Longer Stroke of Electric Adjust Steering Column

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As the steering wheel moves away from the steering column, the resonance frequency decreases, and as it moves closer, the frequency increases, leading to an increased risk of vehicle resonance at the telescopic position. Such resonance may result in abnormal noise or vibrations, causing discomfort to the driver. This issue is particularly significant in steering columns with long strokes designed for extended telescopic movement in applications like autonomous driving, compared to conventional electric columns. The difference in resonance frequency between these and conventional columns is expected to widen, and with the current design, reducing this difference poses a challenge. The cause of the frequency variance is attributed to the fluctuating distance between the component that controls the gap in the drive jacket and the steering wheel. To address this issue, we repositioned the preload component from the fixed side to the drive side. This adjustment successfully reduced the resonance frequency variance by approximately 40% to 50%.

***Key Words**: electric adjust steering column, long stroke, anti-backlash structure*

1. Introduction

With the recent improvement in autonomous driving technologies, accelerator, brake, lane keeping, and other functions equivalent to autonomous driving Level 3 are being performed on the vehicle side, and demand for ensuring a comfortable living space in the driver's seat is growing. In response to this demand, JTEKT is developing an electric adjust steering column (hereafter, "electric adjust column") that can move the steering wheel away from the driver in order to secure living space.

Aiming to move the steering wheel away from the driver in order to expand the living space during autonomous driving, for the electric adjust column, we are considering a mechanism which uses a motor and feed screw to adjust the steering wheel in the vertical direction (hereafter, "tilt"), a mechanism that adjusts it in the extension/retraction direction (hereafter, "telescoping"), and a structure that increases the telescoping amount (hereafter, "long stroke"). However, when long stroke is used, it is necessary to increase the steering wheel movement speed in order to return the steering wheel to the driving position as quickly as possible when the autonomous driving functions fail.

With the structure of current electric adjust columns, possible ways to increase the movement speed include the use of a larger motor to increase the rotation speed and reducing the speed reducing ratio of the reduction gear. In these cases, there is the concern of increased motor operation noise. Another possibility is reducing the sliding resistance when moving parts extend and retract. In this case, there is a tradeoff with an insufficient feeling of rigidity in the steering feel experienced by the driver.

This report introduces the development of an electric adjust column that achieves both long stroke movement speed and rigidity.

2. Structure of the Electric Adjust Column

A schematic diagram of the overall structure of the electric adjust column is shown in **Fig. 1**. The motor rotates when voltage is applied from the vehicle, and the rotating torque is amplified by a reduction gear that uses a worm and worm wheel inside the drive unit. The rotating torque is then converted into linear direction force by the tilt/telescoping feed screw and tilt/telescoping nut. The steering wheel can be tilted by pushing and pulling the link mechanism, and can be telescoped by pushing and pulling the moving jacket.

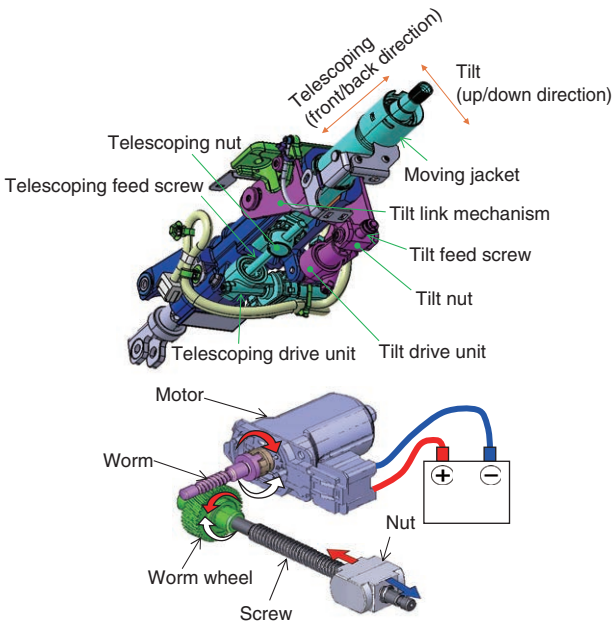


Fig. 1 Electric-adjust column

2. 1 Telescopic Structure of the Electric Adjust Column

A schematic diagram of the telescopic mechanism is shown in **Fig. 2**. During telescoping movement, in order to smoothly move the moving-side upper jacket relative to the fixed-side lower jacket, clearance is provided in the radial direction between the fixed-side lower jacket inner periphery and the moving-side upper jacket outer periphery. However, as a result of this clearance, the steering wheel moves up, down, left, and right when it is gripped, giving the driver a feeling of insufficient rigidity. For this reason, an anti-backlash structure is provided that applies a load to the moving-side upper jacket and presses it against the bottom of the lower jacket inner periphery.

Therefore, the telescopic structure must be able to achieve the contrary performance of reducing sliding resistance of the upper jacket against the lower jacket and increasing rigidity at the steering wheel point.

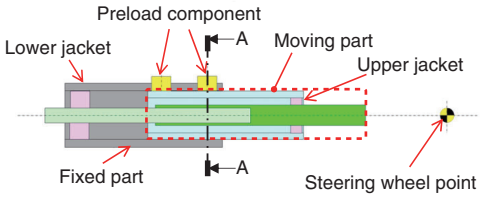


Fig. 2 Telescopic structure for the sliding portion (Conventional product)

3. Anti-backlash Structure

3. 1 Anti-backlash Structure of a Conventional Product

The anti-backlash structure of a conventional product is shown in **Fig. 3**. This figure shows cross-section A-A from **Fig. 2**. The preload component is placed on the fixed lower jacket side, and the structure contains a sliding sheet, washer, and preload disk spring in sequence from the lower jacket side, and is tightened by an adjustment screw. The advantage of this structure is that the friction force between the sliding sheet and upper jacket can be controlled by the clamping torque of the adjustment screw. In other words, it is possible to reduce load variation of the disk spring by controlling the clamping torque of the screw to absorb variation in the dimensions of component parts. However, because the preload component is placed on the lower jacket side, the distance from the steering wheel point to the preload component varies depending on the telescopic position. Therefore, differences in the static rigidity and resonance frequency occur between the telescopic shortest (hereafter, “short”) position and longest (hereafter, “long”) position. In particular with a long stroke, there are significant differences because of the large distance between the long position and short position.

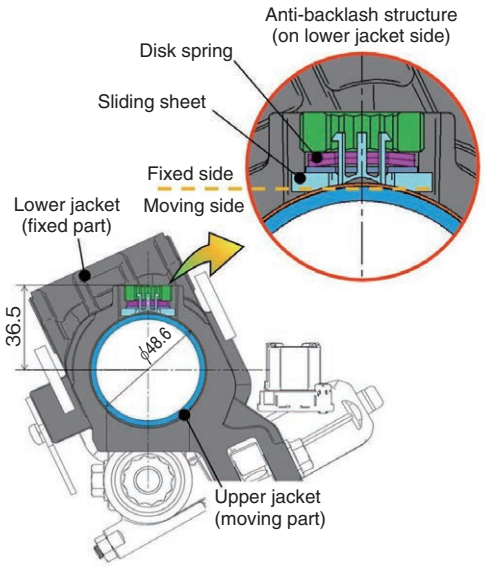


Fig. 3 Anti-backlash structure (Conventional product)

3. 2 Anti-backlash Structure of the Developed Product

The reason for the large performance difference between the long position and short position with a conventional structure is that the distance between the steering wheel point and the preload component varies

as descried above. To counter this, a structure which places the preload component on the moving part side was considered. **Figure 4** shows the structure of the developed product, and **Fig. 5** shows the differences between the conventional and new structures. In order to reduce performance variation depending on the telescopic position, placing the preload component on the moving upper jacket results in a constant distance between the preload component and steering wheel point. The preload component is fastened by inserting a projection located on the holder side into a hole located in the upper jacket. Furthermore, the structure is such that the holder holds the disk spring and sliding sheet, and the sheet is brought into contact with the surface on the inner periphery of the lower jacket.

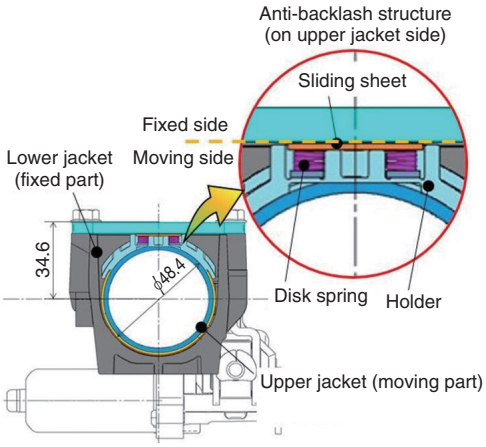


Fig. 4 Anti-backlash structure (Development product)

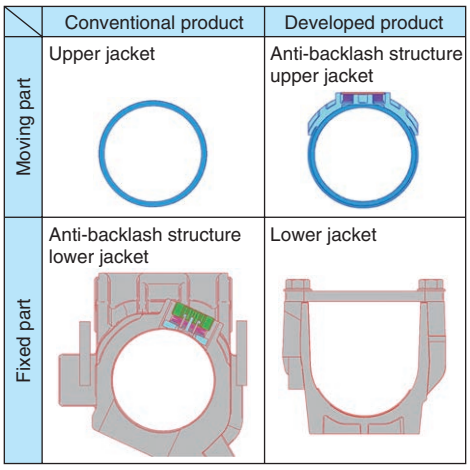
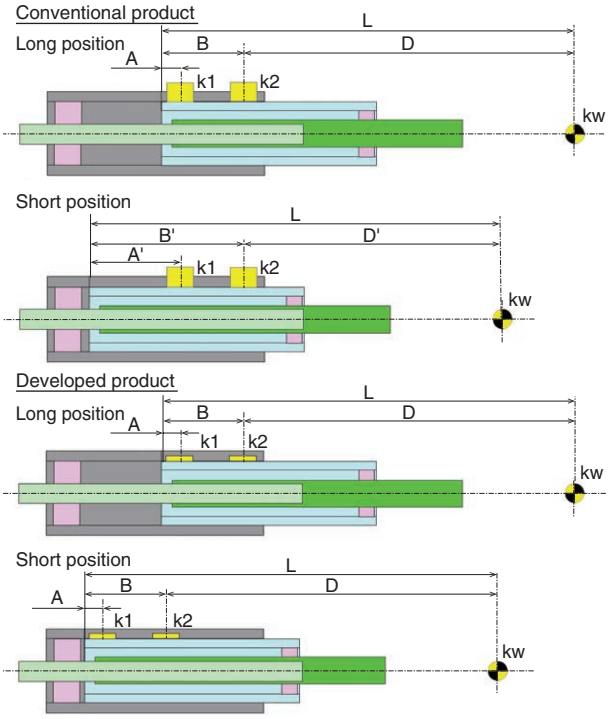


Fig. 5 Difference between conventional and new structures

3. 3 Rigidity of the Developed Product

Figure 6 shows a study model of the static rigidity of the conventional product and developed product. In the conventional product, distance D from the preload component to the steering wheel point varies between the telescopic long position and short position. This means that distance D becomes shorter and steering wheel point rigidity kw becomes higher when moving from the long position toward the short position. On the other hand, in the developed product, the change in kw is small because the preload component is fixed to the moving-side parts and D is constant. Therefore, the difference in rigidity depending on the telescopic position is small in the developed product and the difference in resonance frequency is also small.



L: Upper jacket end - Steering wheel point
A, A' : Upper jacket end - Preload component (1)
B, B' : Upper jacket end - Preload component (2)
D, D' : Preload component (2) - Steering wheel point
kw: Steering wheel point rigidity
k1: Spring constant of preload component (1)
k2: Spring constant of preload component (2)

Fig. 6 Study model

4. Robustness of the Anti-backlash Structure

4. 1 Ensuring Robustness

In the structure of the conventional product, the clamping torque of the adjustment screw is controlled as described above so that a constant load is applied, unaffected by variation in the dimensions of component parts. However, because torque control was eliminated in the developed product, a new means of ensuring

robustness that is not affected by variation in part dimensions is needed.

4. 2 Disk Spring Settings

The load of the disk spring required to press the sliding sheet against the lower jacket is decided by the following conditions. First, the load upper limit must allow the upper jacket to slide at the required speed. Next, the load lower limit must not produce clearance as a result of force from the steering wheel in the up/down or left/right directions.

The disk spring achieves high load with little deformation. When arranged in series, the spring constant decreases. When arranged in parallel, the spring constant increases. This characteristic was used to study load robustness.

Figure 7 shows the relationship between the spring deformation amount and spring load of the conventional product and developed product. In the conventional product, because two disk springs are used in parallel and the load change is large relative to the spring deformation amount, when variation in the dimensions of component parts is added, it is expected that the sliding limit load will be exceeded. For this reason, torque control of the adjustment screw is used to keep the spring load within the required range. In contrast, because the developed product has no adjustment screw, a method that can absorb the change in load within the range of part dimension variation using only disk springs was considered. As a result, by placing two sets of series spring rows in parallel, the spring constant was reduced by half, and the effects of variation in component part dimensions on spring load was reduced. By increasing the maximum spring deformation amount, a sufficient spring deformation amount was ensured without adjustment, and the spring load was also reduced.

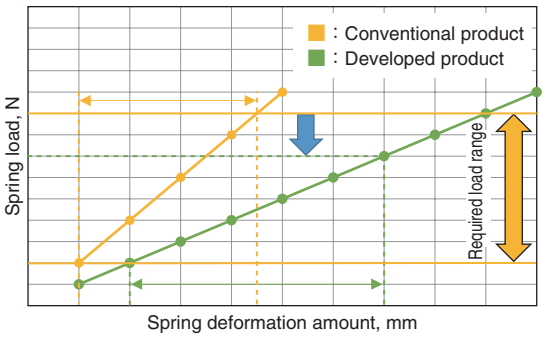


Fig. 7 Spring deformation amount and spring load

5. Performance Evaluation Results

The resonance frequency becomes lower when the steering wheel moves away from the steering column, and becomes higher when it moves toward the steering column. This means that the resonance frequency varies depending on the telescopic position, increasing the possibility of resonance occurring in the vehicle. This risk is particularly high with a long stroke column.

Therefore, a prototype electric adjust steering column equipped with the development structure was produced and the resonance frequency was evaluated. The results are shown in **Fig. 8**. With the normal 60 mm telescopic movement range of the conventional product, there is a 9 Hz difference in both vertical and lateral resonance. However, with the developed product, even though the telescopic movement range is more than double at 130 mm, the change in resonance frequency is 6 Hz for vertical resonance and 4.5 Hz for lateral resonance, reducing the change by 40 to 50%.

The spring constant of the disk spring was reduced by half, increasing load robustness in response to the amount of deformation and reducing the spring load. This also reduced the sliding resistance of the upper jacket, allowing faster telescopic operation speed. **Figure 9** shows the operation speeds of the conventional product and developed product. While 11.8 seconds were required for a 130 mm telescopic stroke with the conventional product, the developed product was able to move the distance in 6.5 seconds.

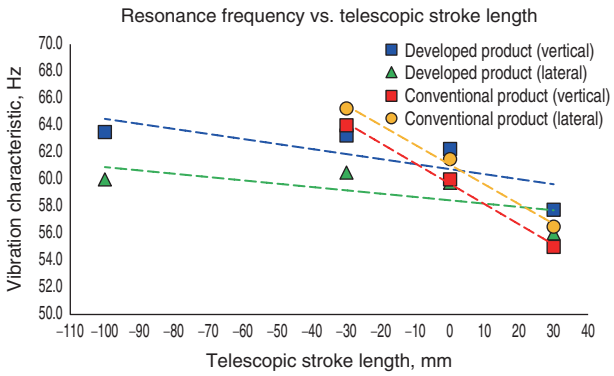


Fig. 8 Resonance frequency dispersion

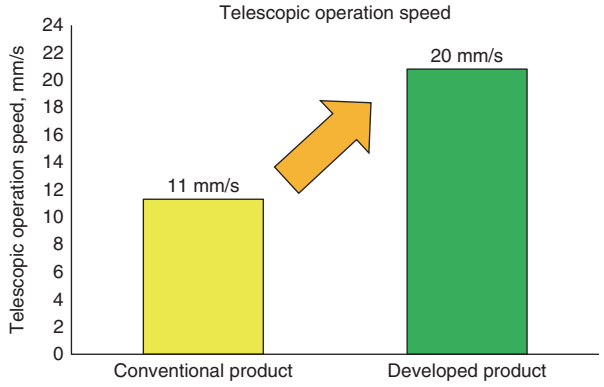


Fig. 9 Telescopic operation speed

6. Conclusions

We newly developed an electric adjust column with longer telescoping stroke—a product where new demand is expected as a result of the transition to autonomous driving. As a result, by installing the anti-backlash structure on the moving-side jacket, the difference in resonance frequency was reduced despite the increased telescoping distance compared to conventional products.

Because the disk spring is capable of absorbing variation in the dimensions of component parts, the adjustment process during assembly can be eliminated, and the telescopic operation speed was also increased. Patents are pending for the structure of the developed product both in Japan and overseas[1), 2)].

We will continue to identify market needs and strive to develop products that delight the customers in the future.

References

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