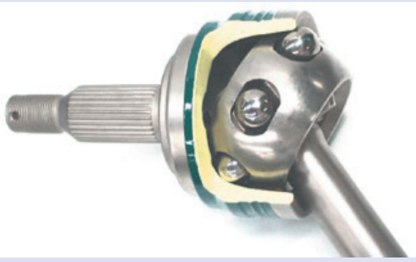
NTN TECHNICAL REVIEW No.75（2007）

[New Product]

Fixed Constant Velocity Joint with a Super High Operating Angle of 54 Degrees (TUJ)

Manabu HOSHINO*
Masashi FUNAHASHI*



NTN Corporation has succeeded in developing a fixed-type constant velocity joint called TUJ that has the world's highest maximum operating angle –54 degrees–for automobile drive shafts. TUJ will allow four-wheel drive and front-wheel drive cars to have a greater steering angle, enabling a very small turning radius. This report summarizes the concept, design and characteristics of TUJ.

1. Introduction

Recently, the needs from car users have been diversifying, and a greater variety of car designs have been marketed. In this context, the car manufacturers are attempting to market unique products by adding unique additional features.

Examples of such additional features may include sharp turning capability and increased passenger space. To satisfy these requirements, a vehicle must feature a smaller turning radius and an extended wheelbase. These requirements can be satisfied by a greater steering angle with the tires. This particular need has been strong for both FWD and 4WD vehicles where steering wheels also function as driving wheels. The tire steering angle is governed by the design limitations as well as the maximum bending angle (hereinafter referred to as "maximum operating angle") of the ball-fixed constant velocity universal joint; hereinafter referred to as "CVJ") in the tire side within the front driveshaft system that transmits the engine output from the differential gear to the driveshaft.

To address this need, we have recently developed a super high angle fixed CVJ "TUJ" (Tapered-track Undercut-free Joint) series capable of greater operating angle compared with conventional fixed CVJs in order to enhance the additional value and freedom of design on the vehicle side.

2. Driveshaft defined

A driveshaft is a power transmitting component that connects the engine power (revolutions and torque) to the tires. It remains capable of running at a constant speed and smoothly transmitting the torque even when an angle occurs between the running input shaft (differential gear shaft) and the rotating output shaft (tire shafts). Generally, a driveshaft assembly in each of the right and left sides comprises a shaft that links a fixed CVJ with a plunging CVJ, wherein the fixed CVJ cannot slide in the axial direction though being capable of a greater operating angle while the plunging CVJ can slide in the axial direction though being capable of only a limited operating angle. More specifically, the fixed CVJs are situated in the tire sides while the plunging CVJs are located near the differential gear (see **Fig. 1**).

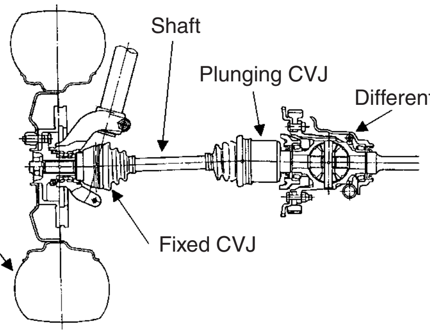


Fig. 1 Example of front drive shaft

*Automotive Sales Headquarters　C.V.Joint Engineering Dept.

The maximum operating angle with the NTNǃs currently mass-produced EBJ (High Efficiency Ball fixed Joint) products, which feature light weight, compact size and high efficiency, is 47 degrees, while the maximum operating angle with the EUJ (High Efficiency Undercut-free Joint) products is 50 degrees.

3. Super high angle fixed CVJ "TUJ"

Compared with the conventional high angle fixed CVJs (maximum operating angle of 50 degrees), the TUJ series CVJ products boast a greater maximum operating angle. The TUJ series CVJs are described below.

3.1 Features of TUJ

The components of the TUJ are identical to those on conventional fixed CVJs, and are composed of outer ring and inner ring each having ball raceway track (hereinafter referred to as ᵡball trackᵋ, six balls seated in the ball tracks and the cage that holds the balls (see **Fig. 2)**.

The typical features of the TUJ are as follows:

[1] Maximum operating angle: 54 degrees

[2] Functions (strength and durability): equivalent to those of conventional fixed CVJs

[3] Transmission of torque is possible even at an operating angle of 54 degrees.

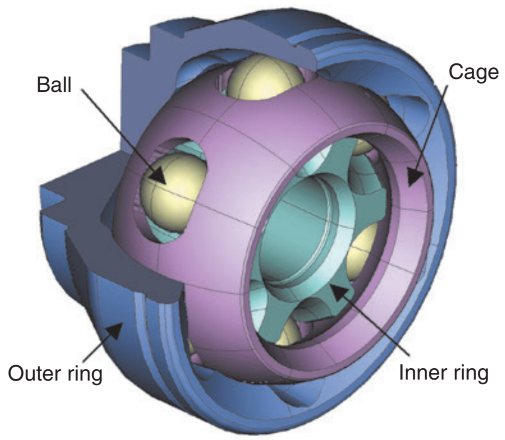


Fig. 2 Composition of TUJ

3.2 Basic structure of TUJ

In order to be able to transmit torque at a super high operating angle in excess of 50 degrees (an application not possible with conventional fixed CVJs), the TUJ incorporates **NTN**'s unique design arrangements. The most unique points of this design are described below:

[1] Tapered ball track (patent pending)

On a fixed CVJ, the amount of axial travel of the balls in the ball track is greater with a greater operating angle.

Therefore, to realize a greater operating angle, a greater axial length of the ball tracks is necessary. The range of axial travel of the balls at a higher angle situation is illustrated below, using the EBJ as an example (see **Fig. 3**).

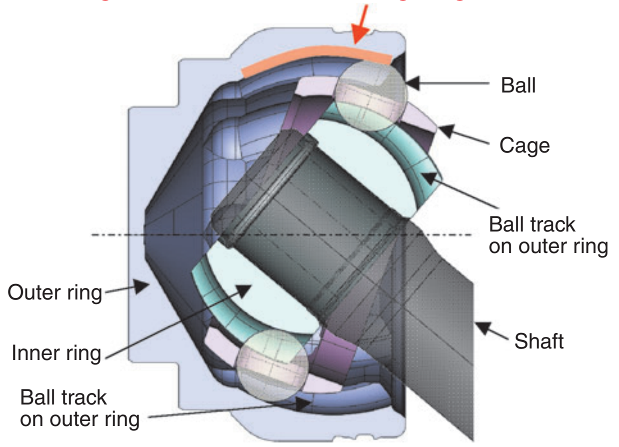


Fig. 3 Construction of EBJ at high-angle

The ball tracks on the EBJ are circular arc-shaped, and the maximum operating angle of the EBJ is 47 degrees. In contrast, the ball tracks on the EUJ (high-angle CVJ) are arc-shaped + straight-shaped, thereby a sufficient ball track length in the axial direction is realized and the maximum operating angle of 50 degrees is achieved. The newly developed TUJ, which is capable of an extremely high range of motion, has a unique ball track shape (arc + tapered) in order to incorporate the longer ball tracks (see **Fig. 4**).

[2] Adoption of offset cage (see Figs. 5 and 6)

The ball track shape adopted for the TUJ (arc + taper) causes the ball tracks on the inner ring and outer ring to force the balls toward the outer ring opening side when the TUJ is at a greater operating angle; consequently, a problem of insufficient strength occurs with the cage that holds the balls.

On fixed ball CVJs, due to of the nature of their mechanism, an offset for controlling the balls is necessary (offsetting of the ball track centers on the outer and inner rings to the axial direction); accordingly, the ball tracks are offset relative to the center of sphere (hereinafter referred to as "ball track offset"). However, this ball track offset method is unfavorable due to structural limitations, the depth of ball track at the far side on the outer ring is shallower when the CVJ takes a greater operating angle.

The TUJ employs an offset cage (a cage with which the centers of the inner and outer spheres are axially offset) to maintain a necessary offset by means of a cage, wherein the thickness of cage can be larger at the outer ring opening side where a greater cage strength is needed and, at the same time, possible decrease in the ball track depth can be prevented.

Thus, the TUJ design can solve not only insufficient joint strength at high angles situation but also possible problems resulting from an insufficient depth of ball tracks.

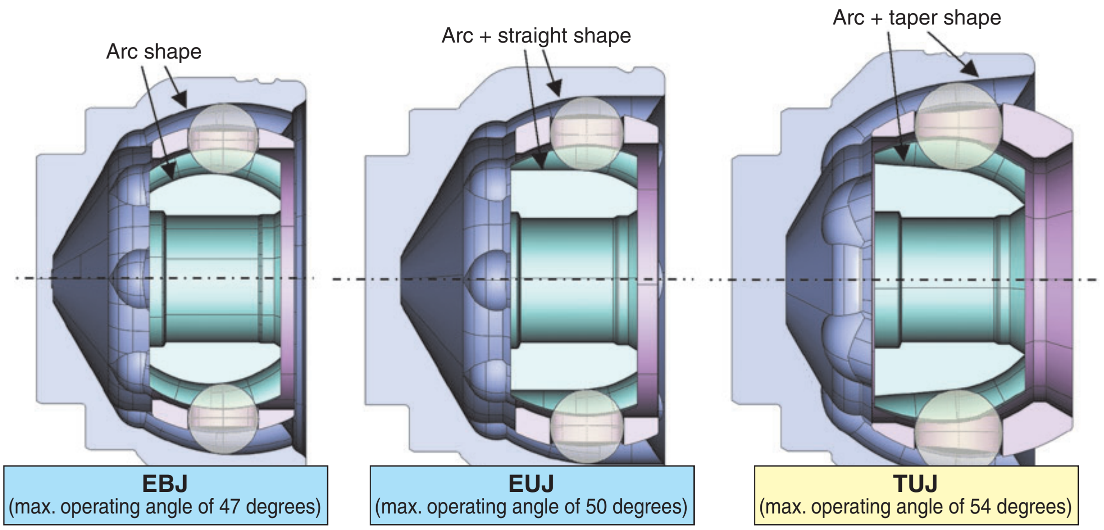


Fig. 4 Comparison of a ball track contour of fixed CVJs high-angle

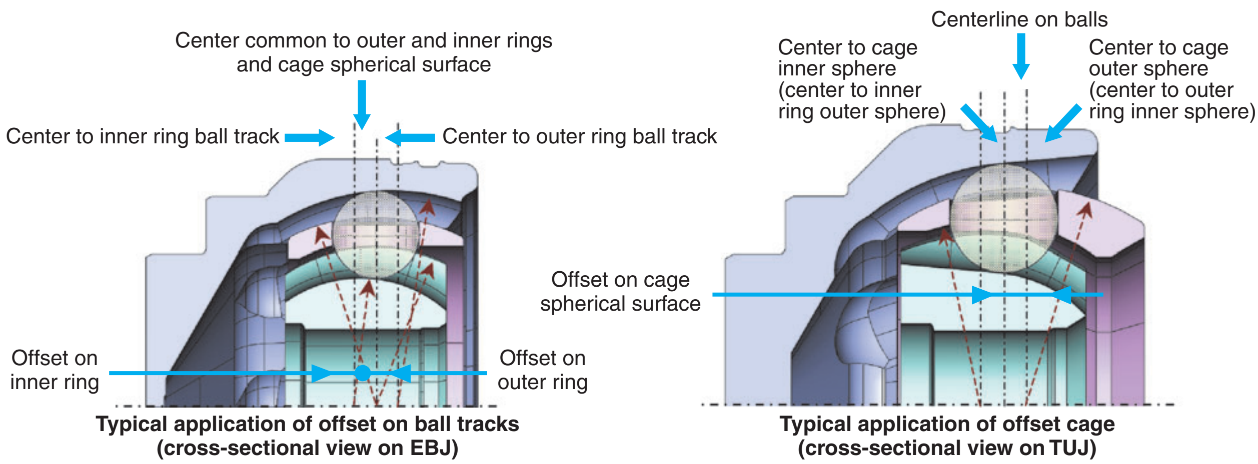


Fig. 5 Comparison of structure between ball track offset and cage offset

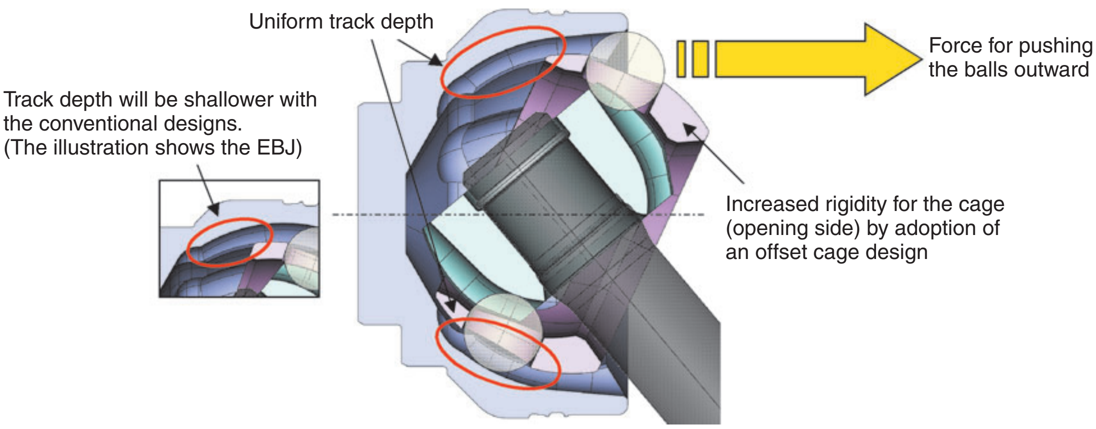


Fig. 6 Construction of TUJ at high angle

4. Joint functions

The TUJ features the performance comparable to that of conventional high angle fixed CVJs (maximum operating angle of 50 degrees). In consideration of an increased operating angle, we set the strength of the TUJ at a maximum operating angle equal to that of the conventional high angle fixed CVJs. More specifically, we have adopted the above-mentioned offset cage and fully utilized an FEM stress analysis (see **Fig. 7**) and dynamic mechanism analysis (see **Fig. 8**), thereby we have realized the mechanical strength at an operating angle of 54 degrees with the TUJ that is equivalent to the mechanical strength at an operating angle of 50 degrees with conventional fixed CVJs. **Fig. 9** provides comparison in terms of dynamic torsion strength.

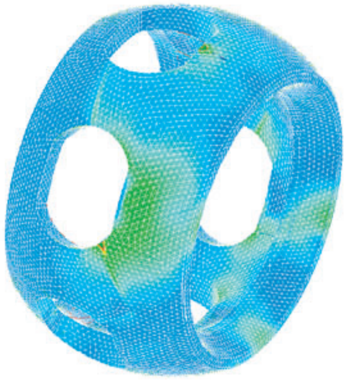
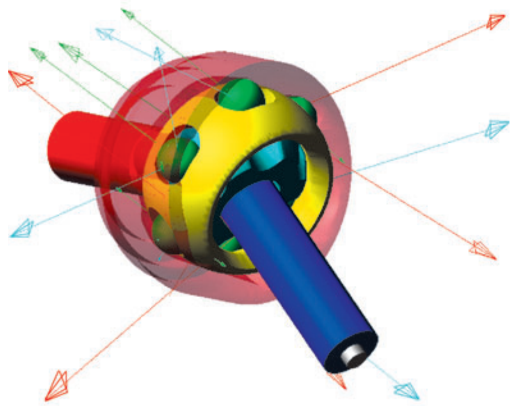


Fig. 7 FEM stress analysis for cage



Red : Load working between outer ring track and balls
Blue : Load working between inner ring track and balls
Green : Load working between balls and cage pockets

Fig. 8 Dynamic mechanism analysis

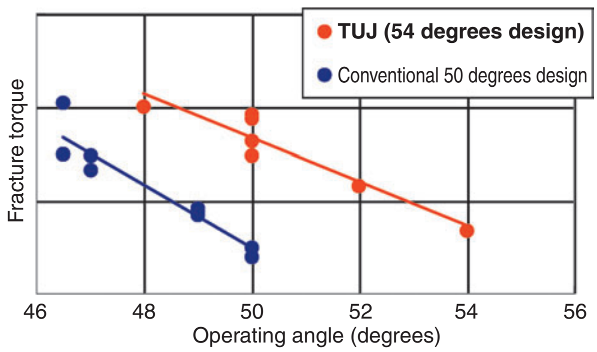


Fig. 9 Comparison of dynamic torsion strength

5. Conclusion

By employing **NTN**'s unique design, we have developed an innovative fixed CVJ featuring a maximum operating angle of 54 degrees while having the performance comparable to that of conventional CVJs (maximum operating angle of 50 degrees). This maximum operating angle (54 degrees) for automotive driveshaft is currently the highest in the automotive industry. The increase of 4 degrees in operating angle means that the minimum turning radius of an average medium-sized FF car can be decreased by approximately 70 cm (13%) or the wheelbase of such class of a car can be enlarged by approximately 40 cm (15%) while maintaining a minimum turning radius. In other words, a medium-sized car can feature a turning radius of a compact car or the passenger space of a larger car allowing designers more flexibility in consideration of layout and design.

References

1) Journal of Society of Automotive Engineers of Japan, vol.61 No.3 (2007)

Photos of authors

Manabu HOSHINO
C.V. Joint Engineering Dept.
Automotive Sales
Headquarters

Masashi FUNAHASHI
C.V. Joint Engineering Dept.
Automotive Sales
Headquarters