

Study of Pinion Gear Support Structure in Electric Power Steering System

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Electric Power Steering (EPS) has been widely adopted in vehicles worldwide because of its contribution to vehicle fuel efficiency. It is estimated that EPS is now installed in more than 80% of passenger vehicles, and, with its widespread adoption, the basic configuration of EPS systems has become largely standardized. At the same time, EPS component evolution has increasingly focused on enhancing system reliability. One approach to enhancing system reliability has been the introduction of redundant sensors and motor drive circuits to maintain motor assist functionality in the event of a system failure. As a result, EPS systems have become increasingly costly, making cost reduction an urgent challenge. As the steering system serves as the primary interface between the driver and the vehicle, it not only conveys the driver's steering intent to the vehicle but also provides the driver with feedback from the road surface. Therefore, system cost reduction must be achieved while preserving these essential functions.

In this study, a press-fit torsion bar assembly method aimed at reducing system cost is investigated. The relationship between the pinion gear support structure and steering feel is experimentally evaluated to identify an appropriate press-fit location. Based on the results, a novel structure satisfying the target performance requirements is proposed.

In addition to the angular velocity fluctuation caused by the initial steering system layout, further fluctuation is generated by the tilt and telescopic adjustment mechanisms. As a result, the steering system may exhibit an angular velocity fluctuation of up to several percent. Although angular velocity fluctuation is perceived by the driver as steering torque variation, steering systems are generally designed so that the total fluctuation, including all contributing factors, remains within an acceptable range. Furthermore, the angular velocity fluctuation induces a bending load on the upper pin of the input shaft. This load interferes with the precise rotational motion of the pinion shaft, resulting in degraded steering feel. In the design investigated in this study, the angular difference between the two intermediate shafts is approximately 3 degrees. Experimental measurements confirmed that a bending load of approximately 80 N acts on the input shaft during normal steering operation.

To distinguish the influence of input-shaft tilting from that of elastic deformation, two configurations with a relocated torsion bar pin position were prepared. In one configuration, input-shaft tilting was reduced by bringing the fixing point closer to the supporting bearing. In the other, the upper ball bearing was additionally removed to alter input-shaft deflection characteristics. The influence of bending load on steering feel was then evaluated in terms of smoothness and steering solidity. Compared with the baseline configuration, both alternatives exhibited superior smoothness and steering solidity. These results suggest that input-shaft tilting has a greater influence on steering feel than elastic deformation.

To verify this hypothesis, the relationships between bending load and input-shaft deflection were measured for each configuration. The results showed that the baseline configuration exhibited a distinct discontinuous response to the applied bending load. These findings clarified the mechanism by which the bending load generated by angular velocity fluctuation acts on the input shaft, induces input-shaft tilting determined by the shaft support structure, and ultimately degrades steering feel.

Based on these findings, a dual-end press-fit structure was proposed, in which both ends of the torsion bar were press-fitted between the two bearings supporting the input shaft. Compared with the relocated-pin configuration, the proposed structure exhibited superior smoothness, steering solidity, and continuity of the bending load-deflection response.

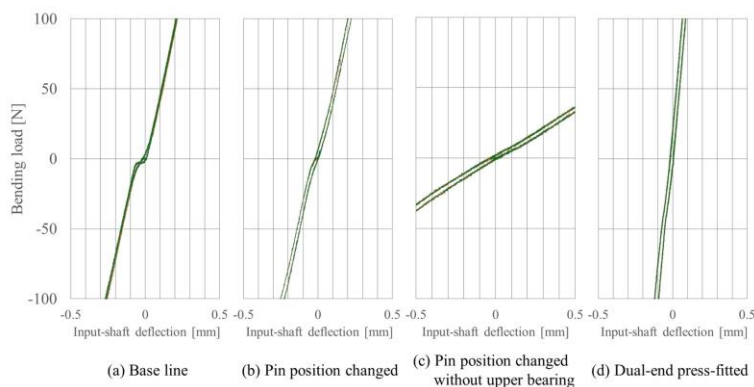


Fig.1 Bending load – input-shaft deflection characteristics

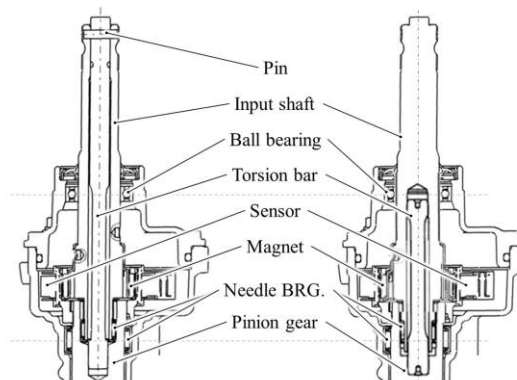


Fig.2 Baseline and proposed structure