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Feature

Development of New Type Wire Winding Machines "Inner Wire Winding Machine" and "Work Rotation Type Wire Winding Machine"

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1. Introduction

Remarkable advances in reducing the size and weight of motors including AC servo motors have been made in recent years, assisted by improvements in wire winding technology. As we face performance and price competition, a key target is to develop better wire winding technology and improve the productivity.
Efforts to improve wire winding technology have focused on better wire alignment degree and higher space factor. The key to better motor performance is how to improve these two aspects at the same time.
With this background, the Production Technology Development Department has developed two models of a new, innovative composite actuator (linear motion/rotary motor and linear motion stepping motor). Using these actuators, we have developed a new inner type (wires are wound directly around the laminated core) wire winding machine.
We have also developed a work rotation type wire winding machine that winds wires (magnet wire) while pressing the wire to bend it until it forms a curve shaped like the divided core. Our "S-MAC" controller is installed in the work rotation type wire winding machine. This paper reports on these two models of new wire winding machine including the composite actuator. The control of the work rotation type wire winding machine that is described in chapter 5 is described in a separate report entitled "Application of "S-MAC" TYPE C (Development of Work Rotation Type Wire Winding Machine)" in this issue.

2. Background of Development

With market demand increasing for the compact and medium size "P3" and "P5" AC servo motors that are the main product line of Sanyo Denki, we decided to introduce the wire winding machine. Wire winding machines are also needed following the development of the 30 kW class large-capacity servo motor, which is based on the existing large-size "P6" and "P8" servo motors. A wire winding machine having good wire alignment degree and high productivity is required. The large-capacity servo motor uses thick wire of up to 3.0 mm diameter that makes winding difficult due to the rigidity of the wire.

3. Wire Alignment Degree and Space Factor

Before describing this development in detail, we describe the alignment degree and space factor which are very important factors in wire winding technology as mentioned at the beginning of this report.
The alignment degree indicates how closely the wires are brought into contact in close alignment with the shape of the laminated core when the wires are wound around the laminated core. The space factor is the ratio of the total cross-section of

the wound wires to the spatial area of the core.
Fig. 1 and Fig. 2 show front and rear views of the laminated core around which the wires are wound with the ideal winding method having good wire alignment degree. The wires are wound across each other as shown in Fig. 2, which is essential to achieve good wire alignment degree.
Also, the better the alignment degree, the higher space factor achieved.

4. Development of New Type Inner Wire Winding Machine

4.1 Features of the Wire Winding Machine

In the inner type wire winding machine that is developed for the "P3" and "P5" AC servo motors, the nozzle has a box-shaped movement (linear forward + rotation in forward direction + linear backward + rotation in reverse direction), and a linear motion/rotary motor (AC servo motor) is used as the power source of these motions. The linear motion/rotary motor (AC servo motor) can control both the linear motion and rotation as desired. The linear and rotary motions of the nozzle can be controlled as desired while winding the wires with the linear motion/rotary motor, and the deflection angle and stroke of the nozzle can be changed at will in the new wire winding machine.
The new type inner wire winding machine has the following features:
(1) Highly-aligned wire winding is achieved by changing the nozzle stroke during winding.
(2) Operation and setup performance are improved; the deflection and stroke of the nozzle, as well as model switchover, can be done by single touch panel operations.
(3) Ideal crossover of wires is achieved by the linear motion stepping motor and servo controlled indexes.
(4) The simple mechanism generates good linear motion.
(5) The winding time of the nozzle triplet is shorter,improving productivity (200% better than conventional equivalent).

Fig. 3 New type inner wire winding machine

4.2 Linear Motion/Rotary Motor

The linear motion/rotary motor as shown in Fig. 4 is the main part of the "P6" and "P8" AC servo motors. This AC servo motor has two pairs of stator and rotor in one housing that are controlled by independent encoders.
The linear motion/rotary motor has two hollow shafts as shown Fig. 5. The spline nuts and ball screws are attached to each hollow shaft. Rotation of the front rotor revolves the output shaft (spline shaft), while rotation of the rear rotor revolves the ball screw nut. At this moment, rotation of the ball screw is withheld, and its rotation is converted to linear motion that is then transmitted to the output shaft. With this structure, the dual-axes drive of rotation and linear motion is achieved. The linear motion/rotary motor shown in Fig. 5 has the maximum stroke of 250 mm with linear motion of thrust force of about 2.6 kN (rated). The resolution per pulse is 0.036° in the rotary direction and 0.002 mm in the linear motion.

4.3 Linear Motion Stepping Motor

The linear motion stepping motor is developed on the basis of the "89 steps, five-phase" series stepping motor. It has a ball screw spline inside the hollow motor shaft as shown in Fig. 6. The nuts of the ball screw spline include the ball screw nut in the front and the spline nut in the rear. Rotation of rotor is caught by the spline and the shaft moves in the linear motion with the stroke of 200 mm. The linear motion stepping motor that is used in the wire winding machine develops thrust force of about 2.5 kN with the resolution of 0.016 mm/p.

4.4 Improvement of Wire Alignment Degree

One of the key factors for improving the wire alignment degree is not to wind the wires while the wires are loose.

In the inner type wire winding, the crossover wire processing moves the wire end of a winding to the next slot. In the conventional wire winding machine, the nozzle stroke is fixed as shown in Fig. 7, so the nozzle is moved while space is secured for the needle that is inserted. As a result, unwanted wire of length ΔL is wound around the laminated core while the wires are loose, which adversely affects the wire alignment degree.

The newly developed wire winding machine can change the nozzle stroke, which is impossible to do with the conventional mechanism, by using the linear motion/rotary motor. The nozzle stroke is extended as long as length ΔL only when the crossover wires are processed. Thus, wires are wound without allowing play in the wires, so the wires are wound tightly with better wire alignment degree.

5. Development of Work Rotation Type Wire Winding Machine

5.1 Features of the Wire Winding Machine

The wire winding machine that is developed for the large-capacity AC servo motor is shown in Fig. 8. It consists of five-axis AC servo motors and a single-axis induction motor, and all motors are controlled by our servo motor controller, "S-MAC". This machine has the following features:

(1) Winds the wires while finely adjusting the position between the nozzle and divided laminated cores.

(2) Winds the wires while pressing the wire against the laminated core.

(3) Winds the wires while bending them until they form curves shaped like that of the laminated core.

By these three features, this machine can wind wires with excellent alignment degree. Its performance is particularly effective when winding wires of large diameter.

5.2 Structure of the Wire Winding Machine

The table on which the divided laminated core is set, is moved in the directions of right to left (X direction), back and forth (Y direction) and rotation (θ direction) freely by the AC servo motors as shown in Fig. 9. At the same time, the nozzle is moved in the direction of up and down (Z direction) by the AC servo motor. Between the divided laminated core and the nozzle there is a support mechanism that presses the wires against the divided laminated core by moving vertically with respect to the wires. In addition, the bobbin that feeds wires is equipped with a tension system that adjusts the wire tension.

This is the configuration of the wire winding machine. All motors of the machine are controlled by "S-MAC".

5.3 Improvement of Wire Alignment Degree

The configuration of the newly developed wire winding machine as described above allows the positional relationship between the divided laminated cores and the nozzle to be finely adjusted, and the wires are wound while being pressed against the divided laminated core as the wire is fed to the nozzle tip.

To improve the wire alignment degree, the machine has processes as shown in Fig. 10. The new winding method winds the wires while bending them by 90 degrees around one end of the divided laminated core as the pivot using the combined forces of the pressing force of the supporting mechanism and the rotary force of the divided laminated cores, thus overcoming the rigidity of the thick wires. The wire tension is increased so that the wires are wound tightly, thus improving alignment degree.

6. Conclusion

We have described the two models of the new wire winding machine that were developed in 1997 together with the composite actuator that is installed in the machine. These innovative technology developments have proved successful.
We are planning to develop a series of linear motion/rotary motor for the inner wire winding machine, and to continue developing the machine for various sizes of motor. We hope to develop the linear motion/rotary motor for wider applications using the feature of free control of the direction of rotary and linear motions.
We will endeavor to improve the wire winding technology to increase wire alignment degree and space factor, and develop more compact, higher space factor motors in the future.

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Fig.1 Front view of the divided laminated core

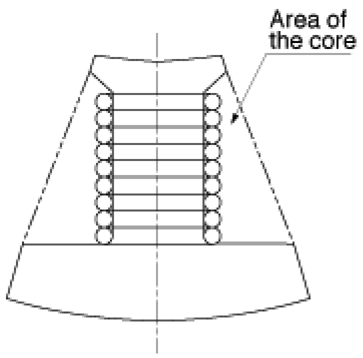

Fig.2 Rear view of the divided laminated core

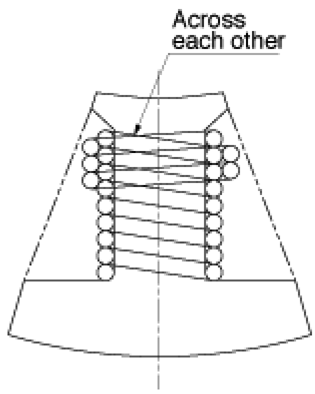

Fig.3 New type inner wire winding machine

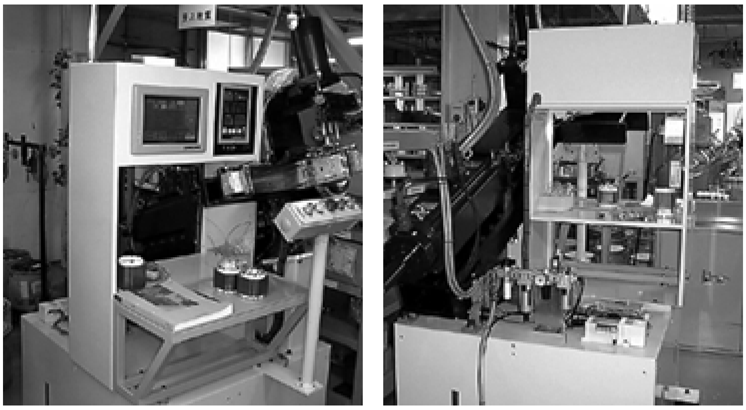

Fig.4 Outside view of the linear motion/rotary motor

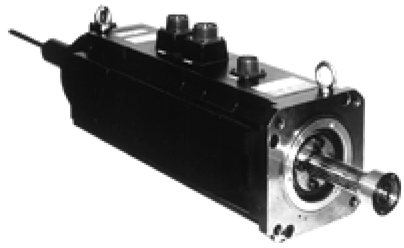

Fig.5 Cross-section of linear motion/rotary motor

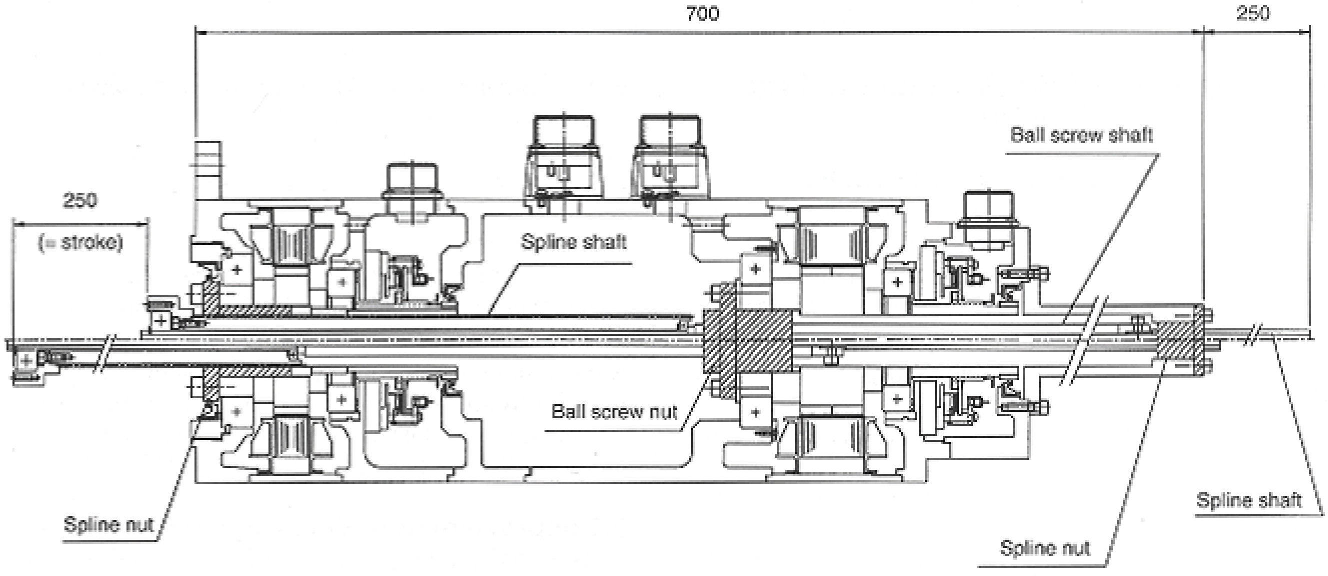

Fig.6 Cross-section of linear motion stepping motor

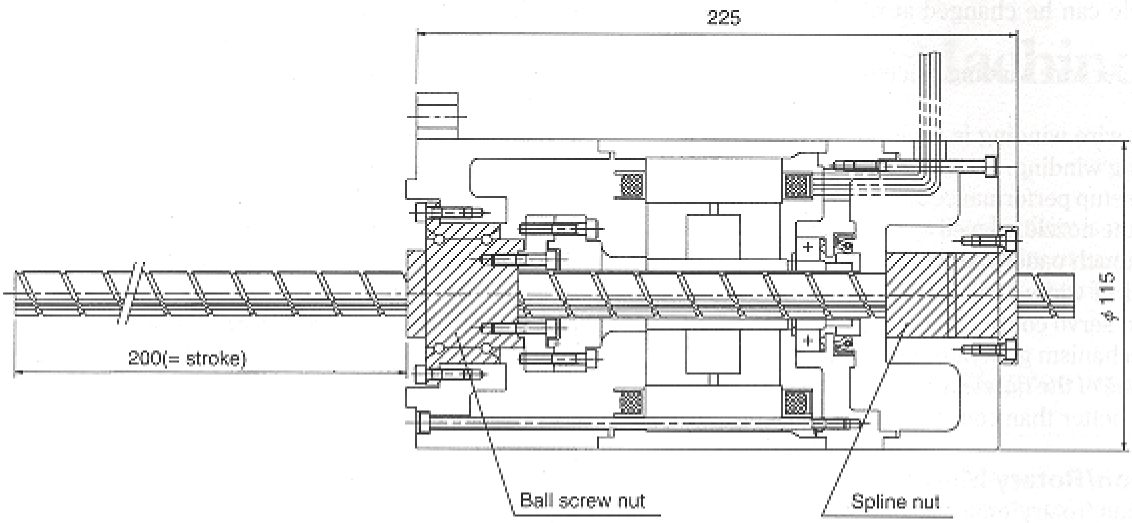

Fig.7 Locus of nozzle

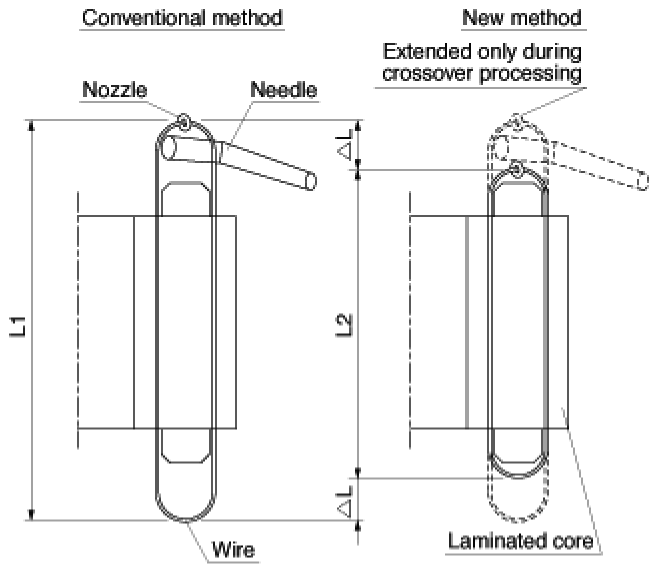

Fig.8 New work rotation type wire winding machine

Fig.9 Mechanism of the wire winding machine

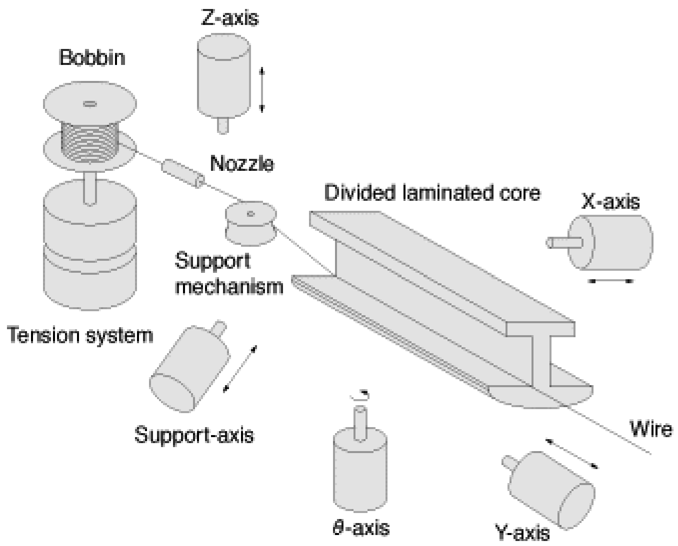

Fig.10 Process of wire winding