Development for Concentric Shaft Gearbox of Parallel Gear Reduction Mechanism

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Oriental Motor's gearboxes having a conventional parallel gear reduction mechanism have a structure in which the output shaft of the gearbox (herein after referred to as gear output shaft) is offset from the center of the motor. The newly developed **CS** gearbox, however, has a parallel gear reduction mechanism, and also its gear output shaft is arranged to be concentric with the center of the motor. This makes it easier to design equipment such as a motor mounting plate. In addition, due to design innovation, the allowable torque and the permissible radial load have been significantly improved compared to conventional models. The **CS** gearbox is added to the line-up for the **PKP** Series 2-phase stepper motors and the **BLH** Series connector type brushless motors. The following describes the structure and features of the **CS** gearbox.

1. Introduction

In the 1950s, when foot mounting type motors were the mainstream, Oriental Motor released easy-to-use flange mounting type motors. In 1951, we launched the H Series and promoted “standardization” of compact AC motors which frame size and mounting pitch were unified for each output power (see Figure 1). At the same time, in order to take advantages of the flange mounting type motors, we developed the dedicated parallel shaft gearboxes using a parallel gear reduction mechanism.

It is easy and common to interchange Oriental Motor's gearboxes to that with a different gear ratio since the frame size and the mounting pitch are compatible even in different gear ratios (see Figure 2).

Figure 1. **H** Series AC Motor

Figure 2. **2G** Parallel Shaft Gearbox

Afterward, Oriental Motor has evolved our motors into compact and high power motors. In accordance with evolution of motors, we have made efforts to improve the performances of parallel shaft gearboxes in terms of high torque, high strength, long life, and low noise.

The conventional parallel shaft gearboxes have a structure in which the gear output shaft is offset from the motor output shaft.

To meet the market request, we have developed a concentric shaft gearbox (**CS** gearbox), which is a parallel shaft gearbox and also has a concentric structure of the motor output shaft and the gear output shaft (see Figures 3 and 4). The following describes the structure and features of the **CS** gearbox.

Figure 3. **PKP** Series Stepper Motors
CS Geared Type

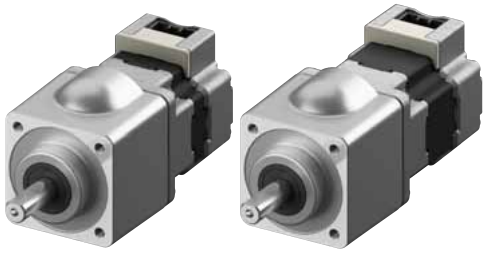

Figure 4. **BLH** Series Brushless Motors
CS Geared Type

2.Parallel Shaft Gearboxes

2.1 Structure

Figure 5 shows the structure of a parallel shaft gearbox of a parallel gear reduction mechanism. The gear output shaft of parallel shaft gearboxes is arranged avoiding the motor output shaft. Therefore, a structure in which the gear output shaft is offset from the center is commonly used. Arranging as large a gear as possible in the output stage enables to obtain a high allowable torque and design gearboxes with various gear ratios. The offset amount should be carefully considered because it is closely related to the gear design (see Figure 6).

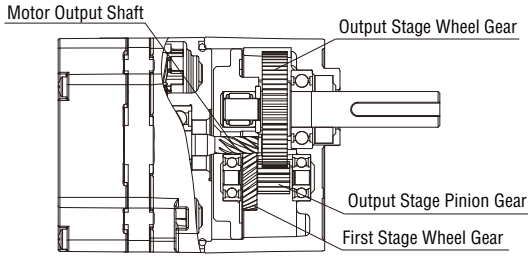

Figure 5. Structure of Parallel Shaft Gearbox

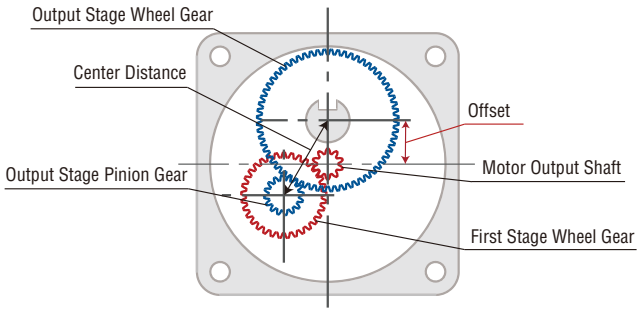

Figure 6. Arrangement of Gears for Parallel Shaft Gearbox (View from front side)

Oriental Motor offers a wide range of products, including the **GFS** and **GFV** gearboxes for brushless motors, the **GN** and **GV** gearboxes for AC motors, and the **SH** geared type for the **PKP** Series 2-phase stepper motors.

2.2 Installing to Equipment

When conventional parallel shaft gearboxes are installed to equipment, it is necessary to design the mounting plate while considering the offset amount of the gear output shaft relative to the center of the rotating shaft of the equipment side since the gear output shaft is offset from the center of the mounting surface of the gearbox (see Figure 7).

On the other hand, a concentric shaft gearbox, where the output shaft is positioned at the center of the mounting surface of the gearbox, allows the mounting plate to design at the center of the rotating shaft of the equipment side, making it easier to design the equipment.

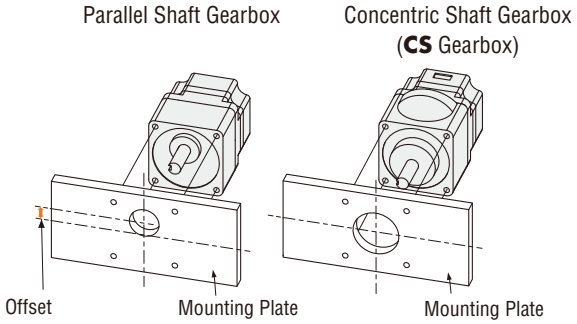

Figure 7. Installing to Equipment

3.Concentric Shaft Gearboxes

3.1 Planetary Gear Reduction Mechanism

A planetary gear reduction mechanism is a typical mechanism of concentric shaft gearboxes. This mechanism features allowable torque can be significantly increased compared to parallel shaft gearboxes because the torque is dispersed in multiple planetary gears. In the line-up of Oriental Motor products, concentric shaft gearboxes of a planetary gear reduction mechanism are used for the **PS** geared type (see Figure 8) and the **PN** geared type.

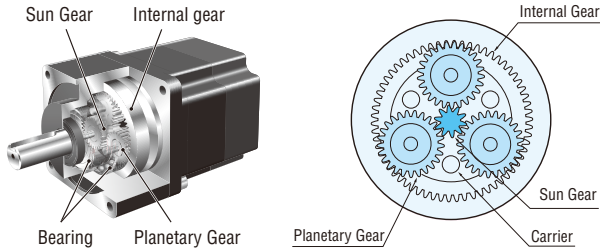

Figure 8. Example of Planetary Gear Reduction Mechanism (**PS** geared type)

A planetary gear reduction mechanism requires high-precision annulus gear machining and multiple bearings to hold planetary gears. Therefore, the manufacturing man-hours and the number of parts are considerably increased compared to gearboxes of a parallel gear reduction mechanism. In addition, since the gear specifications of the motor output shaft (sun gear) must be changed for each gear ratio, a dedicated motor is required for each gear ratio (see Figure 9).

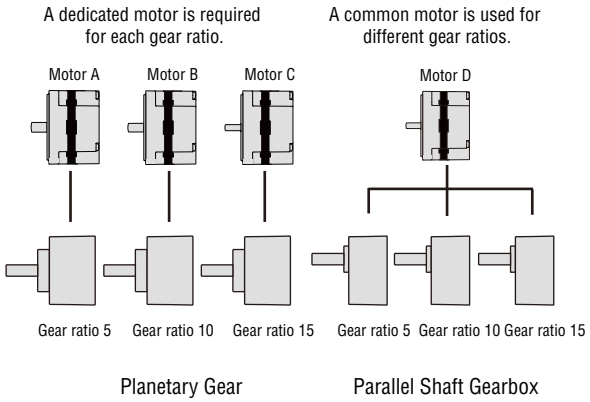

Figure 9. Comparison of Motors Combined

3.2 Development of **CS** Gearbox

3.2.1 Renewal of Structure for Parallel Shaft Gearbox

With regard to the **CS** gearbox developed this time, we have examined a structure that a concentric shaft gear box can be achieved while inheriting the structure of the conventional parallel shaft gearboxes.

The conventional parallel shaft gearboxes were basically designed so that the outer shape of the gearbox would fit within the projection plane of the motor frame size. If both this design constraint and a concentric structure are tried to satisfy, the center distance between the motor output shaft and the first stage wheel gear is restricted. This makes the center distance of each gear pair be short, and as the result, the output stage wheel gear will be a small diameter. Therefore, it is difficult to design gear ratios exceeding 10 or transmit a large torque. To overcome this matter, it is necessary to increase the center distance of gear pair and enlarge the diameter of the output stage wheel gear (see Figure 10).

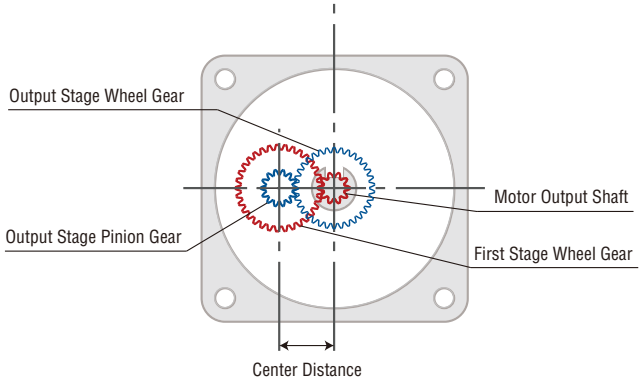

Figure 10. Concentric Structure by Design of Conventional Parallel Shaft Gearbox (View form front side)

In the development of the **CS** gearbox, having a bulge on the gear case to arrange the first stage wheel gear in the bulged space while maintaining the mounting hole pitch, we secured the center distance. (See Figures 11 and 12.) As a result, we could enlarge the diameter of the output stage wheel gear and design the gear ratios of up to 20, enabling to transmit a large torque.

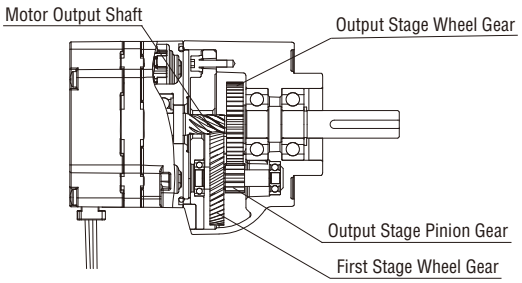

Figure 11. Structure of **CS** Gearbox

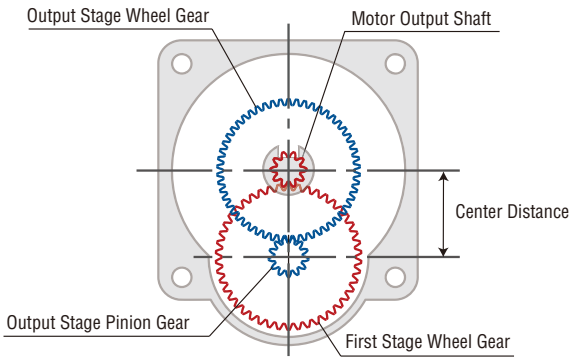

Figure 12. Concentric Structure of **CS** Gearbox (View form front side)

3.2.2 Curved Shape of Gear Case

The bulge of the gear case was made with a special curved shape that fits inside the circumscribed circle of the gear case, and was provided on the outlet side of the motor lead wires in order to minimize an impact on the surrounding area as much as possible (see Figure 13).

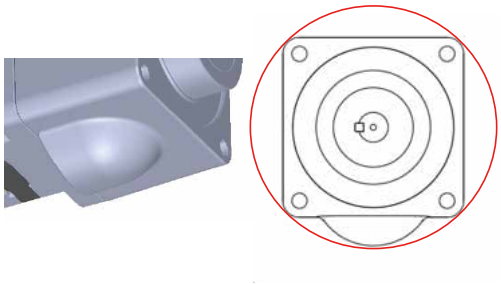

Figure 13. Special Shape of Gear Case

3.2.3 Improvement of Bearing Support Structure

If a concentric structure is applied to the parallel shaft gearbox based on the conventional design method, bearings of the gear output shaft must be supported by the gear case and the intermediate flange (see Figure 14). This structure causes the number of parts and the overall length of the gear case to increase. Therefore, for the **CS** gearbox, we adopted a structure in which bearings of the output shaft were supported by the gear case only, and the intermediate flange was eliminated (see Figure. 15). This reduced the number of parts and shortened the overall length of the gear case.

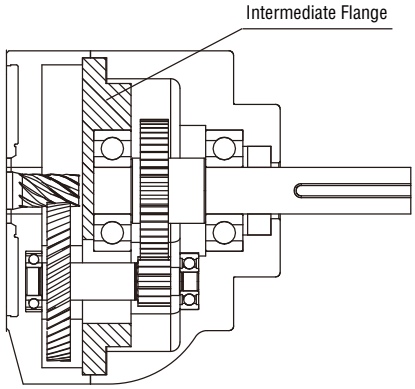

Figure 14. Bearing Support Structure (With intermediate flange)

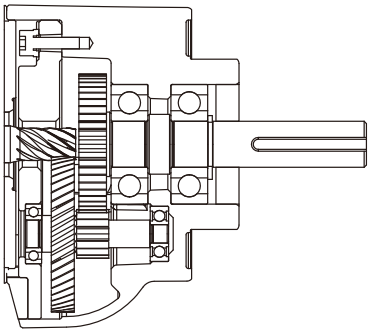

Figure 15. Bearing Support Structure (Without intermediate flange)

3.2.4 Improvement of Allowable Torque and Radial Load

In addition to enlargement of gears on the first and output stages, applying heat treatment to gears increased the allowable torque of the **CS** gearbox by approximately two times compared to the **SH** gearbox (see Figure 16).

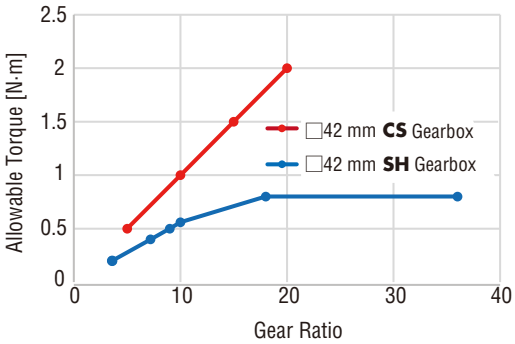

Figure 16. Allowable Torque Comparison of **PKP** Series

Increasing the center distance of gear pair could also increase the size of bearings, which made the permissible radial load increase by up to four times compared to the **SH** gearbox. This enables appropriate tension control when heavy load transmission is required with the belt drive (see Figure 17).

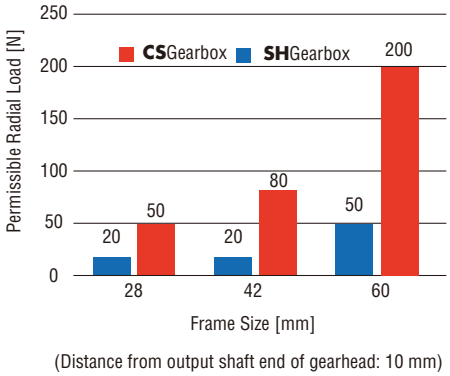

Figure 17. Radial Load Comparison of **PKP** Series (Gear ratio 10)

3.2.5 Making Products Smaller and with Higher Torque

In the case of the conventional **BLH** Series brushless motors, the output power of the frame size 42 mm was 15 W and that of the frame size 60 mm was 30 W. This time, however, combining with the **CS** gearbox which allowable torque was improved, we added a new line-up of products that achieved the output power of up to 30 W despite its small frame size 42 mm (see Figure 18).

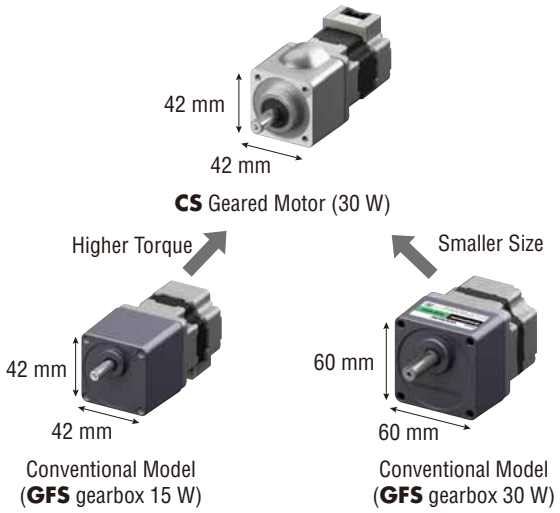

Figure 18. Size Comparison of **BLH** Series (Gear ratio 10)

When the **BLH** Series conventional model of a 42 mm frame size (output power of 15 W) with a gear ratio of 10 is used, changing to the CS geared type with the same frame size (output power of 30 W) can drive a load up to twice the allowable torque of the conventional model if the same gear ratio is used. If a desired torque is the same, using the **CS** geared type of gear ratio 5 can increase by twice the rotation speed (see Figure 19).

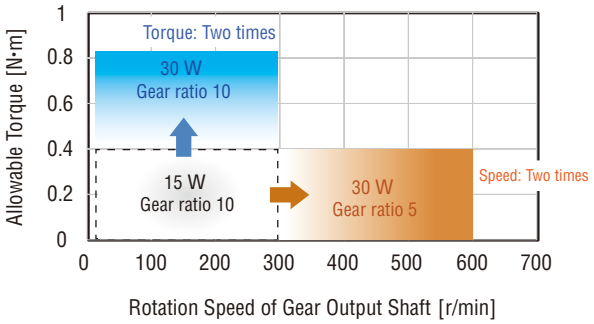

Figure 19. Characteristics Comparison of **BLH** Series Conventional Model and CS Geared Type

The permissible radial load is also improved compared to the conventional model (see Figure 20). It contributes to downsizing and higher performance of equipment.

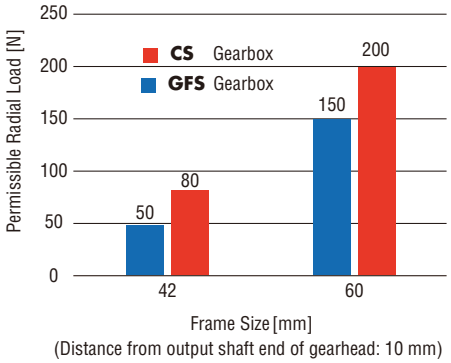

Figure 20. Permissible Radial Load Comparison of **BLH** Series (Gear ratio 10)

4. Summary

Re-evaluating the design constraint of conventional parallel shaft gearboxes, we have successfully commercialized concentric shaft gearboxes of a parallel gear reduction mechanism. We have also achieved improvements in the allowable torque and the permissible radial load for gearboxes by increasing the size of gears and bearings and applying heat treatment to gears. Although the motor output power is the same as the conventional models, making the motor size compact contributes to reduction in size and weight of equipment. We will continue to develop products that meet customer needs.

Reference

(1) Shigeki Tsukamoto, "PS gear developed as a new planetary gear", RENGA, No.174, (2011), p16

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