the environment surrounding the servo system market is undergoing significant changes. Such changes include global warming, changes in operating environments to accompany the industrial globalization, and changes in customers' needs. SANYO DENKI must solve issues accompanying these market changes, and offer new products on a timely basis so that our customers can create new value.

This paper introduces the technological evolution of servo systems in order to solve issues which accompany market changes.

First, we will introduce technologies for lowering noise, vibration, and heat in stepping motors. Following that, we will introduce our development of the 20 sq. servo motor which achieved high output, weight reduction, and low loss. These technologies "pursue performance that is friendly to people and to the environment", which is one of our major goals stated in SANYO DENKI's eighth Medium-Term Management Plan.

Next, we will introduce technological evolutions in designing servo amplifiers that enable us to quickly respond to market changes and changes in customers' operating environment and needs, and to offer new products that can be used with peace-of-mind.

2. Technologies for Lowering Noise, Vibration, and Heat in Stepping Motors

Stepping systems can be open-loop controlled and make it easy to build a system. For this reason, stepping systems are used in a wide range of applications, including general industrial machinery, semiconductor manufacturing equipment, and medical equipment. Particularly in recent years, there is an increasing number of cases in which stepping systems are used for applications in the vicinity of people, such as medical equipment. Accordingly, our customers' needs relating to stepping motors are changing, with emphasis not only on torque performance, but also low vibration, low noise and low heat generation.

This section provides an overview of the technologies applied to the SANMOTION F5 5-phase stepping motor [(1)], released in 2015, for achieving low vibration, low noise, and low heat generation.

We devised the current control of the driver in order to reduce torque ripple on the SANMOTION F5 5-phase stepping system. Moreover, we used an optimized design technique to raise structural rigidity by being innovative with the fitting dimensions of the motor stator, flange and end bracket, and the shape of abutting portion. As Figure 1 shows, these technologies have made it possible to significantly reduce speed fluctuation, which causes vibration, and reduce noise level by around 3 dB(A). Speed fluctuation of stepping motor can cause machinery to vibrate, significantly reducing speed fluctuation helps to minimize machinery vibration and further increase design freedom. Moreover, the noise level has been reduced by 3 dB(A) (acoustic energy is 1/2), significantly reducing harsh noise.

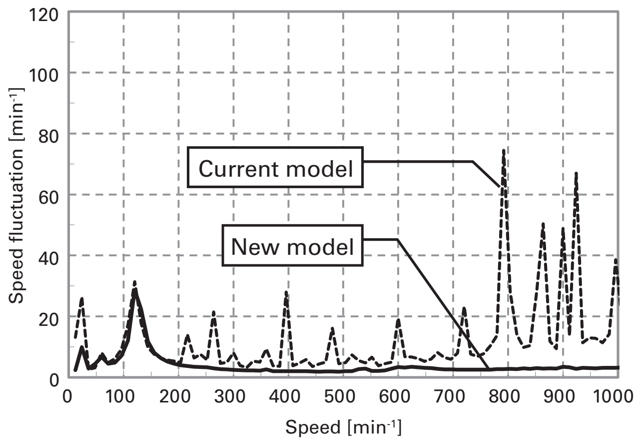

Fig. 1: Comparison of speed fluctuation with the current model

In the case of the 5-phase stepping motor, the abovementioned low vibration and low noise have been achieved, and motor temperature rise has been significantly suppressed. Next, we will discuss reduction of motor loss and temperature rise.

We quantitatively analyzed the causes of motor loss, then developed and applied a technology to minimize loss and maximize torque. For example, iron loss was reduced by optimizing design of the stator and rotor core magnetic path and electromagnetic steel plate material. Moreover, by expanding winding space and aligning windings, winding occupancy factor was improved, thereby reducing copper loss.

Compared with current motors, on the 5-phase stepping motor, loss has been reduced by around 24%, while motor surface temperature has been halved. Moreover, holding torque has been improved by 24%.

In this way, SANYO DENKI's latest 5-phase stepping system has evolved to make it ideal for applications close to people as it offers high torque, low noise and vibration, and minimal temperature rise.

Moving forward, we plan to apply these technologies to our 2-phase, 42 sq. stepping motors, etc. and develop new, easy-to-use products for our customers. The key is balancing improvement of motor specific power (power output per unit mass) with the reduction of vibration, noise and temperature rise. We wish to continue contributing to our customers' creation of new values through this technological evolution.

3. Development Initiatives for the Small Diameter 20 sq. AC Servo Motor

Figure 2 shows a 20 sq. flange motor[2] of the SANMOTION R series released in 2015. This was developed as a next-generation product to provide a new solution for the head drive portion of the equipment it is implemented on in response to changes in demands regarding the implementation process, such as higher implementation speed and multi-functional implementation. The three basic development concepts for this product were high output, weight reduction, and low loss.

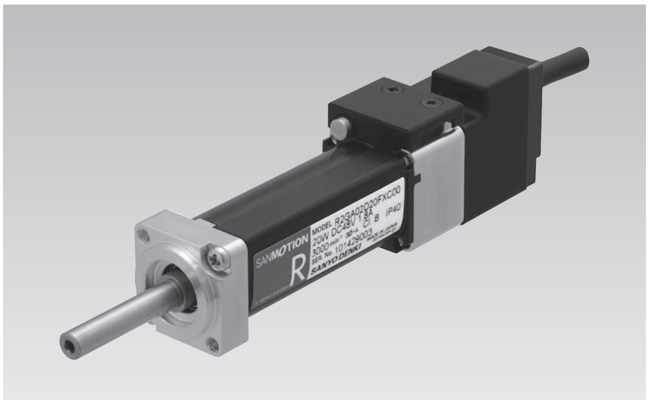

Fig. 2: Small-diameter, 20 sq. AC servo motor

This 20 sq. servo motor uses high-space factor winding technology in which windings made with wire are mechanically bent then inserted into the core. This has resulted in the significant reduction of copper loss as well as expanded output range and minimized loss in general. Furthermore, by making the frame cross-section circular and magnetic to include it in the magnetic circuit, a higher occupancy factor and weight reduction have been simultaneously achieved. Also, through the coupled analysis of optimization support tools and electromagnetic field simulation, we have solved the issue of motor property improvements conflicting with weight reduction efforts, which had been affecting the actual design when applying these technologies.

Figure 3 shows the torque vs. speed characteristics. The solid line shows the new model's characteristics while the dashed line shows the current model's characteristics. Compared with the current model, the new model has higher torque and speed, and achieves a wide output range. It also succeeds in balancing weight reduction and improved motor efficiency (8.5% weight reduction, 34% loss reduction).

In this way, the features of the 20 sq. servo motor are high output, high efficiency (low loss), with technological evolutions significantly contributing to machinery and equipment by enabling higher performance, energy saving, and downsizing.

This development is of great significance in that we produced a high-performance and low-loss product while saving resources, by the lightweight motor design requiring less materials. SANYO DENKI wishes to continue helping our customers create new value through reducing environmental impact and improving output.

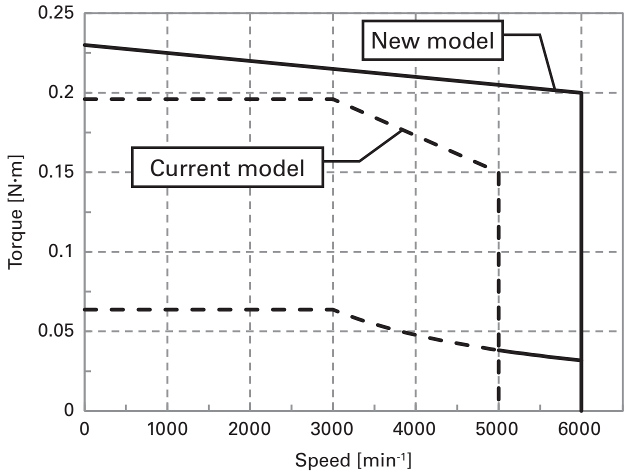

Fig. 3: Torque vs. speed characteristics (SANYO DENKI amplifier combination, 48 VDC)

4. Evolution of Servo Amplifier Design Technology

As best represented by IoT (Internet of Things), production systems of recent years are becoming increasingly sophisticated. Moreover, they are used in various regions due to the industrial globalization. In accordance with these changes in technology and market environment, there is a need to develop servo systems with even better performance, multi-functionality, and high reliability, then offer these to customers on a timely basis. For that reason, it is essential that we advance our design technology that improves product development efficiency and product quality. Here we shall explain the design technologies for the printed circuit board (PCB) and software of the servo amplifier.

4.1 PCB Design Technology

The electronic circuits of servo amplifiers are growing in speed and density due to the high performance of servo control and the widespread use of industrial Ethernet. In line with faster and denser electronic circuits, it is imperative to suppress the electromagnetic noise (emissions) generated from inside servo amplifiers and increase immunity against external electromagnetic noise in order to offer customers a reliable product.

If emissions noise and immunity noise are not tested until the final product evaluation phase, when problems arise, it is necessary to examine the causes of the noise generated and to take measures by the cut and try approach. This is an extremely time-consuming process and creates design set-backs.

In order to improve this issue, SANYO DENKI used a magnetic near-field analysis system to measure the electromagnetic noise generated by a PCB in the prototype phase to analyze the cause of the noise and verify the effectiveness of countermeasures. In the magnetic near-field analysis system, a magnetic field probe scans the surface of the PCB to measure magnetic field strength and conduct an FFT analysis, which achieves visualization of the PCB's noise level and distribution.

PCBs designed using this analysis system are shown in Figure 4 for a prototype machine and Figure 5 for a mass production machine.

By analyzing the prototyped PCB using the magnetic near-field analysis system, we identified the location where noise level was high and considered countermeasures such as reviewing wiring patterns and component layout. By reflecting countermeasures to the PCB of the mass production machine and visually confirming the effects, the quality of the PCB can be confirmed before conducting the later process of noise testing. Moreover, by accumulating PCB design know-how obtained by utilizing this analysis system, we have increased the quality of the PCB from the prototype phase and improved design efficiency.

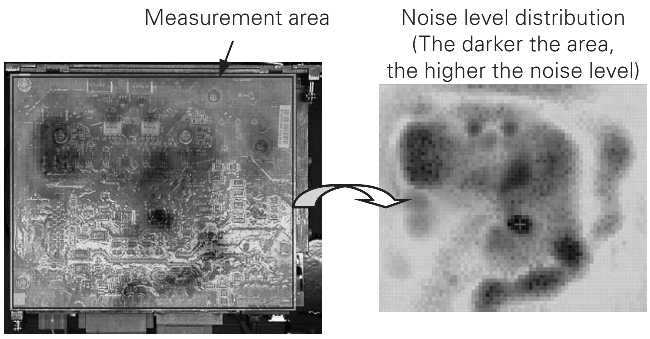

Fig. 4: PCB of a prototype production machine (before countermeasures)

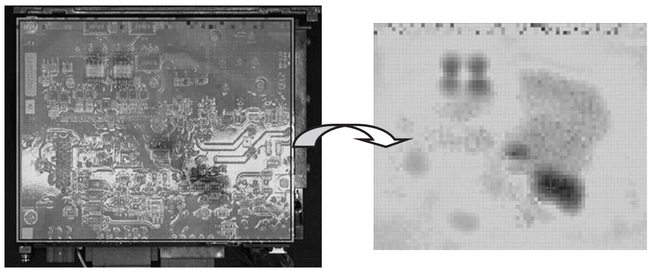
Fig. 5: PCB of a mass production machine (after countermeasures)

4.2 Software Design Technology

Servo amplifiers are becoming multi-functional and user-friendly with softwares. Functions include servo tuning support, various diagnosis/monitoring functions and so on. In line with this shift to multi-functionality, the amount of time taken up by software design and evaluation within the entire product development process has increased, and manufacturers must ensure quality software can be created in the limited development period that is assigned. To achieve this, We believe it is important to create highly reliable source code and conduct efficient verification. These beliefs inspired us to engage in the following initiatives.

4.2.1 Highly-reliable source code

Faster CPUs have led to a development trend where high-level language, such as C programming, is used for servo amplifier programs rather than an assembly language. C programming language, while offering excellent convenience and portability, is weak in regards to reliability and safety due to the ambiguity of its specifications (rules). As such, we developed a program in line with the coding regulations established by MISRA-C (Motor Industry Software Reliability Association), which are standardly adopted by the automotive industry, with the aim of using the strengths of C programming at the same time as increasing reliability and safety.

4.2.2 Highly efficient software testing

Figure 6 shows a flow chart for SANYO DENKI's software design and testing processes. It is important to conduct unit testings such as white box testing and path coverage testing in order to verify the designed software, but the number of such tests is increasing in line with an increasing number of software functionalities. As such, we introduced the latest dynamic analysis tool to create a testing environment in which source codes could be automatically verified in a PC environment without using an actual machine, thus improving the efficiency of unit testings. Moreover, by automating unit testings, it becomes possible to easily re-verify corrections of errors discovered during integration testings, thereby preventing degradation and ensuring software quality.

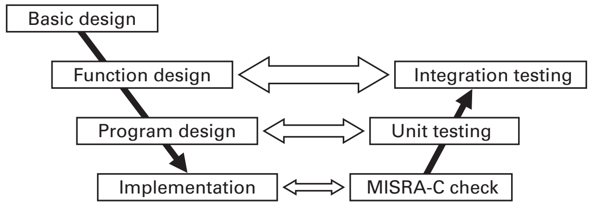

Fig. 6: Software design and testing processes.

5. Conclusion

This paper has introduced the below initiatives for the technological evolution of servo systems aimed at solving issues which accompany market changes.

(1) Using the example of the SANMOTION F5 5-phase stepping motor, we introduced the technology which improves torque performance at the same time as suppressing vibration, noise, and temperature rise.

(2) Using the development example of the 20 sq. motor of the SANMOTION R series, we introduced technology which achieves high output, high efficiency (low loss), and weight reduction. This servo motor achieves high torque and high speed at the same time as reducing mass by 8.5% and loss by 34% compared with the current model.

(3) "PCB design technology" utilizing a magnetic near-field analysis system, and "software design technology" including design of a highly-reliable source code and higher efficiency verification process were introduced as examples of our evolved servo amplifier design technologies.

Servo systems are energy conversion systems which convert electrical energy into mechanical energy, and its essence is in realization of high efficiency with compact and lightweight design. SANYO DENKI shall continue to further pursue "smaller, lighter, more efficient, and quieter" servo systems, and utilize ICT technology, such as IoT, to continue offering servo systems which can create "new value" hand-in-hand with our customers amidst a constantly changing market.

Reference

(1) Mizuguchi, Miyahara, and others: "Development of the "SANMOTION F5" - An AC Power Input 5-Phase Stepping System", SANYO DENKI Technical Report No.39 (May 2015)

(2) Miyashita, Horiuchi, and others: "Development of SANMOTION R Series, a Small Diameter 20 sq. AC Servo Motor", SANYO DENKI Technical Report No.40 (November 2015)

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