Development of Anti-Creep Ball Bearing for Outer Ring

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In ball bearings receiving heavy radial load, there have been problems in the past where, for example, the bearing housing became worn due to creep caused by continuous strain in the outer ring of the ball bearing. The conventional countermeasure against this creep phenomenon is to increase outer ring thickness. However, this countermeasure comes with the setbacks of increased weight and larger outer ring diameter. JTEKT has therefore developed an anti-creep ball bearing which was designed without increasing the outer ring thickness.

Key Words: *creep, ball bearing, wear, strain*

1. Introduction

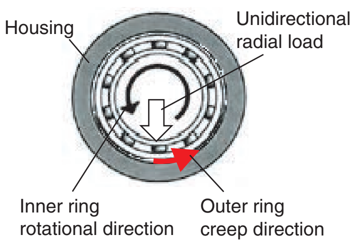
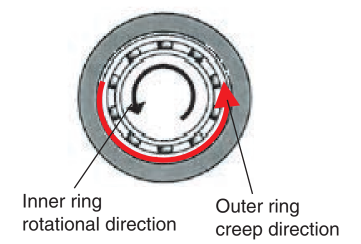
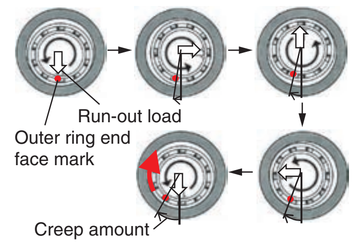
Various types of transmissions are used in automobiles, from the conventional manual transmission (MT) and automatic transmission (AT) to transmissions for HV/FCV, and these are all constantly undergoing improvement. Many bearings are used in these transmissions to support the gear, and in recent years the percentage of ball bearings with thin outer ring being adopted is increasing due to the market needs requiring bearings to be low torque, compact and lightweight.

Due to these circumstances, bearing creep has become viewed as problematic, whereas it hardly ever had been in the past, and countermeasures are being sought to address this issue.

One form of creep often seen as a problem from the perspective of ease of assembly, is the creep which forms between the outer ring and housing which serves as the clearance fit. Outer ring creep is categorized into three types as shown in **Table 1** depending on the mechanism occurrence.

If creep occurs, wear will progress between the bearing and housing, causing misalignment and inclination of the shaft to increase, which will in turn result in problems such as abnormal noise. In support bearings for CVT pulleys, which are subjected to a large radial load, and

Table 1 Types of outer ring creep

	①	②	③
Creep type	Creep caused by strain	Creep caused by drag	Creep caused by run-out
Creep direction	Bearing rotational direction	Bearing rotational direction	Opposite to bearing rotation
Creep speed	Slow	Fast	Slow
Cause of creep occurrence	Outer ring circumferential strain caused by large unidirectional radial load	Bearing rotational torque > Friction torque between the outer ring and housing Easily occurs when no load or light load	If the outer ring is the clearance fit, creep will occur due to the difference in perimeter length of the outer ring outer diameter and housing inner diameter which is created through run-out radial load
Schematic			
Countermeasure	Increase outer ring thickness, anti-rotation pin	O-ring, resin winder, increased interference with housing, anti-rotation pin	

thin ball bearings used for HV transaxles to achieve weight reduction, creep easily occurs due to outer ring strain, therefore there is concern problems caused by housing wear will emerge.

In order to prevent creep caused by outer ring strain, it is effective to thicken the outer ring, however this comes with the setbacks of being difficult to mount and heavier due to an increase in the outer diameter.

As such, instead of making the outer ring thicker, JTEKT has developed an anti-creep ball bearing which succeeds in suppressing creep and reducing housing wear.

2. Mechanism of Creep Occurrence Caused by Outer Ring Strain

Ball bearings used for inner ring rotation, if subjected to a radial load in one direction, are more likely to have strain occur on the outer ring than if the outer ring was subjected to load from a rolling element (rolling element load). When the bearing is rotating, the strain will occur consecutively on the outer ring due to the balls passing by.

Moreover, there is a large surface pressure being created when directly subjected to rolling element load therefore seizure due to frictional force will occur whereby the outer ring outer diameter surface and housing inner diameter surface come into contact. At the boundary of this seized portion, the outer ring will become distorted as though it is being crushed in the circumferential direction due to strain in the circumferential direction on the outer ring towards the front of the direction in which the ball is travelling. Towards the back of the direction in which the ball is travelling, the outer ring will distort when it returns to its original state after being crushed.

Every time the balls pass through the area being subjected to load, the abovementioned distortion caused by outer ring strain occurs consecutively causing the outer ring to gradually shift the same direction as the ball is travelling relative to the housing. This is the mechanism by which creep occurs due to outer ring strain (**Fig. 1**).

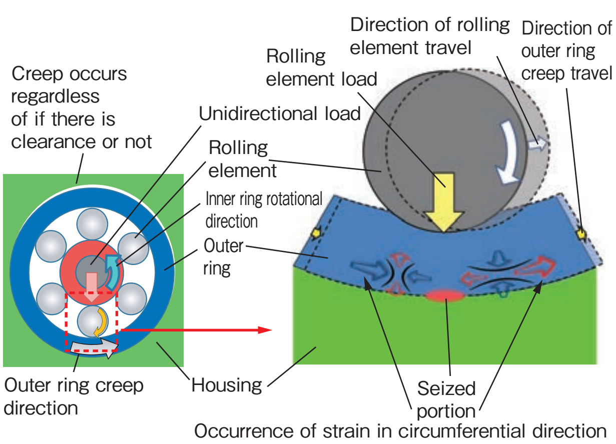


Fig. 1 Mechanism of creep occurrence due to outer ring strain

3. Outline of the Developed Bearing

3.1 Concept of the Developed Bearing

Based on the abovementioned occurrence mechanism, it was deemed that reducing the strain which occurred on the outer ring would be effective as a countermeasure against creep caused by outer ring strain. The conventional creep countermeasure of making the outer ring thicker was believed to reduce outer ring strain and be effective in suppressing creep as the shortest distance from the contact point of the outer ring raceway and rolling element to the contact point of the outer ring outer diameter face and housing inner diameter face is extended.

First, in order to confirm the relationship between outer ring thickness and creep amount, we performed a CAE analysis. The results are shown in **Fig. 2**. This analysis confirmed that, by making the outer ring thicker, the strain is reduced and creep can be suppressed.

As such, we conceived the concept of creating a space (groove contour) in the center of the outer ring outside diameter face in order to extend the shortest distance between the contact point of the outer ring outer diameter face and the housing inner diameter face, thereby reducing the strain which occurs on the outer ring in a circumferential direction and suppressing creep caused by outer ring strain (**Fig. 3**) like what can be achieved from the thickening of the outer ring.

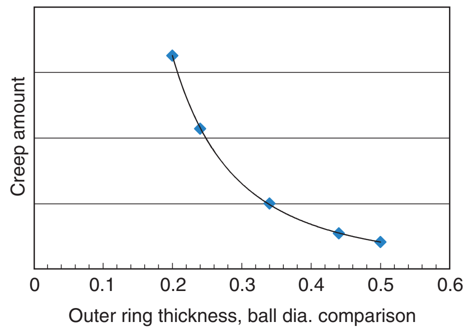


Fig. 2 Results of CAE analysis of outer ring thickness and creep amount

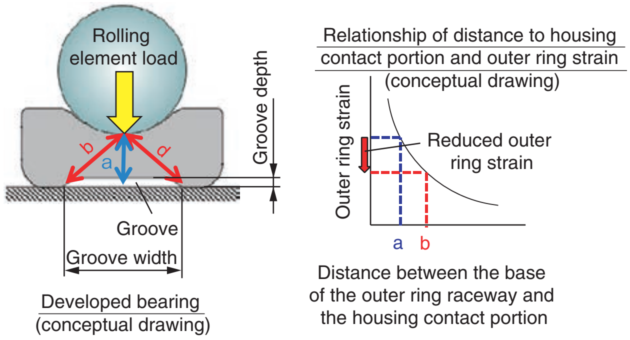


Fig. 3 Concept of developed bearing

3.2 Design of the Outer Ring Groove

Increasing the groove width shown in **Fig. 3** would be effective in suppressing creep, however this would increase stress at the groove base, therefore the design of the groove contour must be a balanced one. We conducted another CAE analysis using groove width and depth as parameters in order to find the amount of creep that occurs due to outer ring strain and the amount of stress that occurs at the groove base. The results were used to determine groove contour.

A CAE analysis was conducted to compare the creep amounts of the current bearing (standard bearing) and a bearing with a thicker outer ring versus the developed bearing. The analysis conditions are shown in **Table 2** and the results are shown in **Fig. 4**. The bearing housing model used in the CAE analysis was identical to the housing of the device for measuring creep amount (**Fig. 5**). Results showed that the developed bearing, as was the case with the thicker outer ring bearing, suppressed creep amount caused by outer ring strain by around 50% compared with the current bearing.

Moreover, a CAE analysis using a housing model equivalent to that on an actual unit was performed on a bearing with a thicker outer ring as a countermeasure to outer ring creep. This analysis showed that creep had not occurred. This suggested that if the creep amount on the developed bearing found through evaluation of the bearing in isolation was less than that of the bearing with the thicker outer ring, creep could be prevented on the actual unit.

Table 2 CAE analysis conditions of creep amount

	Current bearing	Bearing with thicker outer ring	Developed bearing
Outer ring outer dia, mm	ϕ70	ϕ72.4	ϕ70
Outer ring thickness, mm	3.2	4.4	3.2
Radial load, kN	4		

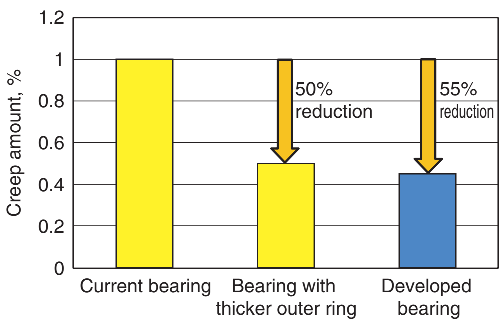


Fig. 4 Results of CAE analysis of creep amount

4. Performance of the Developed Bearing

4.1 Method of Confirming Creep Amount

Figure 5 shows the measuring device used to find creep amount. In order to clarify the effectiveness of the anti-creep ball bearing for outer ring, the housing was made from steel - a material in which creep easily occurs. Moreover, in order to verify the behavior of the outer ring, the outer ring end face was marked (**Fig. 6**) and filmed using a video camera. The amount of creep per unit time was found by conducting an image analysis on the filmed video.

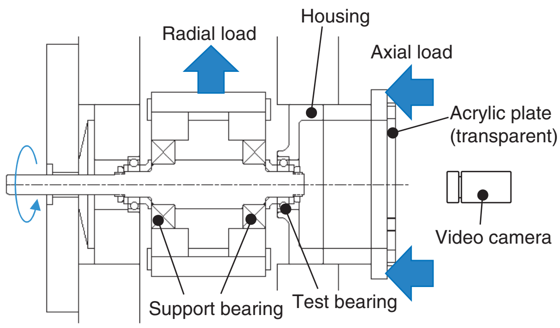


Fig. 5 Device for measuring outer ring creep amount

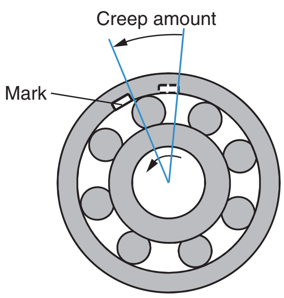


Fig. 6 Method for measuring outer ring creep amount

4.1.1 Creep amount under a pure radial load condition

The effect on suppressing creep under a pure radial load condition was confirmed. The creep amount measurement conditions are shown in **Table 3** and the results are shown in **Fig. 7**. It can be seen that, for the current bearing, the bearing with a thicker outer ring and the developed bearing alike, creep amount increases as the radial load increases and is virtually proportional to radial load. Furthermore, compared to the current bearing, creep amount was reduced by 40% on the bearing with a thicker outer ring and 55% on the developed bearing, meaning that the developed bearing had less creep than the bearing with a thicker outer ring.

Table 3 Test conditions

Radial load, kN	1, 2, 4
Rotational speed, min^{-1}	10 000
Lubrication	Oil application

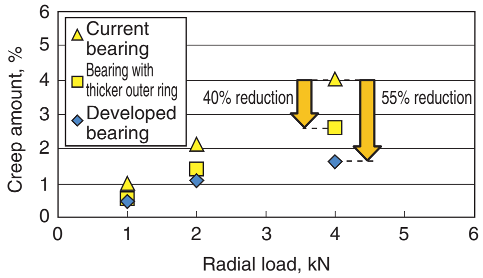


Fig. 7 Relationship of radial load and creep amount

4.1.2 Creep amount under a combined load condition

The effect on suppressing creep under a combined load condition, consisting of both radial and axial load, was confirmed. The creep amount measurement conditions are shown in **Table 4** and the results are shown in **Fig. 8**. The results demonstrated that the developed bearing also succeeded in suppressing creep by 40% compared to the current bearing under a combined load condition.

Table 4 Test conditions

Radial load, kN	3.6
Axial load, kN	1.8
Rotational speed, min^{-1}	10 000
Lubrication	Oil application

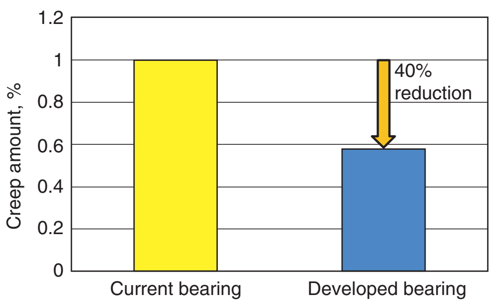


Fig. 8 Measurement results of creep amount under combined load conditions

4.2 Housing Wear Amount

Using housing made from aluminum alloy, the same material as that used on an actual unit, we made a comparison of the housing wear amount on the developed bearing and that of the current bearing. In order to promote the occurrence of creep, the housing was shaped to be highly rigid and the radial load was set higher than the operating conditions on an actual unit (equivalent to the basic static load rating). The conditions of the wear test are shown in **Table 5** and the results are shown in **Fig. 9**. **Figure 10** provides a representative example of post-test housing wear contour. The developed bearing had 50% less housing wear than the current bearing. This result confirms that housing wear caused by outer ring creep has been suppressed on the developed bearing.

Table 5 Test conditions

Radial load, kN	11.9
Rotational speed, min^{-1}	5 000
Lubrication	Immersion

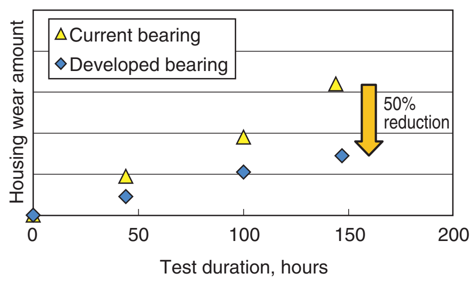


Fig. 9 Measurement results of housing wear

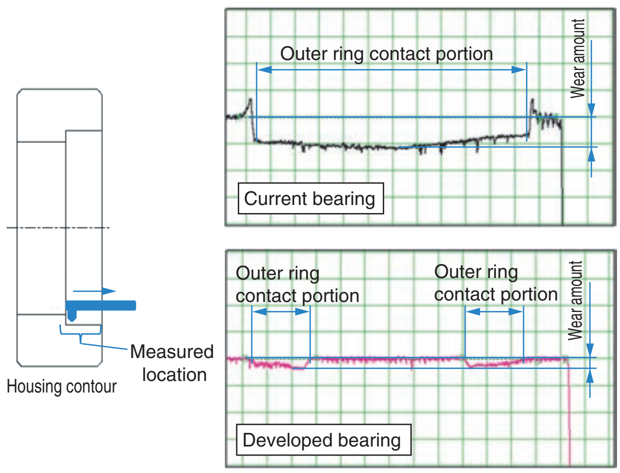


Fig. 10 Contour of housing wear

5. Confirmation of Setbacks

A high-load endurance test was performed on the developed bearing to confirm the raceway peeling life and outer ring fatigue strength. The result showed that the actual life was more than ten times greater than the calculated life, which is also the case with the current bearing. It was also confirmed that there were no issues regarding outer ring strength due to the absence of abnormalities such as cracks in the outer ring.

6. Conclusion

JTEKT has developed an anti-creep ball bearing for outer ring able to suppress creep caused by outer ring strain without increasing the outer diameter by making a groove in the outer ring outer diameter face, thus ultimately reducing the amount of housing wear.

It was confirmed that the anti-creep ball bearing for outer ring was effective in reducing housing wear compared to the current bearing and there were no setbacks in regards to bearing life and outer ring strength.

The adoption of the anti-creep ball bearing for outer ring can reduce both the size and weight of the bearing and, through its popularization, JTEKT wishes to contribute to the realization of vehicles with enhanced fuel economy and energy-saving benefits.

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