Lightweight and High-efficiency Drive Shafts for Rear-wheel-drive Cars

Tatsuro SUGIYAMA*
Yuichi ASANO*

A lightweight and high-efficiency drive shaft designed exclusively for rear-wheel-drive cars with a mass reduction by 16% and a torque loss rate reduced by 40% in comparison with conventional products.

1. Introduction

Constant velocity joints (hereinafter referred to as CVJ) are often used for automotive drive shafts. Front-wheel-drive (FWD) cars such as a one shown in Fig. 1 use fixed CVJ (for example, NTN’s EBJ) on the tire side because of greater operating angle. In the engine side, the CVJ must be capable of sliding in axial direction to compensate for suspension movement (for example, NTN’s ETJ) is used.

On the other hand, rear-wheel-drive (RWD) cars can use a tire-side CVJ whose operating angle is not greater than 23˚. Thus, RWD cars can adopt mounting procedure for fixed and plunging CVJs reverse to that of FWD cars, or may utilize drive shafts whose both sides are capable of plunging.

Recently, needs for more compact, lighter, more efficient drive components have been mounting to reduce fuel consumption in addressing environmental conservation. This trend is also true with luxury cars of larger engine displacement.

Generally, RWD cars use CVJs whose design specification is identical to that of CVJs for FWD cars. Nevertheless, NTN has newly developed high performance drive shaft dedicated to RWD cars. This drive shaft is intended for luxury RWD cars that require an amply sized (high load capacity) drive shaft: this product is compact, light-weight, much more efficient rear wheel-dedicated drive shaft that contributes to lighter car design and improved fuel economy.

This special rear wheel drive shaft consists of two sets of newly developed compact, light-weight, highly efficient cross groove type plunging CVJs that are coupled with each other via a light-weight hollow shaft. The structure and features of this new product are hereunder described.

2. Structure of Newly Developed Driveshaft

The structure of NTN’s newly developed drive shaft is shown in Fig. 2

Both ends of this drive shaft are each equipped with a cross groove type plunging CVJ featuring improved efficiency and smaller size through increasing the number of balls as compared with conventional cross groove CVJ’s, wherein both CVJ’s are linked with a light-weight hollow shaft not undergoing any drawing processes.

* Automotive Business HQ.  C.V. Joint Engineering Dept.
Various structures are available for installing CVJ to car bodies. On an example in Fig. 2, the mount system in tire side of CVJ is stem mount system where the splined shaft end of CVJ is fitted into the counterpart (hub) and the mounting system in the differential side of CVJ is a disk mount system where the shaft end of differential side is bolted down to the companion flange; thereby, stem specification may be applied to both drive shaft ends.

The two CVJs on both ends of drive shaft may be identical in terms of their internal structure; thereby, the plunging CVJs at both ends of drive shaft can both accommodate axial displacement.

Compared with conventional cross groove CVJ (NTN's LJ), the NTN's newly developed CVJ has an increased number of balls of smaller diameter. This new CVJ design has contributed to higher efficiency and much compact size of drive shaft.

This unique CVJ has been designated "ELJ" that constitutes a part of NTN's E series constant velocity joint products boasting light weight, compact size and higher efficiency.

In addition, the light-weight hollow shaft for coupling the two ELJ CVJs is joined to the inner rings by amply sized splines; thereby, the thin-walled shaft having near-uniform bore diameter and outside diameter over the entire shaft length can be designed, and this feature contributes to realization of light-weight drive shaft. This drive shaft is very unique in that it does not require drawing at the shaft ends that is necessary for standard splined joint on a conventional hollow shaft (refer to Figs. 2 and 8).

3. High-Efficiency Plunging CVJ (ELJ)

3.1 Construction and features of newly developed CVJ

NTN's conventional cross groove plunging CVJ "LJ" has six cross grooves for rolling balls on the inner ring and outer ring; wherein, these grooves are oriented inclined toward the circumferential direction and two adjacent grooves are inclined in reverse directions (refer to Figs. 4 and 5). The balls are held at the intersection points between cross grooves on inner ring and outer grooves (grooves on the inner ring are inclined in the direction opposite to that of grooves on outer ring), all the balls are situated on a common plane in a bisector with the cage; thereby, the CVJ can run at constant speed while the inner ring can slide in the axial direction.

Fig. 3 shows an exploded view of NTN's newly developed cross groove CVJ "ELJ", and Fig. 4 gives an exploded view of conventional cross groove CVJ "LJ". Compared with "LJ", "ELJ" features increased number of balls of smaller diameter, and inclination of cross grooves on inner ring and outer ring is smaller; thereby the ELJ CVJ is capable of maximum operating angle equivalent to that of conventional CVJ "LJ" while achieving compact size, lighter weight and more efficient torque transmission.

Table 1 summarizes characteristics of NTN's newly developed cross groove plunging CVJ "ELJ" as compared with those of conventional cross groove CVJ "LJ". Fig. 5 schematically illustrates difference between the newly developed cross groove CVJ and conventional cross groove CVJ in terms of inclination of their cross grooves by referring to cutaways of their disk type outer rings.
3.2 Reduced size and weight with "ELJ"
As previously mentioned, "ELJ" has achieved smaller size through size reduction and increase in number of balls and decrease in inclination of cross grooves for rolling balls. At the same time, smaller ball size allows the wall thickness of the inner ring to be greater; consequently, the diameter of splined bore of inner ring to be joined to the splined shaft end can be greater. As a result, the axial dimension of inner ring can be further reduced; thus the weight of inner ring has been much reduced.

In Fig. 6, a cutaway of the newly developed stem outer ring type ELJ109 (109 is designation of NTN's drive shaft) is compared with that of conventional design. Compared with conventional design, the outside diameter of ELJ 109 is approximately 9% smaller and weight reduction with the joint alone has amounted to approximately 22% (2.63 kg to 2.05 kg).

3.3 Efficiency enhancement for ELJ
Smaller ball size, increased number of balls, and reduction in inclination of cross grooves on inner ring and outer ring each help improve efficiency of CVJ. Reduction in inclination of cross grooves helps reduce axial sliding friction on the balls, and decrease the shift of balls; consequently, torque loss is much decreased.

Fig. 7 shows the result of torque loss reduction ratio with ELJ with the operating angle of CVJ kept at 5 degrees. Compared with conventional "LJ", the torque loss with the newly developed "ELJ" is approximately 40% smaller.
4. Light-weight hollow shaft

Conventional hollow shafts used in drive shafts have limitation in size of splined section because as shown by the lower example in Fig. 8, a smaller diameter is adopted for shaft end while maintaining sufficient wall thickness for the inner ring. Since necessary strength needs to be maintained for shaft end even with a smaller diameter, the shaft end is subjected to drawing to provide greater wall thickness for this area.

The newly developed drive shaft is dedicated to RWD applications, and will not be operated at greater operating angle. Furthermore, adoption of the newly developed “ELJ” helps enlarge the splined section for joining to the inner ring as previously explained in Sec. 3.2; consequently, as shown by the upper example in Fig. 8, the newly developed hollow shaft does not need drawing on either end. This is because the NTN’s newly developed drive shaft technology allows the diameter of splined section on shaft end to be larger; consequently, sufficient mechanical strength can be provided for both ends of the hollow shaft without modification of both ends to increase wall thickness.

NTN’s new hollow drive shaft features thinner wall thickness, with its bore diameter and outside diameter remaining uniform over nearly entire longitudinal dimension. This feature helps to further reduce the weight of drive shaft. For comparison purpose, a hollow shaft whose outside diameter at its midpoint is equal to the newly developed drive shaft, with both ends subject to a drawing process such that its both ends have strength equivalent to the newly developed drive shaft; then the weight of this comparison hollow shaft was compared with the new drive shaft. Consequently, it has been found that the NTN’s new hollow shaft achieved weight reduction of approximately 18%. Thanks to this weight reduction, hollow drive shaft may have greater wall thickness to enhance rigidity of the hollow shaft provided that increase in wall thickness does not lead to weight of drive shaft greater than that of conventional design.

5. Conclusion

(1) NTN’s newly developed rear wheel drive shaft achieves approximately 16% of weight reduction*1 by adoption of “ELJ” + thin-walled hollow shaft + “ELJ”.
(2) Adoption of “ELJ” realizes approximately 40% reduction in torque loss*2 (higher efficiency)
(3) Adoption of “ELJ” realizes approximately 9% of reduction in outside diameter*2 (outside diameter of stem outer ring type).
(4) Adoption of thin-walled hollow shaft that has not undergone the drawing process on either end leads to further weight reduction.

*1 Comparison in weight of drive shaft assembly with conventional design LJ + hollow shaft (drawn shaft ends). Total of approximately 16% weight reduction by stem outer ring type CVJ (Sec. 3.2, approximately 22% weight reduction) + hollow shaft (Sec. 4, 18% weight reduction) + disk outer ring type CVJ.
*2 Comparison with conventional LJ.

Compared with conventional LJ, NTN’s newly developed drive shaft (ELJ) dedicated to rear wheel drive cars has achieved size reduction, lighter weight and higher transmission efficiency. As people are going to be more eco-conscious, NTN will apply its improved drive shaft technology to automobiles that need higher efficiency in transmitting driving power.

Photo of authors

Tatsuro SUGIYAMA
Automotive Business HQ
C.V. Joint Engineering Dept.

Yuichi ASANO
Automotive Business HQ
C.V. Joint Engineering Dept.