Expand into “Wider Markets in Depth”

—Understand customers “in depth” in “wider” applications, and develop technology and products together—

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1. Introduction

Servo Systems products have traditionally been widely used primarily in manufacturing applications and have been optimally customized for each customer. To deliver optimal customization, it is vital to know our customers well and deeply understand the problems they have and the solutions they seek, and share a clear image of their ideal goal. In recent years, our products have been used in applications besides manufacturing equipment, and our application range has been expanded.

This article first introduces two examples of customized products for manufacturing applications that were realized through a deep knowledge of the customer. One is high-speed motors for machine tool spindles and the other is a servo product for spring forming machines, which were the cases we solved their issues together with a great understanding of our customers.

Next, we will introduce two non-manufacturing applications in welfare and medical equipment. Powered wheelchairs and radiation therapy equipment are the two examples of using Servo Systems products, which we worked on designing mechanisms and performance from the perspective of wheelchair users and radiotherapy patients from the beginning of the development stage with our customer.

2. Custom Products for Manufacturing Applications Realized by Gaining a Deep Knowledge of the Customer

This chapter introduces two examples in which we solved problems together with the customer by gaining a deep understanding of their problems with machine tools for manufacturing use. The first one is the development of a servo motor for driving machining center spindles, and the second one is the customization technology to incorporate some of the functions of the customer’s spring forming machines into our servo amplifier.

2.1 High-speed technology for machine tools Servo motor for driving machining center spindles

2.1.1 Product overview

Motors for driving machining center spindles must be capable of variable speed operation up to the high-speed range and deliver high-torque performance to handle various machining processes. Also, it is important to improve acceleration and deceleration performance to reduce spindle start and stop time. In addition, spindle motors are required to deliver high efficiency with low loss for energy-saving processing.

To meet those requirements, we developed a high-torque, low-inertia servo motor specialized in driving machine tool spindles. Figure 1 shows the appearance of the motor. This servo motor is an interior permanent magnet (IPM) synchronous servo motor (IPM motor), and the permanent magnet is embedded into the rotor. This servo motor contains relatively little magnet material and is capable of delivering high torque up to the high-speed range, as well as high efficiency with little power loss. The rotor moment of inertia is also low, ensuring outstanding acceleration and deceleration characteristics[1]. This greatly contributes to improved machine tool performance and energy savings.

Fig. 1 Motor appearance

2.1.2 Achieving both variable speed operation up to the high-speed range and torque performance

In addition to the torque generated by the permanent magnet, IPM motors are capable of generating torque (reluctance torque) resulting from the difference in rotor magnetic reluctance. Using these characteristics, we were able to generate high torque in a wide speed range up to high speed, helping to realize a spindle servo motor with little power loss.

IPM motors have permanent magnets embedded into the rotor, making it easy to prevent the magnet scattering caused by centrifugal force. Variable speed operation up to 30,000 min^{-1} is also available.

2.1.3 High-acceleration/deceleration operation achieved through low inertia[2]

With machine tools, it is necessary to reduce the startup time until spindle machining speed is reached, and perform sharp reversal operation quickly when performing tapping. High-acceleration/deceleration operation is also important to reduce cycle time. This new IPM motor has been optimally designed to minimize rotor moment of inertia and increase torque, achieving high-acceleration/deceleration characteristics.

2.1.4 Low-loss, high-efficiency design

Power loss (iron loss) inside the motor's iron core generally increases at high speed. With our new IPM motor, the shape and material of the iron core were revised to minimize iron loss at high speed. Also, the reluctance torque is optimally controlled based on the rotational speed of the motor to reduce power loss and improve efficiency. Our new motor also has a low rotor moment of inertia, resulting in less power consumption during acceleration and deceleration. These improvements contribute greatly to energy savings in machine tools.

2.1.5 Environmental durability and maintainability

Machining centers normally perform machining using cutting oil, and cutting oil is scatters around the drive motors. For that reason, materials with high oil resistance is used for motor parts. The design also enables easy cleaning and replacement of the cooling fan and other components. Such design featured in environmental durability and maintainability contributes significantly to improving the environmental durability of machine tools and reducing maintenance time.

Through gaining a deep knowledge of the customer's equipment, we worked together and further deepened our technologies to solve problems and contribute to improving machine tool performance.

2.2 Customization technology for machine tools Spring forming machines

2.2.1 Overview of equipment

Spring forming machines produce springs by feeding linear or rod-shaped spring material with rollers, and coiling the material at equal intervals. Springs are often used as important parts involved in ensuring the safety of human lives, requiring high and uniform durability, as well as high machining precision for the equipment.

Figure 2 shows the appearance of equipment from The Itaya Engineering Ltd. a leading spring forming machine manufacturer, and one of our customers.

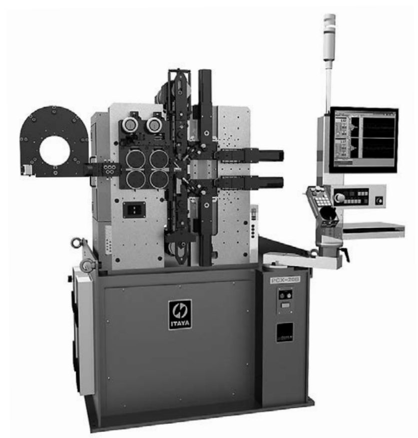

Fig. 2 Spring forming machine
(Image source: The Itaya Engineering Ltd.)

Generally, ball screws or rack and pinions are used to convert motor rotation into linear motion.

By using a simple linkage configuration as shown in Figure 3, the customer has reduced the number of mechanical parts and improved equipment productivity.

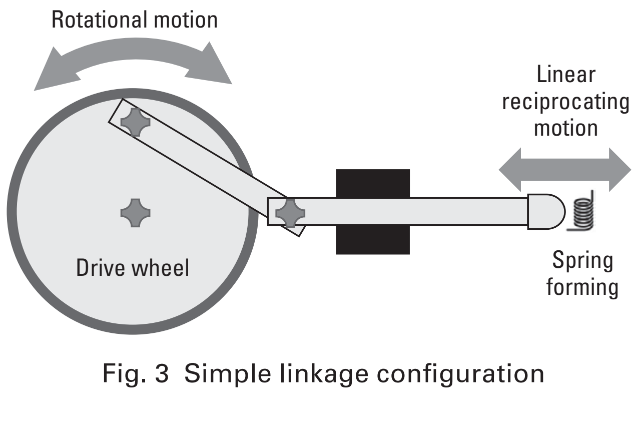

Fig. 3 Simple linkage configuration

2.2.2 Compatibility with new equipment without changing the controller

To achieve the linkage configuration shown in Figure 3, the controller uses virtual cam control. Virtual cam control converts linear position commands to angular position commands.

Machines that process more precise or complex shapes need more axes, and it is difficult to perform processing for all axes within the command update cycle.

To solve this issue, the virtual cam control that had been performed by the controller was installed in the servo amplifier. By allotting functions with the servo amplifier, the controller load is reduced so that all axes can be performed.

Gaining a deep understanding of, and optimally customizing the customer's functions in this way contributed to the development of new equipment without significant changes to the controller.

3. Customization with Deep Involvement in Welfare and Medical Applications

In this chapter, we will introduce examples of welfare and medical applications, two non-manufacturing applications. The powered wheelchairs and radiation medical equipment are examples of using servo systems products, which we worked on designing mechanisms and performance from the perspective of wheelchair users and radiotherapy patients from the beginning of the development stage with our customer.

3.1 Technology that promotes people's health In-wheel motor for powered wheelchairs

3.1.1 Product overview

Figure 4 shows a powered wheelchair developed as a joint project with a wheelchair manufacturer. SANYO DENKI was responsible for designing the in-wheel motor and peripheral mechanisms. The motors are mounted in the center of the wheels of the powered wheelchair, and the main mechanisms are the clutch, brake, and speed reducer, all of which are integrated. We designed and developed the new motor dedicated to the wheelchair to make those mechanisms thin, compact, and lightweight.

The powered wheelchair can extend the range of activities for those with disabilities and support their active lifestyles.

Fig. 4 In-wheel motor for wheelchair (example of installation in a wheelchair)

3.1.2 Required features of the motors

We made the following improvements to develop a servo motor for wheelchairs.

(1) High torque characteristics in the low-speed range

Servo motor torque characteristics were set by specifying the weight of the user, accelerating performance, and maximum speed. The maximum rotational speed was reduced compared to the standard servo motors to achieve higher torque in the low-speed range.

(2) Dustproof and waterproof performance

The joints of the motor are waterproofed to achieve high dust and water protection, even when used in the rain or on muddy or gravel roads.

(3) High efficiency, low heat generation

Since the wheelchair is powered by a battery, the higher efficiency of the motor directly leads to an increase in the driving distance. The low heat generation of the motor is also required in case users touch them with their bare hands. Thanks to low-loss design technology which we cultivated in industrial motors, high efficiency and low heat generation were both achieved.

(4) Silence and weight reduction

To ensure comfortable use of powered wheelchairs, we designed motors to minimize noise during motor rotation. High motor rigidity is required for low-noise operation, while motor weight should also be reduced for easy handling by operators at the same time. The motor structure was optimally designed to ensure both high rigidity and light weight.

(5) Solid encoder that won't break

Considering the impact during operation, the motor is equipped with a solid, hard-to-break magnetic encoder.

High-precision, high-resolution encoders required in industrial equipment are not necessary for wheelchairs. Instead, an encoder with the optimal performance for driving a motor with a human operator is installed.

3.1.3 Joint development with customer

This is an example of joint development where a new powered wheelchair was realized by combining the customer's (wheelchair manufacturer) technological strengths with those of ours.

We worked closely with the customer from the product development stage to deliver the required performance and functionality to ensure that wheelchair users can use the products comfortably and safely. We hope that we were able to bring happiness to people who use wheelchairs.

We were able to develop this new product not only by using technology cultivated in manufacturing applications but also by incorporating a new sense of values and new technology different from those used in servo motors for manufacturing use.

For welfare applications, we considered the performance required from the user's point of view and developed the product with the equipment manufacturer to contribute to user comfort.

3.2 Technology that ensures treatment with peace of mind Servo system for radiation therapy equipment

3.2.1 Overview of equipment

The customer's equipment is radiation medical equipment for brain tumors and is capable of the targeted treatment of lesions only with high-accuracy positioning and high-definition beam irradiation.

The system has a total of 6 axes, including 2 axes to control the beam irradiation direction, and 4 axes to control the cradle (bed) on which the patient lies. The axes which control the beam irradiation direction are generally driven by a rotary motor with a conversion mechanism such as a belt, but this equipment uses an arc-shaped linear servo motor[3]. By driving the arc-shaped linear motor directly, high-accuracy positioning is possible without any backlash or drop in rigidity. Moreover, as shown in Figure 5, axis 2 is mounted on the axis 1 mechanism, and the beam irradiation device is mounted on the axis 2 rotating bases. The tumor can be irradiated with a high-definition beam from any direction by driving these two axes.

We worked closely with the customer from the very concept stage to customize the system to provide high-speed, high-accuracy positioning with stable motion, and notify the user of errors before vibrations and abnormal noises increase.

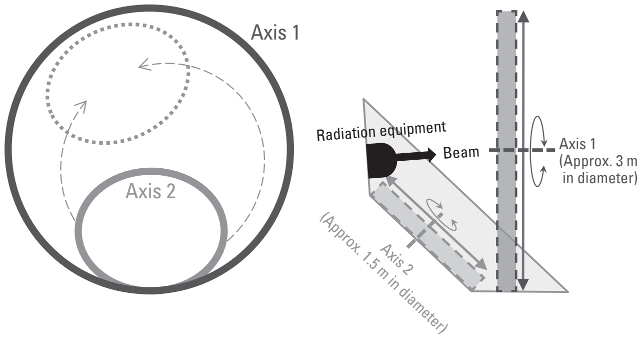

Fig. 5 Beam irradiation direction servo mechanism and size

3.2.2 High-speed, high-accuracy positioning with stable motion

The control axes for the beam irradiation direction mechanism use an ultra multipole motor with linear motor coil arranged in arc and magnets arranged in the circumferential direction[3]. The motor diameter is approximately 3 m for axis 1 and approximately 1.5 m for axis 2, making it extremely long in circumference. As shown in Table 1, there is an extremely large number of motor poles, with 450 poles for axis 1, and 250 poles for axis 2. Moreover, an encoder resolution of 2.2 to 3.3 million subdivisions is required. Our servo amplifiers can control motors with standard 128 poles and encoder resolution of up to 2 million subdivisions.

We were able to realize high-accuracy positioning by changing the electrical angle calculation processing method for current control, and offering compatibility for ultra multipole motors and high-resolution encoders.

Table 1 Motor pole number, encoder resolution, and amplifier limitations

Axis	Motor pole number [poles]		Encoder resolution [subdivisions]	
	Motor used	Amplifier limitations	Encoder used	Amplifier limitations
1	450	128 max.	2,200,000	2,000,000 max.
2	250		3,300,000	

Control of this equipment tends to be unstable due to the large load inertia. To stabilize high-speed positioning, we simulated operation under the customer's equipment load conditions and optimized the servo gain and filter.

3.2.3 Error notification before vibrations and abnormal noises increase

Since there tends to be very little distance between the patient and the medical equipment, the noise and vibration generated by the equipment may upset the patient.

With this system, encoder scale tape is attached to the motor stator periphery, and the motor position is detected by the encoder head mounted on the moving part. If the gap between the encoder scale tape and encoder head exceeds the allowable value due to equipment vibrations, operating temperature or humidity, or degradation over time, the encoder will count incorrectly, which results in large vibrations and abnormal noises.

To address this issue, we ensured to perform maintenance and overhauls before large vibrations occur and abnormal noises are emitted. As shown in Figure 6, by mounting two encoder heads and redundantly monitoring positions from these two heads, incorrect encoder counts caused by positional displacement are detected, and errors are notified before vibrations and abnormal noises increase.

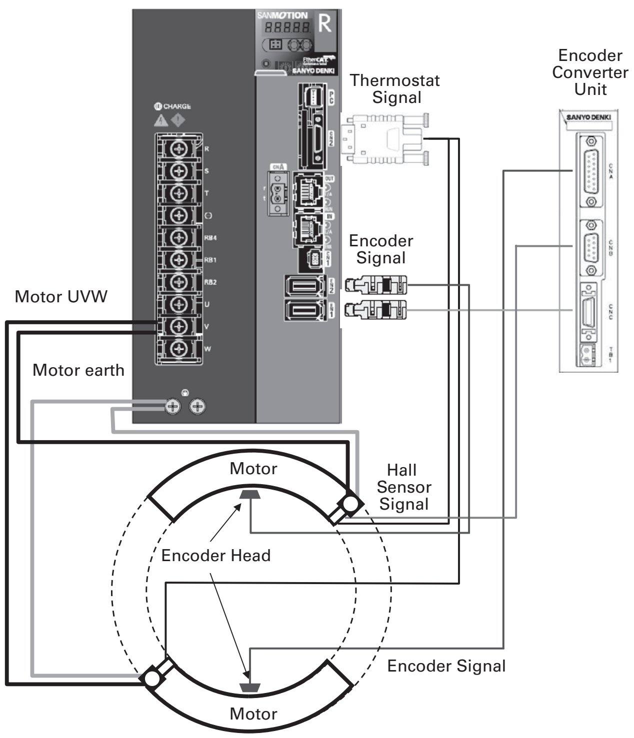

Fig. 6 Image of encoder signal redundancy

In this way, by considering servo performance and functions from the perspective of the treatment recipient and optimally customizing motors, we have contributed to the development of radiation medical equipment that provides safe treatment for patients.

4. Conclusion

This article introduced the following four examples realized by harnessing the strengths of both the customer and SANYO DENKI.

(1) Servo motor for driving machining center spindle
(2) Servo system for spring forming machines
(3) In-wheel motor for powered wheelchairs
(4) Servo system for radiation medical equipment

The technologies and products for spindle servo motors and spring forming machines are examples of how we have achieved optimum customization for "manufacturing" applications through a deep knowledge of our customers.

The technologies and products for motors for powered wheelchairs and radiation medical equipment are examples of applications other than "manufacturing," where we worked with customers to consider and develop mechanisms and servo performance from the standpoint of wheelchair users and radiation therapy patients.

In addition to conventional manufacturing applications, we aim to contribute greatly to "promoting people's health" and "restoring the global environment" by "gaining a deep knowledge" of the needs of both the customer and the world.

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