Koyo

Development of Steering Columns for Medium and Large Trucks

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New steering columns for medium and large trucks have been developed. Performance requirements for such columns are severer than those for passenger cars. But the developed columns have satisfied these requirements through changes in design and structure of parts and introduction of new mechanisms.

Key Words: *steering column, medium or large truck, shock absorbing mechanism*

1. Introduction

Steering columns which are critical safety parts in automobiles are required to have various basic performance such as the collision safety, steering feeling, and anti-theft performance. Nowadays, steering columns are required to be more convenient by having additional performance such as the tilt and telescopic functions.

Although Koyo steering columns have been mainly used for mini vehicles and passenger ears, Koyo developed the columns for medium and large trucks, which satisfy the truck's peculiar severe usage conditions, by applying techniques obtained through the development of passenger car steering columns and examining the mechanics of conventional steering columns. The columns developed for medium and large trucks started to be mass-produced in December 2001. Hereinafter, the outline of the development of these columns is described.

2. Design Specifications of Truck Columns

Main specifications of the developed column are as follows:

① Having the tilt mechanism for moving and adjusting the steering wheel in the direction perpendicular to the shaft axis (i.e. front-to-rear direction[*1)]) and the telescopic mechanism for moving and adjusting the steering wheel in the direction of the shaft axis (i.e. up-and-down direction[*1)]) in order to provide a comfortable steering wheel driving position.

② Having the folding mechanism for securing, when a vehicle collides with another vehicle or other obstacle, a space for protecting a driver by bending down the steering wheel in the forward direction.

③ Satisfying the high strength and durability requirements peculiar to trucks with lower cost and lighter weight.

[*1)] The direction along which the steering column of an ordinary vehicle or the like is tilted is normally represented as the "up-and-down direction." However, in this paper, the direction along which the developed truck column is tilted is represented as the "front-to-rear direction." The reason is that this truck column already has relatively large angle to the vehicle body when it is attached to the vehicle and thus this tilting direction of the developed column can be more suitably referred to as the "front-to-rear direction." The same applies to the direction along which the telescopic mechanism of the developed column works and thus the telescopic direction of the column is referred to as the "up-and-down direction."

3. Structure

Figure 1 shows the structure of the developed truck column.

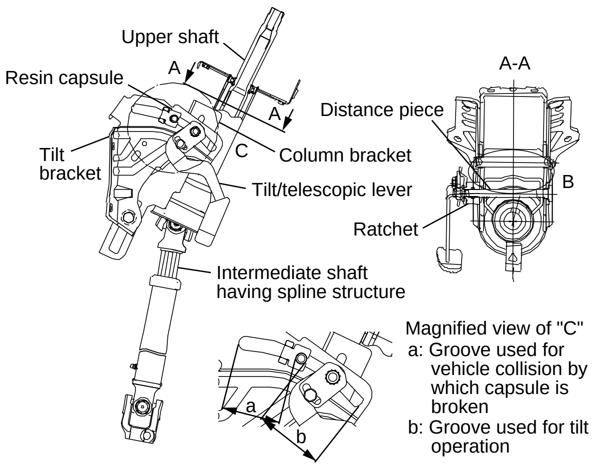


Fig. 1 Structure of developed column

4. Design of Components

4. 1 Upper Shaft and Intermediate Shaft

The developed truck column has an upper shaft and an intermediate shaft with the hollow structure for reducing the cost and weight. The sliding part of the intermediate shaft which connects the column with the steering gear is coated with nylon in order to reduce the sliding resistance in the telescopic movement and the amount of looseness in the rotational direction.

This nylon coating is performed by the electrostatic spray coating, whose cost is lower as compared with that of conventional fluitized powder dip coating. This is the first use in Japan for the column intermediate shaft.

Figure 2 shows the comparison data of wear amount and friction coefficient between the conventional product and the developed one.

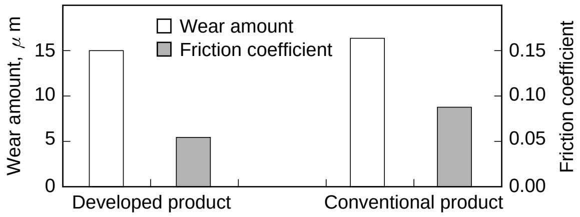


Fig. 2 Sliding characteristics

4. 2 Operation Mechanism of Cam-type Tilt Telescopic Column

The developed column is a cam-type column, which allows the driver to adjust the position of the steering wheel to a preferable position by the tilt and telescopic mechanism by which the column moves in the front-to-rear and up-and-down directions. This cam-type column with click stop feeling also allows the driver to fix and release the position of the steering wheel by the single operation of the lever. This cam-type column is suitable in that the operation section of the column converts a force applied to the lever into the force for fastening a holding part for fixing the column.

Through the development process, the mechanism had the following two problems of ① and ②. Thus, countermeasures against these problems were performed as follows.

① Reduction of tilting force in the evaluation of tilting operation durability

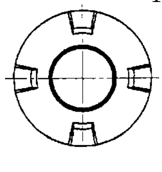
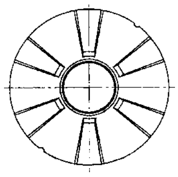
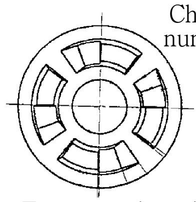
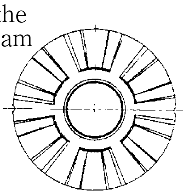
The reduction of tilting force was caused by wear between the cam engaging surfaces. Thus, as a countermeasure for this reduction of the tilting force, the pressure on the cam engaging surfaces was reduced by increasing the outer diameter of the cam and by changing the number of cam threads (i.e. four cam threads in equal spaces → six cam threads in equal spaces). Material with improved wear resistance was also used for the developed column.

Table 1 shows the shapes of the cam before and after the countermeasure.

② Insufficient feeling of the tilt lever

In order to improve the feeling of the tilt lever, it is important to determine a suitable range of the tilt lever operation force and to eliminate the difference between the force applied to the tilt lever when the column is locked and the one when the column is released. Thus, the cam having the profile as shown in **Fig. 3** was designed. Specifically, this cam profile has a two-stepped slope to reduce the force applied to the lever when the column is locked and also has the cam thread flat surface part having reverse tapered profile to increase the force applied to the lever when the column is released, thereby reducing the difference between the force applied to the tilt lever when the column is locked and the one when the column is released. The maximum load applied to the lever for locking the column and the maximum load applied to the lever for releasing it were also confirmed to be within the development specification range.

Table 1 Cam shapes before and after countermeasure

	Before	After
Drive side	 Increase of outer diameter	
Driven side	 Change of the number of cam threads Four cam threads in equal spaces	 Six cam threads in equal spaces

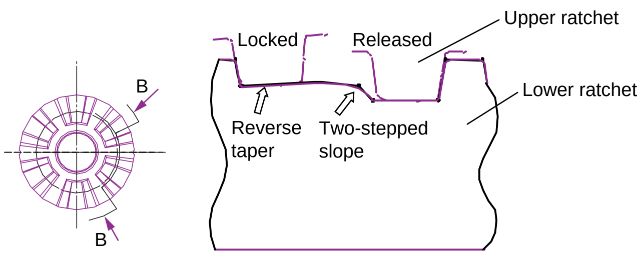


Fig. 3 Cam profile

As a result, this cam profile satisfied the specification for the lever operation force and also improved the lever feeling.

Figure 4 shows the lever operation force before and after the above countermeasure.

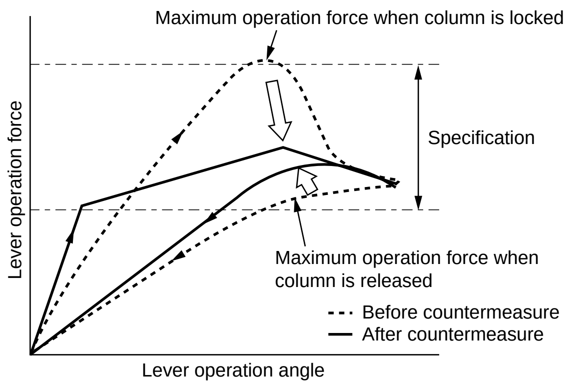


Fig. 4 Relation between lever operation force and lever operation angle before and after countermeasure

4. 3 Impact Absorption Mechanism

The developed column has the folding mechanism shown in **Fig. 5** for securing, when a vehicle having this mechanism is subjected to a strong secondary collision[*2)], a space for protecting a driver by bending the steering shaft down in the forward direction.

This folding mechanism works as follows. The steering wheel moves forward to the maximum tilting position to subsequently collapse the instrument panel part while further moving to the forward direction. In other words, as shown by "C" in **Fig. 1**, when the vehicle has a strong collision, the resin capsule for fixing the distance piece is broken to allow the distance piece to further move forward along the long groove provided in the tilt bracket. This capsule must be designed not to break when receiving an impact caused by the adjustment of the tilting force but to break when receiving an impact caused by strong collision of the vehicle. In order to provide the optimized design, FEM analysis was performed to optimize the notch shape of the capsule.

[*2)] The form of collision generated at the moment when the vehicle collides with an obstacle in the forward direction is called the primary collision. A collision through which the vehicle stops after the primary collision and then immediately a passenger collides with an obstacle in front of him/her (e.g. the steering wheel) by the inertia force of the passenger is called the secondary collision.

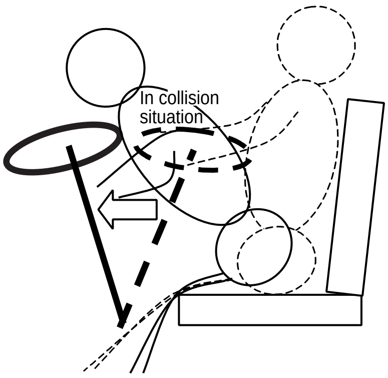


Fig. 5 Folding mechanism

4. 4 Optimized Design of Bracket

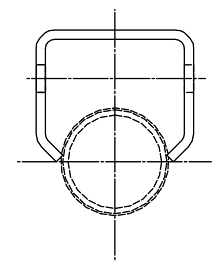
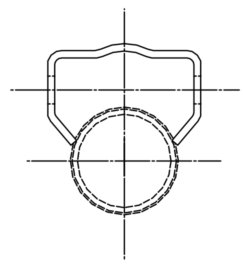
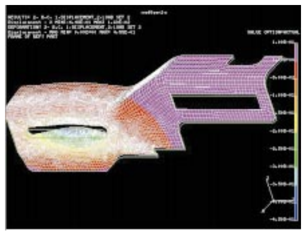
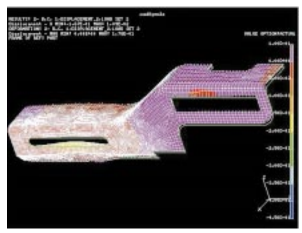
(1) Column bracket

In the developed column, there is a bracket with an oblong hole that enables the column to move in the telescopic manner as shown in **Fig. 1**. During the development process, however, a problem occurred wherein this oblong hole was deformed when the lever was fastened. In order to eliminate this deformation, the bracket design was examined through FEM analysis to obtain an optimized bracket shape having a certain level of rigidity and having reduced thickness for reducing the weight. **Table 2** shows the shape of the bracket before and after the above countermeasure.

Another problem was found during the durability testing of the tilting operation. A distance piece, provided at the maximum tilting position to work as a stopper of the tilting movement, pointedly contacted with the column bracket on one side. Consequently, the left and the right sides of the resin capsule received unequal loads, resulting in the breakage of the resin capsule only on one side.

Figure 6 shows the structure of the bracket before and after the countermeasure. The authors thought that this countermeasure is effective in that the bracket and the distance piece contact at the center. In order to confirm the effect by this design change in a short time, a conventional sample was used and wire was wound up around the center portion of the distance piece. This would easily reproduce the condition where the bracket and the distance piece have pointed contact at the center. The result of this simple test showed that this design change in which the bracket and the distance piece have contact at the center was effective.

Table 2 Column bracket shapes before and after countermeasure (upper section) and FEM analysis results (lower section)

Before	After
	
	

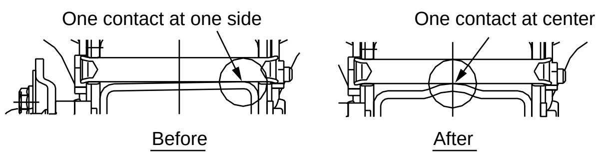


Fig. 6 Bracket shapes before and after countermeasure

(2) Tilt bracket

When the driver gets into or out of the truck, he or she will typically grab the steering wheel. Thus, the tilt bracket of the truck column is subjected to high moment in the lateral direction, thus requiring several times larger rigidity in lateral direction as compared to that of the bracket of a passenger car column. A bracket for a passenger car or a mini vehicle is typically composed of upper and lower parts and is fastened to the vehicle body. In contrast, the bracket of the developed column has a box-shaped structure for integrating the upper and lower parts in order to obtain higher rigidity. This box-shaped structure was examined through FEM analysis to specify the weakest portion therein, and a few ribs were provided at the weakest portion.

Figure 7 shows the results of FEM analysis of the tilt bracket of the developed column.

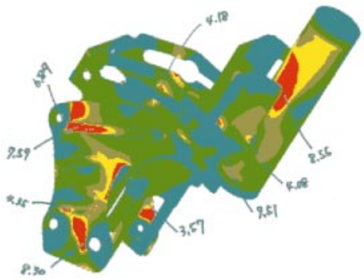


Fig. 7 FEM analysis result for tilt bracket

5. Evaluation Results

It was confirmed that the developed columns satisfied all targeted specifications such as the strength and durability requirements.

The developed column achieved 20 percent reduction in cost and 15 percent reduction in weight of the column assembly as compared to those of conventional products by reconsidering the component designs and the structure and by incorporating the new mechanisms.

6. Conclusion

The details of the development of columns for medium and large trucks were described. Performance requirements for such special columns are higher than those for passenger vehicle columns, and thus the developed columns had a totally new design by repeating the calculation with regards to dynamics and by optimizing the design through FEM analysis. As a result, the developed columns could additionally achieve the reduction in weight and cost. The authors will further develop the design of lower-cost and higher-quality columns by using the knowledge and experience obtained through this development.

References

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2) K. Koyagi, K. Kitahata, A. Uemura: Koyo Engineering Journal, 160E (2002) 52.



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