Small and Lightweight CVJ for Rear Sub-axles

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FF-based 4WD vehicles generally have a smaller rear torque distribution than the front, so small load capacity is applied to the constant velocity joints for the sub-axle.
There is a market demand for small-sized CVJs for rear sub-axles, similar to the “R series”; “R series is a compact and lightweight CVJ for rear of main axle, which is already in mass production and pursues miniaturization and weight reduction.
Introducing the features and performance of the developed “small and lightweight CVJ for rear sub-axles”.

1. Introduction[1) 2)]

Passenger cars are categorized by front-wheel drive (FF), rear-wheel drive (FR) or 4-wheel drive (4WD) driving methods, with 4WD vehicles further classified as being based on an FF layout or FR layout.

Constant velocity joints (CVJs) that are used as driveshafts for driving the front wheels of FF vehicles and 4WD vehicles have the role of transferring power from the engine or motor smoothly to the tires. These CVJs need to move with the tires steering and the suspension changing, and as such, consist of fixed type CVJs with a larger work angle used on the tire side, and sliding type CVJs that can slide in the axial direction used on the differential side

While rear driveshafts of FR vehicles and 4WD vehicles can actually use fixed axles (rigid axle with the left and right wheels connected in a line along the same axle), vehicles designed for ride comfort and driving stability require CVJs because they use suspension systems that allow the left and right axles to move up and down independently (independent suspension systems) **(Fig. 1)**. Yet they differ from the CVJs used for front wheels because the rear tires are not used for steering so a large operating angle is not needed.

NTN has developed a wide variety of CVJ types including fixed types and sliding types that provide different functions to suit specific applications. Furthermore, each type of CVJ is also available by load capacity in a range of sizes, from small (such as #75 for compact cars) to large (such as #113 for large vehicles).

Until recently **NTN** had used front wheel CVJs as rear wheel driveshafts, however as large operating angles are not required for rear wheel CVJs, **NTN** has developed the small and lightweight R Series[3)] with a minimal operating angle. This product has been released in sizes with high load capacities and marketed toward European automotive manufacturers for use as main axles in FR vehicles.

More recently, rear wheel CVJs have also been developed as small and lightweight CVJs in sizes with low load capacities for sub axle applications.

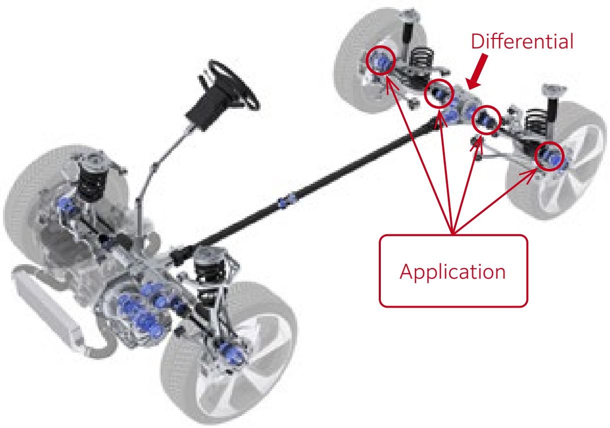

Fig. 1 Application of CVJ for rear

2. Developed Product Structure and Features

SUVs have been dominating the automotive market in recent years, and there are many models that are available with 4WD powertrains. C segment or smaller compact SUVs that are particularly popular in Japan and Europe also come in 4WD configurations based on an FF platform in order to maximize cabin space.

In general FF-based 4WD vehicles have a smaller torque distribution to the rear compared to the front, and in many cases small CVJs are used for the rear.

In light of this, **NTN** adapted its existing lightweight “R Series” rear driveshaft to develop the small size “Small and Lightweight CVJ for Rear Sub-axles.”

A comparison of the developed “Small and Lightweight CVJ for Rear of Sub-axle” and the

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conventional product is shown in **Fig. 2**.

The developed product mass and outer diameter reduction rate from the conventional product is shown in **Table 1**. Compared to the conventional product, the fixed type CVJ is approximately 6.2 % lighter and the sliding type CVJ approximately 29 % lighter in weight.

This corresponds to a 429 g lighter weight per driveshaft for the #75 size, making each vehicle 858 g lighter when both left and right driveshafts are taken into account.

The outer diameter has also been reduced significantly, with an 8.5 mm smaller (12.3 % reduction) diameter achieved on the sliding type CVJ in particular.

Note that as the vehicle mounting structure differs for each customer, the mass calculations shown in **Table 1** do not include the stem section (fitting shaft for vehicle mounting) in the shape shown in **Fig. 2**.

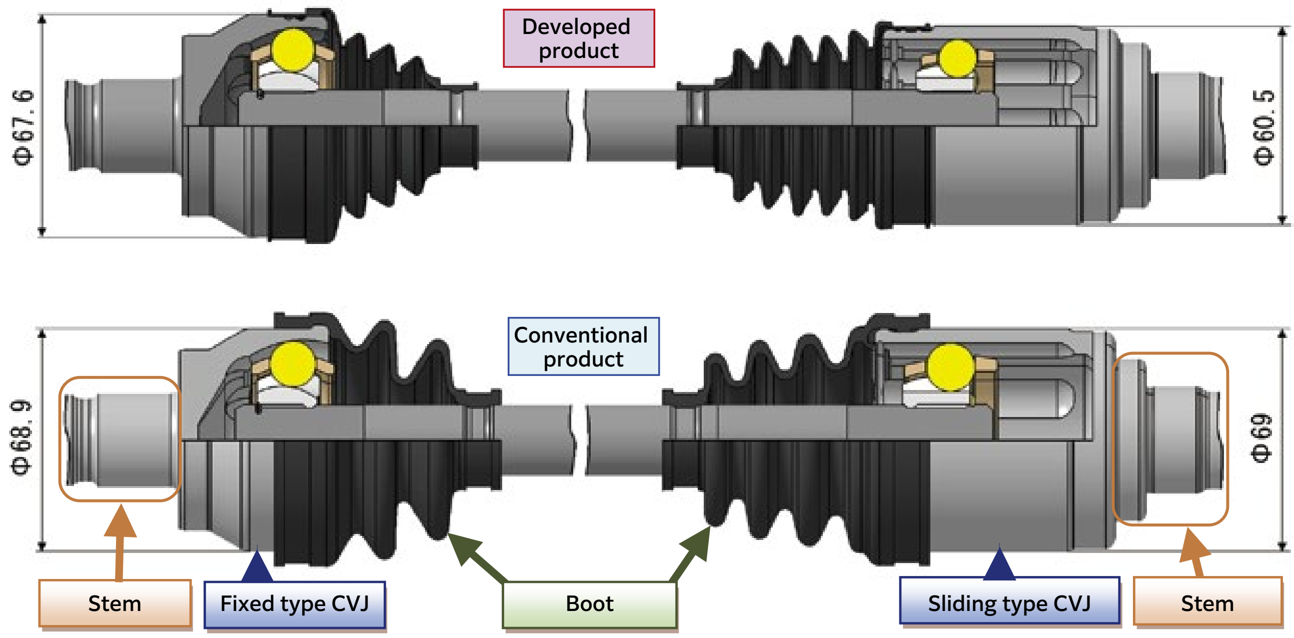


Fig. 2 Development product VS Conventional product (#75 size)

Table 1 Development product mass and outer diameter reduction rate (#75 size)

Developed Product	Mass Reduction Rate	Diameter Reduction Rate
Fixed type CVJ	6.2 %	1.9 %
Sliding type CVJ	29.0 %	12.3 %

3. Small and Lightweight Fixed Type CVJ for Rear Sub-axles

Fixed type CVJs for front wheels have a maximum operating angle of 47 to 50° as they need to cater to vertical movement of the suspension and turning of the wheels with steering.

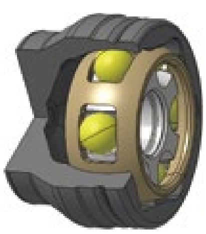
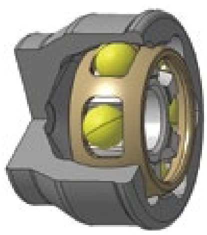
In contrast, CVJs for rear wheels only need to cater to the vertical movement of the suspension, and as such an operating angle of 20° or less suffices on most vehicles when actual usage conditions are considered. As some vehicles may need an operating angle of 20° or more for mounting or handling requirements, the maximum operating angle of fixed type CVJs is 30° .

In the conventional product, the internal parts (inner ring, cage, ball) of the existing 47° design were adopted together with the 30° design, where the outer ring is shorter in the axial direction to achieve a lighter weight. To make the developed product even lighter in weight, each part was shortened in the axial direction, as well as a shorter design incorporated in the radial direction.

3.1 Features

A comparison of the lighter weight #75 size developed product and the conventional product is shown in **Table 2**.

Table 2 Comparison of development product and conventional product

Item	Developed Product	Conventional Product
Maximum operating angle [°]	30	30
Outer diameter [mm]	φ 67.6	φ 68.9
No. of balls	6	6
Mass [g]	834 Compared to conventional product - 6.2 %	889
SUB-ASSY		

The conventional product was based on the CVJ for front wheels, with the maximum operating angle limited to 30° and only the outer ring shortened in the axial direction. However, there was excess thickness in the material of each part designed with a maximum operating angle of 47° .

The developed product was designed for rear wheels so the maximum operating angle was made smaller, which results in a smaller maximum input load and allows each part to have thinner material. Smaller diameter balls could also be used to successfully make the outer ring outer diameter and cage smaller, which helped achieve a small size and light weight **(Fig. 3)**.

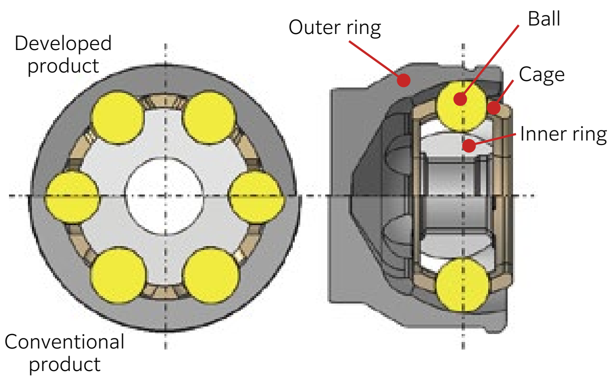


Fig. 3 Comparison of outer dia. and axial length

3.2 Functional Evaluation

The functional requirements are as outlined below.

① Strength: equivalent to conventional product (at maximum angle)

② Durability: equivalent to conventional product

Examples of strength test results for the developed product are shown in **Fig. 4**, and durability test results in **Fig. 5**.

The developed product meets the development targets set based on past test data for the conventional product, and was verified as having equivalent strength and durability as the conventional product.

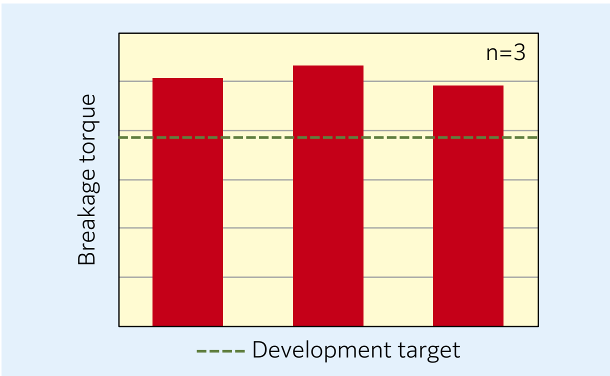


Fig. 4 Static torsion strength test result of developed product (θ=20°)

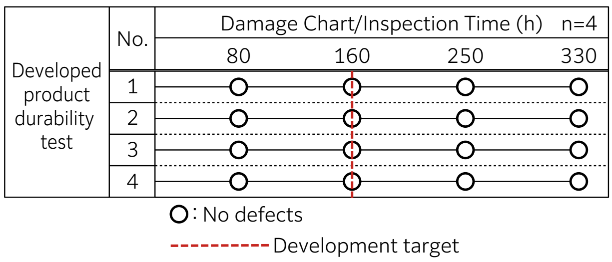


Fig. 5 Durability test result of developed product (θ=6°)

4. Small and Light Sliding Type CVJ for Rear Wheels[4)]

While there are many variations of sliding type CVJs available, FF vehicles and the front wheels of 4WD vehicles use either tripod or ball type CVJs. Tripod type CVJs have a low sliding resistance to limit engine vibrations being transmitted to the tires, steering and other parts of the vehicle body via the CVJs, while ball type CVJs are able to reduce rattle in the drivetrain.

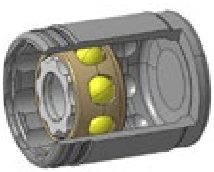
For a long time, **NTN** had been using ball type sliding double offset joints (DOJ) as small CVJs for the rear wheels, but had been using the CVJs outlined above for front wheels.

The developed product was also applied to the DOJ to develop a new small and lightweight sliding type CVJ for rear wheels by limiting the maximum operating angle (23° → 20°) for the rear wheels only.

4.1 Features

A comparison of the lighter weight #75 size developed product and the conventional product is shown in **Table 3**.

Table. 3 Comparison of development product and conventional product

Item	Developed Product	Conventional Product
Maximum operating angle [°]	20	23
Outer diameter [mm]	φ 60.5	φ 69
No. of balls	8	6
Mass* [g]	910 Compared to conventional product - 29 %	1,284
SUB-ASSY		

* Slide amount: calculated at 45 mm

The conventional DOJ was designed with 6 balls, however the developed product was designed with 8 balls with the goal of reducing size and weight considerably.

Using 8 smaller diameter balls for transmitting torque helps to better disperse the load acting on each ball to achieve a smaller size and lighter weight. Limiting the maximum operating angle and using a smaller ball PCD decreases the range of movement of balls in the axial direction and reduces the groove length of the inner and outer rings. The result is that the inner and outer rings, and the axial length of the cage, can be reduced to achieve a more compact size as well as a lighter weight **(Fig. 6)**.

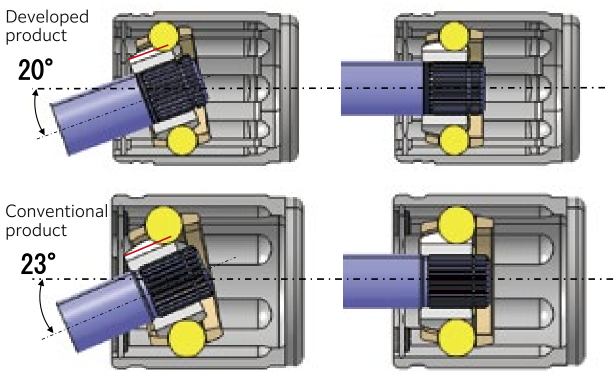


Fig. 6 Comparison of ball groove length (red line)

As the balls have a smaller diameter than the conventional product, the width of the cage window, and thus the width of the cage, could be reduced. Limiting the maximum operating angle and using a smaller ball PCD also decreases the range of motion of balls within the cage window, thus the length of the cage could be made shorter. Limiting the operating angle also allows for a smaller taper angle to be used for the outer diameter, which makes it easier to achieve the thickness for the cage and a smaller size in the radial direction **(Fig. 7)**.

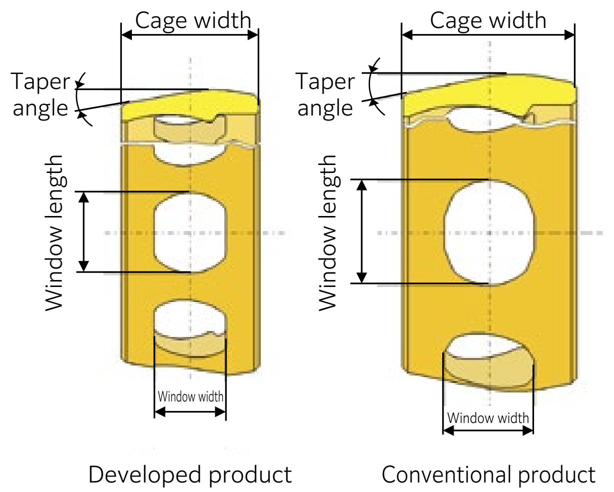


Fig. 7 Comparison of development product cage and conventional product cage

As the width of the cage and inner ring can be shortened, the length of the outer ring cup can be reduced while ensuring the same slide amount (L1 < L2 in **Fig. 8**), thereby making it shorter in the axial direction than the conventional DOJ.

Smaller diameter internal parts also mean the outer ring can be a smaller outer diameter.

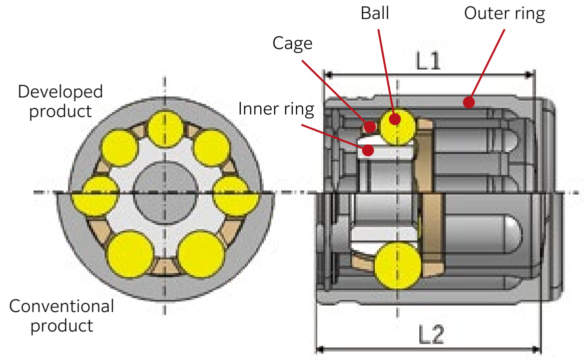


Fig. 8 Comparison of outer dia. and axial length

4.2 Functional Evaluation

The functional requirements are as outlined below.
① Strength: equivalent to conventional product (at maximum angle)
② Durability: equivalent to conventional product

Examples of strength test results for the developed product are shown in **Fig. 9**, and durability test results in **Fig. 10**.

The developed product meets the development targets set based on past test data for the conventional product, and was verified as having the equivalent strength and durability as the conventional product.

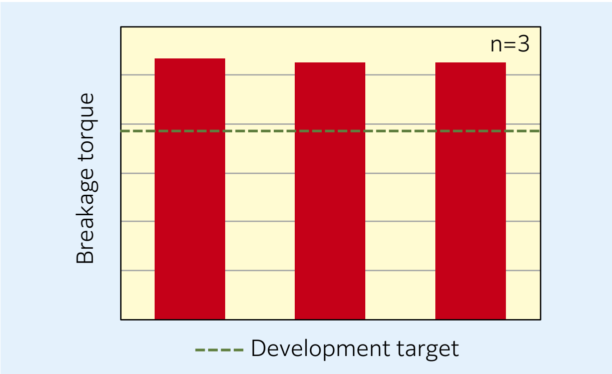


Fig. 9 Static torsion strength test result of developed product (θ=20°)

	No.	Damage Chart/Inspection Time (h) n=4			
		80	160	250	330
Developed product durability test	1	○	○	○	○
	2	○	○	○	○
	3	○	○	△	△
	4	○	△	△	△

○: No defects △: Continuous operation possible
---------- Development target

Fig. 10 Durability test result of developed product (θ= 6°)

5. Boot and Amount of Grease

Limiting the maximum operating angle also allowed for a small and lightweight boot to be used. Furthermore, the amount of injected grease could also be reduced due to the smaller size of the CVJ and boot.

Small and lightweight boot designs for fixed type CVJs and sliding type CVJs are being developed with the aim of reducing the weight of driveshafts even more.

6. Conclusion

This article outlined the features and performance of the "Small and Lightweight CVJ for Rear Sub-axles" developed for use with the sub-axle rear wheels of FF-based 4WD vehicles.

With the growing demand for small SUVs, there has been an increase in models designed using FF-based 4WD vehicles. The developed product can also be used for rear-wheel drive vehicles that need small size CVJs. With more environmentally friendly designs an essential requirement of recent vehicle development, this significantly lighter weight developed product is anticipated to meet a range of market requirements.

References

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