Development of 2nd Generation Rack Parallel Type Electric Power Steering

1. Introduction

JTEKT began mass production of rack parallel type electric power steering (hereafter, "RP-EPS") that can be installed in large-size vehicles in December 2016. In order to achieve carbon neutrality, vehicles have been transitioning to plug-in hybrid vehicles and electric vehicles. In order to contribute to improve fuel economy and electrical efficiency in these vehicles, we improved the first-generation RP-EPS (hereafter, "first generation"), creating a second-generation RP-EPS (hereafter, "second generation") that maintains the same functions and performance while reducing weight and cost. This report introduces the details of this development (**Fig. 1**).

Fig. 1 2nd generation RP-EPS

2. RP-EPS System Configuration

The main function of electric power steering is using motor output to assist the steering operations of the driver and reduce the steering load. The reducer portion of the RP-EPS is shown in **Fig. 2**. The reducer has a two-step reduction mechanism consisting of a toothed belt and ball screw, and the ball screw structure converts the rotational motion of the motor into linear motion for the steering rack. The reducer has a large effect on the durability of the steering system and the steering feel experienced by the driver. The rack housing must fulfill various functions while ensuring the mountability of the surrounding parts, and be sufficiently strong against external input. The end damper is installed in order to protect the rack housing and reducer portion from the impact load that is input when the steering wheel is rotated all the way to the end.

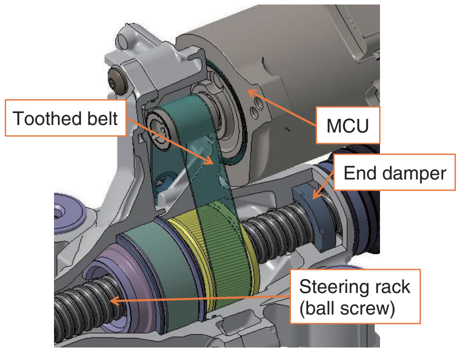

Fig. 2 RP-EPS (Reducer)

3. Characteristics of the Second Generation RP-EPS

3. 1 Weight Reduction

3. 1. 1 Utilization of the Topology Optimization Method

The topology optimization method was used as the design method for the rack housing rib shape shown in **Fig. 3**. The topology optimization method is an analysis method that identifies the placement of materials in the space available for design that will produce an appropriate structure. With the second generation, the optimal shape was studied considering not only the design requirements, but also the casting requirements, assembly requirements, and other manufacturing requirements. Changing the rib shape and overall thickness achieved a 20% reduction in weight from the first generation while still satisfying the strength requirements.

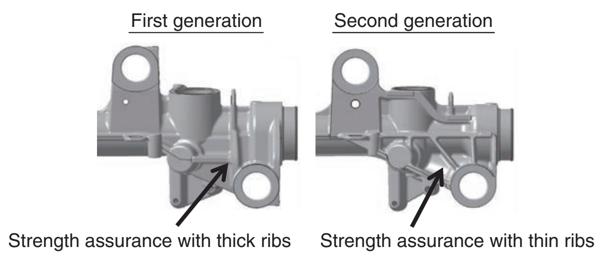

Fig. 3 Comparison of rib arrangement in rack housing

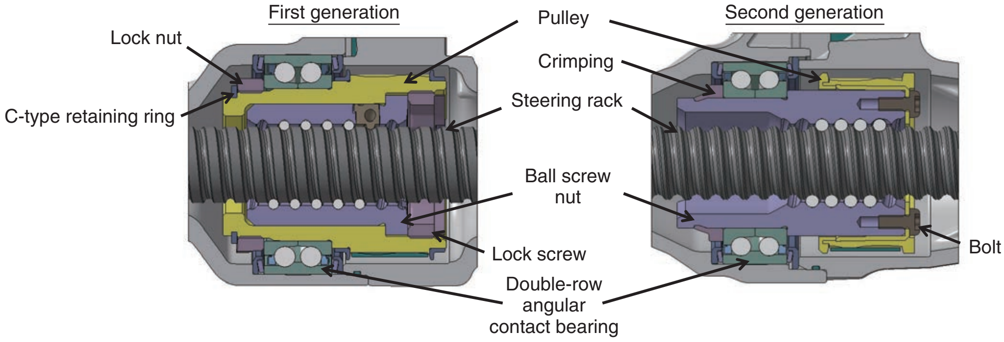

Fig. 4 Comparison of ball screw

3. 1. 2 Reducing the Steering Rack Outside Diameter

For the steering rack shown in **Fig. 4**, the evaluation criteria were optimized jointly with the vehicle manufacturer, and the steering rack outside diameter was reduced (example: $\phi 30 \rightarrow \phi 28$), achieving a 15% light-weighting effect compared with the conventional rack.

3. 1. 3 Review of the Reducer Structure

The double-row angular contact bearing holding function was removed from the pulley in the second generation ball screw structure shown in **Fig. 4**, enabling a smaller size and lighter weight (change to plastic).

The method of fastening the double-row angular contact bearing was changed from a locknut and C-type retaining ring to crimping, and fastening of the ball screw nut and pulley was changed from a lock screw to a bolt fastening structure, reducing the weight. A C-type retaining ring was previously used as a failsafe against rotational loosening of the lock nut, but with the adoption of crimping, it was eliminated. As a result of the above improvements, the mass of the second generation was reduced by 22% from that of the first generation, creating the lightest product of this class in the world, as shown in **Fig. 5** (investigation by JTEKT).

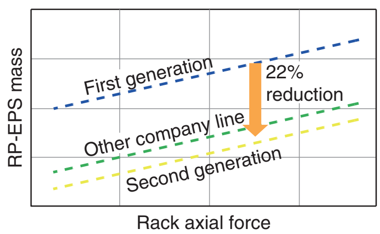

Fig. 5 Comparison of mass

3. 2 Cost Reduction

3. 2. 1 Higher Speed Reducing Ratio

The motor control unit (MCU) shown in **Fig. 2** accounts for a large fraction of the steering system cost. In order to achieve higher assist output with the same motor output, the speed reducing ratio was increased (approximately 20% higher than before). There were concerns about worsening operation noise as a tradeoff; however, by optimizing the belt and other specifications, the noise was maintained at the same level.

3. 2. 2 Simplifying the Structure of the End Damper

The end damper shown in **Fig. 6** was simplified from the previous structure by reducing the number of brackets and the volume of the rubber in the damper section. By controlling the impact load applied to the end damper, the same durability as before was ensured.

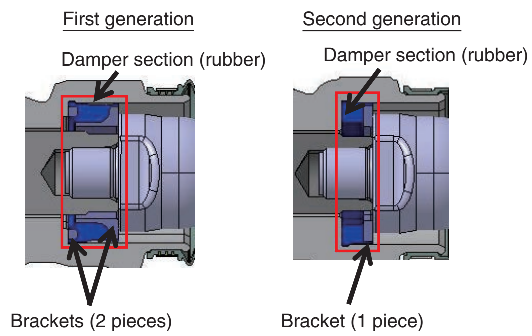

Fig. 6 Comparison of end damper

3. 2. 3 Changes to the Ball Screw Manufacturing Method

Further cost reductions were made possible by changing the processing method from cutting to rolling for ball screws in low operating noise sensitivity vehicles (such as frame vehicles). **Fig. 7** shows photos of the ball screws produced by the different processing methods. Because rolling is a processing method that does not produce machining chips, it not only reduces waste but also contributes to carbon neutrality. The light-weighting measures introduced in **Section 3. 1** also contributed to reducing cost.

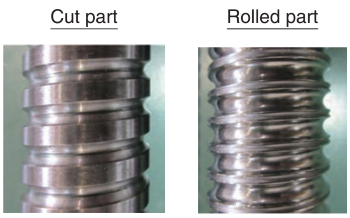

Fig. 7 Comparison of ball screw processing

4. Automation and Labor Savings on the Second Generation RP-EPS Production Line

At the second generation production lines in Japan, unmanned operation was achieved by automating transport and installation on the production line. In the assembly line shown in **Fig. 8**, parts that have shapes which are difficult to maintain (belts and harnesses) must be handled by an operator; however, as a result of a partial design change, the plastic boots can be assembled by a robot. The overall product quality inspections were changed from operator eyes to cameras, achieving 80% labor savings as shown in **Fig. 9**.

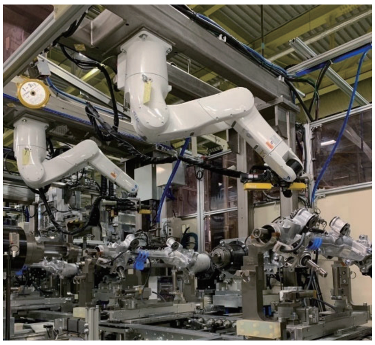

Fig. 8 Assembling multiple parts with a robotic arm

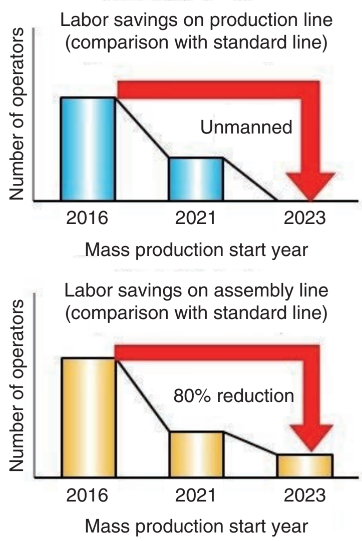

Fig. 9 Domestic factory miniaturization achievements

5. Conclusion

The second generation RP-EPS newly developed by JTEKT has already been used in the Toyota Motor Corporation new model CENTURY, ALPHARD, and VELLFIRE. In the future, we plan to expand sales to other automobile manufacturers.

(Steering System Engineering Dept., Automotive Business Unit)