Development of New Double Cardan Constant Velocity Joint (DCJ)

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Due to the need for low noise and vibration at high rotational speeds and high operating angles, Koyo developed a double cardan joint (DCJ) for use as a constant velocity joint in propeller shafts used in 4WD vehicles and other vehicles.

Recently, vehicle manufacturers have been requesting DCJ suppliers to reduce the product’s weight and size as well as the rotational unbalance in order to decrease the amount of noise and vibration in the driveline (including the propeller shaft). Because of the trend among automakers toward increased higher engine torque output, bearing life and strength must also be improved.

This paper presents outlines of Koyo’s new DCJ, which is lightweight and compact, exhibits improved performance, and has lower cost.

This new DCJ has been in production since December 1998.

1. Introduction

Koyo’s double cardan joint (hereinafter “DCJ”) is a constant velocity joint developed for propeller shafts used in 4WD vehicles requiring low noise and vibration at high rotational speeds and high operating angles. (See Fig. 1.)

Because the RV market is expanding rapidly and automakers are requiring lower noise levels from the driveline, including the propeller shaft, constant velocity joints with lighter weight, smaller size and reduced unbalance are being demanded. As well, greater strength and longer life are required because of the trend among automakers toward increased engine output, in addition to lower cost.

This paper introduces a newly developed DCJ with lower weight, smaller size, higher performance and lower cost. This product has been in production since December 1998.

2. Features of Developed Product

Cross sections of the existing DCJ and newly developed DCJ are shown in Fig. 2.

The targets in Table 1 were set for new DCJ from the viewpoints stated in Section 1.

Table 1 Development targets

<table>
<thead>
<tr>
<th>Items</th>
<th>Targets</th>
<th>Points aimed at</th>
<th>Main improved points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight reduction</td>
<td>10%</td>
<td>• Compact design</td>
<td>• Excess thickness reduction</td>
</tr>
<tr>
<td>Strength improvement</td>
<td>10%</td>
<td>• Shape reconsideration by FEM analysis</td>
<td>• No machining of square-hole (square-part stress concentration reduction)</td>
</tr>
<tr>
<td>Life improvement</td>
<td>10%</td>
<td>• Coupling yoke rigidity improvement</td>
<td>Reduction of distance between joints</td>
</tr>
<tr>
<td>Initial unbalance</td>
<td>under 10 g-cm</td>
<td>Good-balance design (asymmetry reduction)</td>
<td>Joint section grease fitting moved to rotation center</td>
</tr>
<tr>
<td>Cost reduction</td>
<td>20%</td>
<td>• Adoption of alternate configuration and material</td>
<td>• Adoption of cast iron yoke by substitution from pin to socket</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Disuse of parts or no machining</td>
<td>• Externally locating type of snap ring for automatic assembly</td>
</tr>
</tbody>
</table>
Among the targets in Table 1, in order to improve the life and strength and reduce the weight of the DCJ assembly, the main yoke design was reconsidered.

Yoke strength and rigidity were investigated in advance by FEM analysis, and testing was conducted on a bench machine to confirm the effect.

The contents are explained below.

3. Concerning Yoke Design Contents

3.1 Tube-Side Yoke

3.1.1 Change Contents

Changes made to the tube-side yoke are summarized in Table 2.

After studying various steel types, we selected unrefined medium carbon steel as the material for the developed product because of the need for good pin-area induction hardening and welding with the tube. Although the cost of material is higher, the refining process is eliminated, making the overall cost lower.

3.1.2 Analysis Result

Result of FEM analysis done on the developed product is shown in Fig. 3. Result of FEM analysis carried out on both DCJs showed that the maximum principal stress was 425 MPa for the existing product and 227 MPa for the developed product. The principal stress of the developed product was approximately 53% that of the existing product. The developed product is estimated to be able to satisfy the strength improvement target.

3.2 Coupling Yoke

3.2.1 Change Contents

Changes made to the coupling yoke are summarized in Table 3.

Results of evaluating the existing product are as follows:
(1) The coupling yoke is sometimes the weakest part in regard to fatigue strength.
(2) It is known that fatigue damage occurs first on the coupling-yoke-side cross-shaft, so a coupling yoke with increased strength and rigidity was designed.

By improving rigidity, the relative inclination of the cross-shaft and cup bearing is reduced and a good contact condition can be obtained, so life can be improved.

3.2.2 Analysis Result

Result of FEM analysis done on the developed product is shown in Fig. 4. The results of a comparison of generated stress and torsional displacement are shown in Table 4.

Generated stress was reduced to 81% and displacement to 80% on the developed product. Strength and rigidity improvement targets were achieved, and it is estimated the life can also be improved.

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3. 3. 2 Analysis Result

Result of FEM analysis done on the developed product is shown in Fig. 5. The maximum principal stress is 1 195 MPa for the existing product and 717 MPa for the developed product. The site of maximum stress occurrence for both is the nut bearing surface corner. The influence of the notch effect is large, but generated stress is less, and it is estimated that the strength improvement target can be achieved.

4. Effect Confirmation Results

Results of strength and life testing using actual machines are as follows.

4. 1 Static Strength

The results of static strength evaluation are shown in Fig. 6. Because it was known that the site of damage on the existing product was the cross-shaft, emphasis was placed on strengthening this part when the product was designed. As a result, the same static strength as for yokes was secured, and the target of 10% strength improvement was achieved.

4. 2 Fatigue Strength

Results of the evaluation of fatigue strength are given in Fig. 7.

The number of cycles for the developed product is higher than that for the existing product. This tendency is particularly conspicuous on the low-torque side.

On the high-torque side, the damage site was the coupling yoke, which is the same site as for the existing product. On the low-torque side, the damage site was the blade with flange, which was confirmed by FEM analysis as having maximum

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Table 4 Coupling yoke

<table>
<thead>
<tr>
<th>Items</th>
<th>Existing product</th>
<th>Developed product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generated stress (ratio)</td>
<td>603 MPa (1)</td>
<td>491 MPa (0.81)</td>
</tr>
<tr>
<td>Torsional displacement (ratio)</td>
<td>1.178 deg (1)</td>
<td>0.948 deg (0.80)</td>
</tr>
</tbody>
</table>

Table 5 Flange side yoke

<table>
<thead>
<tr>
<th>Items</th>
<th>Existing product</th>
<th>Developed product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>High carbon steel</td>
<td>Cast iron</td>
</tr>
<tr>
<td>Function</td>
<td>Pin yoke (induction hardening)</td>
<td>Socket yoke</td>
</tr>
<tr>
<td>Nut bearing surface machining</td>
<td>Milling</td>
<td>Spot facing</td>
</tr>
</tbody>
</table>

The existing product uses high carbon steel in consideration of the induction hardening of the pin section. With the developed product, however, by switching the pin to the tube-side yoke and the socket to the flange-side yoke, the need for induction hardening is eliminated, and cost can be reduced by using cast iron as the material.
5. Other Evaluation Results

Results equivalent to or better than those for the existing product were obtained in regard to high-speed durability and muddy water resistance.

Also, we analyzed developed products (new DCJ) that had been installed on a vehicle driven 5,000 km on bad roads, but no problem was found and performance was good. We therefore concluded that the products were suitable for use in vehicles.

6. Conclusion

This paper mainly deals with strength performance. And the results in regard to the development targets are as given in Table 6.

We were able to develop the product to meet the development targets through the use of FEM analysis and others. Mass production of the product began in December 1998.

Opportunities exist to make this product even more lightweight and compact, and we will therefore continue our efforts.