Development of Compact and Light-Weight Column Type Electric Power Steering

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We present a column type electric power steering (C-EPS) with remarkably reduced weight and cost that was developed and specialized for light vehicles by optimizing the system output and reviewing collision safety systems. We adopted the concept of front-loading development in this project. On top of the design department, both the production engineering and purchasing departments also participated in product planning to determine specifications which take into account the ease of manufacturing.

In the future JTEKT plans to launch this newly developed C-EPS in the light vehicle market as its platform for light vehicles.

Key Words: *electric power steering, front-loading development, light-weight, low cost*

1. Introduction

The demand for light vehicles is growing, with more and more people seeking fuel-efficient vehicles due to the heightened environmental awareness and escalating oil prices. Subsequently, there is also a demand for the column type electric power steering (C-EPS) mainly featured in light vehicles to be more compact and light-weight.

This paper introduces a compact and light-weight C-EPS developed by JTEKT, which can be rolled out to all next generation strategic products specialized for light vehicles as a means of answering the above needs of the market.

2. Development Aims and Targets

Development aims

(1) A low cost C-EPS specialized for light vehicles

(2) Design specifications and structure that can be standardized as a platform for light vehicles

Development targets

(1) Performance: Optimal performance for light vehicle application

(2) Weight: 15% less than conventional C-EPS

(3) Cost: 25% less than conventional C-EPS

3. Front-loading Development

Prior to this development, JTEKT performed front-loading development for a period of 12 months (**Fig. 1**). By forming a solid plan in this time, we were able to define target values by the time development started, and aimed for efficiency by reaching these target values in the period between development starting and transfer to production preparation.

The activities involved in front-loading development are shown below.

(1) Work as one with an automotive manufacturer to decide on optimal specifications for C-EPS demanded in vehicles.

(2) The Design, Production and Purchasing Groups all joined forces and established new standard specifications through SE (Simultaneous Engineering) activities.

Targets were reached through the above activities.

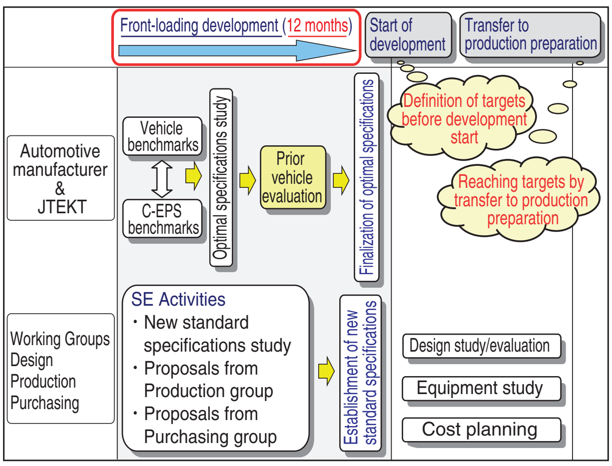

Fig. 1 Outline of front-loading development

4. Outline of New Product

4. 1 Structure of New Product and Development Items

Figure 2 shows the structure of the new product while **Table 1** shows the main development items.

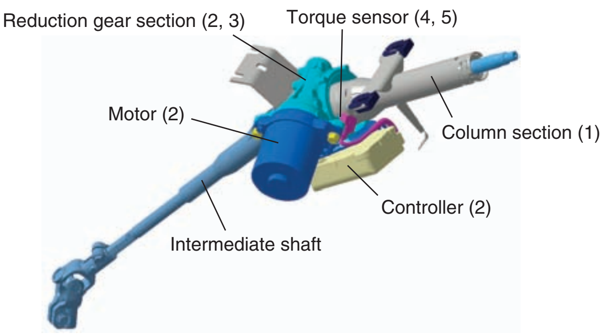

Fig. 2 Structure of developed product

Table 1 Main development items

	Main development items	Description of developed items
1	Simplifi cation of the EA[*1] structure	Single tube type + bending lower bracket
2	Optimization of system output	Reduction gear specialized for light vehicles (Reduction rate 16.67:1, Module 1.3)
		Low-output motor, controller (Current 30 A equivalent)
3	Worm shaft roll forming	Eliminated the grinding process through worm shaft tooth surface one-shot roll forming finishing
4	Tube integrated sensor housing	Integration of the column tube and sensor housing through press-expansion
5	Small and simple torque sensor	Elimination of the magnetic shield plate
		Elimination of mounting flange and securing bolts by changing the securing method

(*1 Energy Absorption)

A total of 21 development items were targeted, including items which do not appear in **Table 1** above.

4. 2 Main Development Items

4. 2. 1 Simplification of EA Structure

For C-EPS EA structure, the double tube type which makes it easy to secure inner impact space was mainstream, however as this type has a high number of parts, it was heavy and expensive. This new structure has achieved the property of the required EA load with using a single tube type and bending lower bracket (**Fig. 3**). The issue of securing impact space was solved by shortening the column length by 50mm compared with conventional types. Moreover, so that the total EA amount until full stroke would be equal, separation load of the capsule, lower bracket shape and material were tuned (**Fig. 4**).

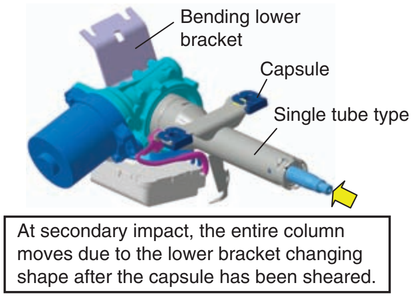

Fig. 3 Details of column structure

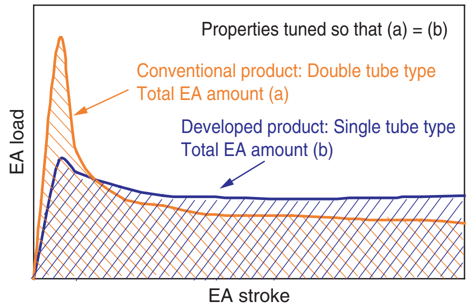

Fig. 4 Relationship between EA stroke and EA load

4. 2. 2 Optimization of System Output

In order to reduce the cost of the motor and controller which significantly affect the weight and cost of the C-EPS, the reduction gear, which is a mechanical component, must have a high reduction ratio. However, the trade-offs with increasing reduction ratio are; (1) Reduced ability of steering response (2) Increased inertia sensation (3) Increased friction, etc., therefore, generally-speaking, worm wheel type reduction gears are limited to a reduction ratio of around 20:1.

In addition to the above trade-offs, factors such as ease of installation and reduction gear strength were considered on the developed product, with the current being made 30 A equivalent for the motor and controller and reduction ratio 16.67:1.

4. 2. 3 Worm Shaft Roll Forming

By making the gear into a small module (module 1.3), it was possible to streamline the cutting/grinding finishing of the conventional worm shaft tooth surface to one-shot roll forming, which resulted in 100% material yield and reduction of the number of equipment and man-hours required for processing.

4. 2. 4 Tube Integrated Sensor Housing

Generally, aluminum die casts are used for the sensor housing which houses the torque sensor part, however on the developed product the pipe is press-expanded in order to integrate the column tube (**Fig. 5**). Mass production has been achieved through optimization of processing methods.

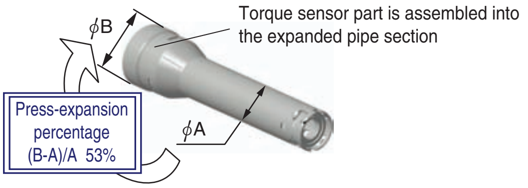

Fig. 5 Press-expanded pipe

4. 2. 5 Small and Simple Torque Sensor

Figure 6 shows the detection principle of Hall IC torque sensor. When steering torque is applied, angular difference occurs between the magnet connected with the torsion bar and the magnetic yoke, and the flux of the magnet is transmitted from the magnetic yoke to the magnetic convergence ring. By transmitting the magnetic flux proportional to the helix angle of the torsion bar to the Hall IC sandwiched between protrusions of the magnetic convergence ring, steering torque can be detected.

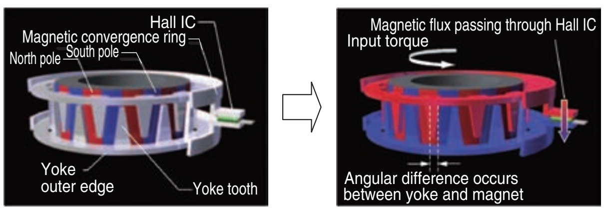

Fig. 6 Detection principle of hole IC type torque sensor

Figure 7 shows the structure of the developed Hall IC torque sensor. By replacing the aluminum sensor housing with the press-expanded steel pipe, the antimagnetic property has been improved and it possible to eliminate the magnetic shield plate that was necessary with conventional magnetic convergence ring. Moreover, the structure has been simplified by changing the securement method from tightening with bolts to pressure fitting into the tube.

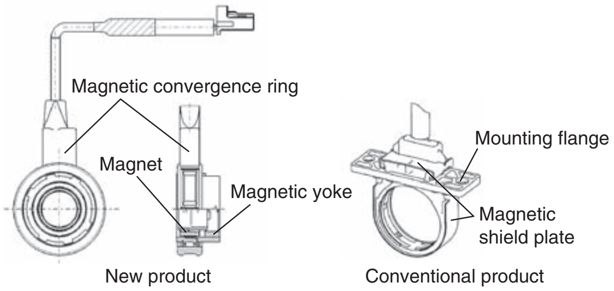

Fig. 7 Structure of hole IC type torque sensor

5. Effects

Figure 8 shows the effects on weight and cost compared with the conventional product as a result of incorporating these countermeasures on the new product and that targets have been reached. Particularly regarding weight reduction, as well as contributing to better vehicle fuel efficiency, vehicle peripheral parts have been made smaller and lighter thanks to reducing the weight of the C-EPS.

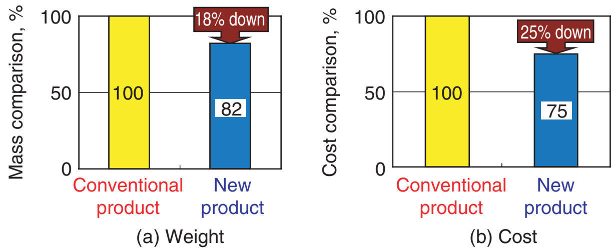

Fig. 8 Effects on weight and cost

Also, the new product was 31% less burdening on the environment than the conventional product, as calculated using the "Environmental Efficiency Basic Formula*2", making it an environmentally-considerate product.

∗2 Environmental Efficiency is a value calculated from factors such as weight reduction, size reduction and energy-saving.

$$\text{Environmental Efficiency} = \frac{\text{Product performance}}{\text{Environmental burden of product}} = \frac{1}{\sqrt{W^2+T^2+E^2}}$$

W: Weight term T: Loss term E: Energy term

$$\text{Environmental Efficiency Value} = \frac{\text{Environmental Efficiency of evaluated product}}{\text{Environmental Efficiency of standard product}}$$

$$\text{Environmental burden reduction percentage} = \left(1 - \frac{1}{\text{Environmental Efficiency Value}}\right) \times 100$$

6. Conclusion

By implementing front-loading development, the weight production of a compact and light-weight C-EPS optimal for use on light vehicles were achieved. The adoption of a working group system whereby each member shared target values and worked together to achieve these targets was effective in achieving results. In the future, JTEKT will roll out the design specifications and structure of this product as the platform for light vehicles. Moreover, using this new structure as the base, we are currently planning on rolling out for application with high output compact cars.

References

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