Recent Trends in Bearings and Bearing-Related Products for Automobile Drive Trains

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In correspond to such needs as energy efficiency or environmental friendliness, transmissions or other driving units of automobiles are required to be more compact, lighter weight, or higher efficiency. Due to these movements, rolling bearings are needed to be improved not only in their individual rolling fatigue life and friction loss, but in anti-seizure, rigidity, anti-wear, anti-vibration performance for compactly designed vehicles. Similarly, bearing-related products are being unitized or integrated to modules for more compactness and higher function. Here, these technical trends are introduced briefly.

Key Words*: rolling bearing, trend, automobile, drive train.*

1. Introduction

The worsening condition of the global environment, of which global warming is a representative example, is being pursued from all angles as a problem that must be solved without delay. In automobile technology, improved fuel consumption, making automobiles more compact and lightweight by advanced technology are important strategies. Enhanced power performance, more stable travel performance, and improved comfort are also being demanded.

Efforts are being made to extend life, reduce friction, and reduce size and weight in the drive train application as well. **Figure 1** shows examples of technical needs of drive trains and what are required of bearings to meet those needs.

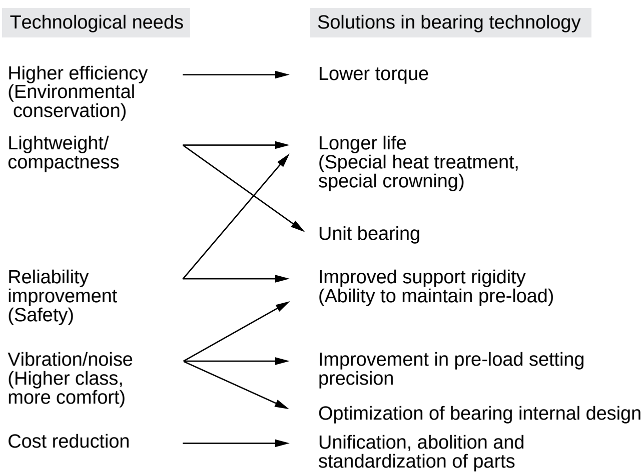


Fig. 1 Needs for drive trains and solutions in bearing technology

With regard to trends of rolling bearing technologies, a general observation of basic technologies and product processing technologies was provided in the previous edition[1, 2, 3]. This paper discusses recent trends in technologies for bearings and bearing-related products for automobile drive trains.

2. Rolling Bearings

2. 1 Longer Life

1) Improved life in contaminated oil

Bearings used in transmissions or differential gears are usually lubricated by oil containing foreign particles such as swarf, burrs produced when parts are machined, worn powders of gears, and debris from the case. Particularly, the failure mode of bearings under lubricating conditions including hard foreign particles is surface flaking originated at the edges of dents due to roll-over of foreign particles or surface layer peeling caused by abrasive wear (see **Fig. 2**)[4]. With ordinary bearings, life is shortened to one of several parts to one of several tens of parts of that in clean oil. Therefore this problem is solved either by the material/heat treatment or the sealing technology improvement as indicated below.

① Material/heat treatment technology solution

With tapered roller bearings, life was extended by apllying Koyo's original carburizing steel materials and heat treatment technology. In order to reduce crack propagation and cracking and at the same time for early elimination of dent edges due to foreign particle, a special heat treatment to raise surface hardness and optimize the amount of retained austenite was developed, which resulted in approximately ten times longer life compared to that of ordinary bearings. Such bearings are named "KE" and have been well received. Ultra-long life technology for an example by finer carbide is currently being developed, and this will promote more compact bearing designs.

Concerning ball bearings and cylindrical roller bearings, long-life bearings using carbon nitrided through hardening steel have been used for many years.

② Seal design solution

Regarding sealed ball bearings in transmissions, entry of foreign particles in the oil into bearings is drastically reduced and running torque is also lowered by the seal lip design to minimize the amount of interference change

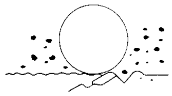
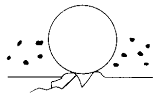
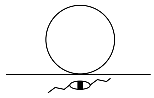
Modes	In contaminated oils			In clean oils
	Flaking initiated from surfaces			Flaking initiated from sub-surface
	Surface layer peeling	Mixed flaking	Flaking from dent	
Appearance				
Mechanism	 Abrasive wear by small hard particles	 Abrasive wear by small hard particles, and plastic deformation by large hard particles	 Plastic deformation by external force or large hard particles	 Material defects at maximum shear stress depth
Measures	Higher surface hardness →Improvement of wear resistance	Higher surface hardness →Reduction of plastic deformation Optimized retained austenite →Early disappearance of plastic deformation		Optimized C% in matrix Optimized surface hardness of rolling element

Fig. 2 Flaking modes of rolling bearings[4)]

relative to misalignment and axial gear load (see **Fig. 3**). The rubber material of the seal is selected considering heat resistance and compatibility with oil. The bearing is filled with grease and sealed to improve initial lubricating performance.

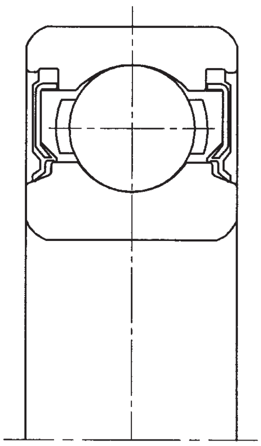


Fig. 3 Bearing with seals

2) Coping with high load and high moment

Along with making units like transmissions more compact and lightweight, more compact bearings are demanded.

On the other hand, engine torque increase and weight reduction of casing bring increase in bearing load and in shaft deflection, providing a harsh condition for the bearing. As a result, particularly with tapered roller bearings having line contact, life is often shortened due to the edge stress. Based on the results of rigidity analysis of case and shaft systems using the latest computer technology, Koyo has developed a special crowning shape in the axial direction that makes contact stress distribution of the area where the rollers contact with the raceway uniformly based on the results of rigidity analysis of case and shaft system, and is now mass producing the bearing with such technology as the LC (Long Life Crowning) bearing. Under moment condition, the LC bearing life is about 3 times compared with an ordinary bearing.

2. 2 Lower Friction

Compared with other bearing types, tapered roller bearings can support both large radial and axial loads. Because of this compactness, they are often used for many drive train units. However, friction torque is large compared with a ball bearing, because of sliding contact between the inner ring rib and the rollers.

A low friction torque (LFT) bearing having 20% to 50% less sliding torque and rolling viscosity torque compared with conventional tapered roller bearings has been developed and is currently being mass produced by optimizing the contact condition of the sliding surfaces, composition of rollers (diameter, length, number), contact angle and raceway crowning while balancing load capacity and rigidity. Koyo plans to increase the production further. **Figure 4** shows an example of rotational torque measurement.

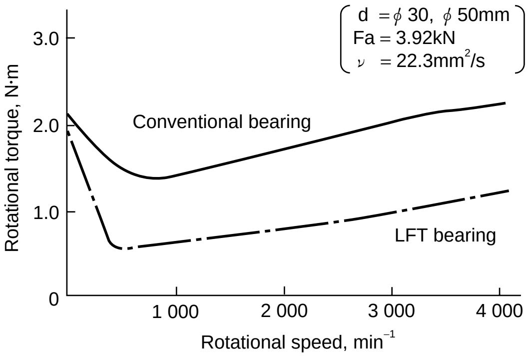


Fig. 4 Example of rotational torque measurement

2. 3 Lighter Weight, More Compact Size, Switch to Unit Construction

Construction of transmissions has become complicated due to using more gears. Improvement in design freedom of bearing support method, securing support rigidity, simplifying mounting and stabilizing pre-load are therefore required.

Koyo produces various types of compact unit bearings which contribute to resource savings and improvement in reliability. Koyo has also developed plastic materials compartible with various types of gear oils, and has adopted plastic cages primarily for ball bearings, and, also, for tapered roller bearings and needle roller bearings, which contributes to reducing weight. **Figure 5** shows typical examples of unit bearings.

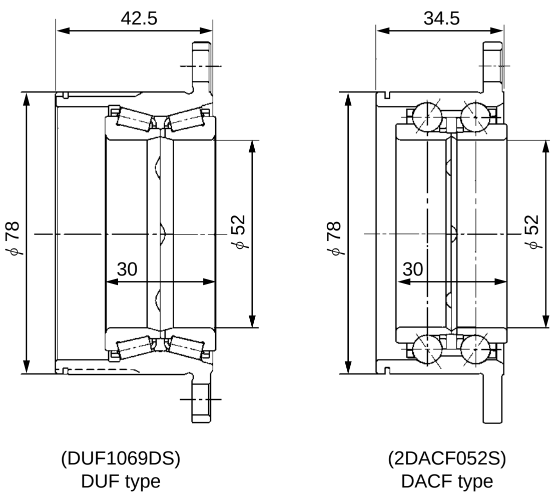


Fig. 5 Typical examples of unit bearings for automatic transmissions

Koyo is coping with weight reduction for thrust needle roller bearings often used for automatic transmissions by changing a double sheet cage to a single sheet cage along with unitized raceway and thin section construction.

When making bearings more compact, it is not only necessary to secure life, but also consider noise, vibration and rigidity of bearing surrounding units and transmission. Optimization of transmissions/bearing systems is being researched.

3. Bearing-Related Products

Here typical examples of product development to cope with the needs on various units are described.

1) Direct release cylinder (DRC)

DRC is a lightweight, compact clutch release bearing unit with a built-in hydraulic cylinder which is expected to make a clutch mechanism compact and to be applied to automatic shifting. The overall DRC construction and cylinder construction are shown in **Figs. 6** and **7**[5].

The most important development points are securing reliability of the hydraulic cylinder section and the design of the packing and cylinder.

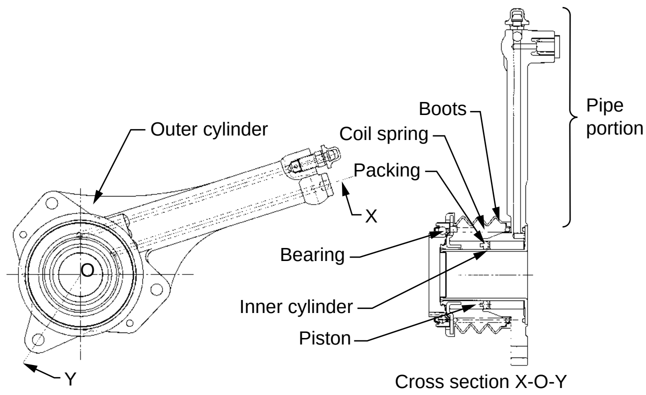


Fig. 6 Structure of DRC[5]

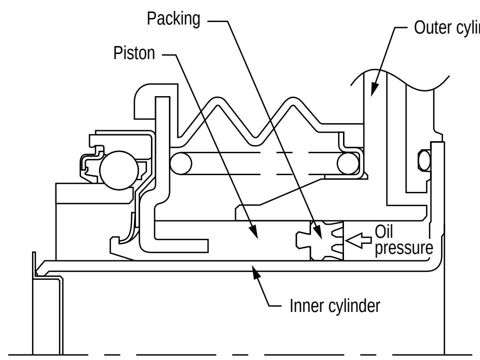


Fig. 7 Cylinder section of DRC[5]

2) One-way clutch

One-way clutch is a functional part required for shift control of an automatic transmission. Double cage type KW series has been used in the past, but the single cage type KX series developed by cooperation of Koyo and SKF, Ltd., is contributing to lighter weight.

For the KW series, Koyo has recently developed plastic cages in order to reduce weight and cost. Appearance and structure of the KX series and KW series with plastic cages are shown in **Figs. 8** ~ **11**[6]

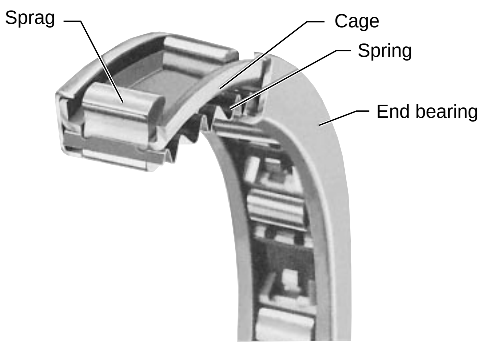


Fig. 8 KX series one-way clutch[6)]

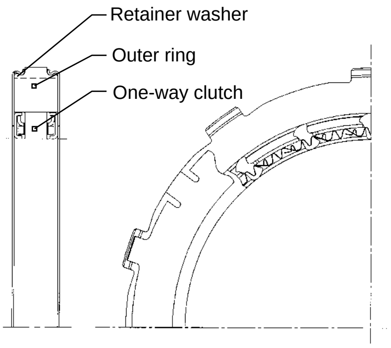


Fig. 9 An integration example of KX series one-way clutch with outer bearing[6)]

Fig. 10 KW series plastic cage[6)]

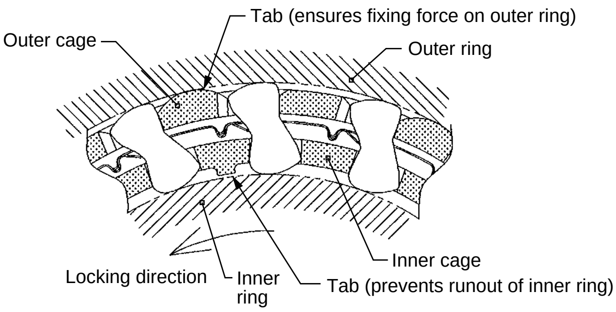


Fig. 11 Structure of one-way clutch with plastic cage[6)]

3) Electric pump unit

An electric pump unit applied to the drive train as a source of hydraulic pressure when the engine is stopped has been developed. The pump unit is a circumscribed gear pump with a side plate. The motor is brushless and sensorless type, and the motor driver has been newly developed.

A system example for an automatic transmission or a continuously variable transmission (CVT) equipped with the assist pump is shown in **Fig. 12**[7)]. An example of the efficiency evaluation of the electric pump unit is shown in **Fig. 13**[7)]. This performance is enough to be applied to drive trains for improving efficiency and durability.

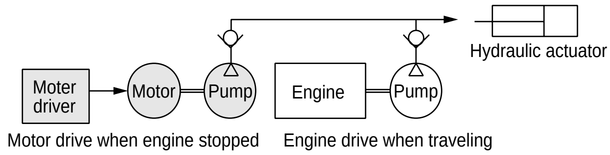


Fig. 12 Example of system using electric auxiliary pump[7)]

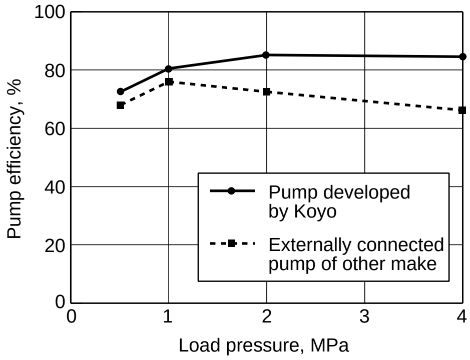


Fig. 13 Results of pump efficiency[7)]

4) Needle roller bearing for propeller shaft

Shell shaped needle roller bearings (drawn cup bearings) are used as universal joint bearings for propeller shafts of passenger vehicles for the purpose of improving driving performance and reducing weight and cost. The structures of the drawn cup bearings are shown in **Fig. 14**[8)].

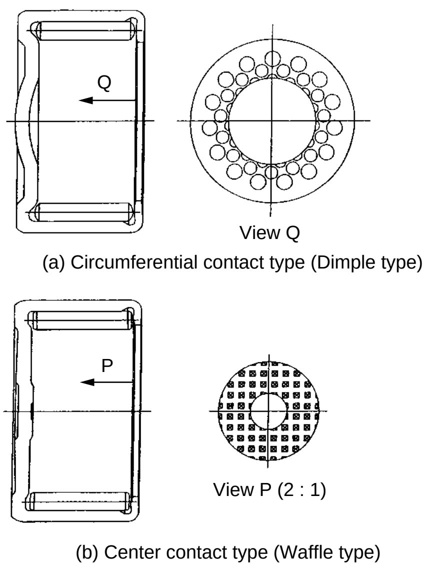


Fig. 14 Designs of drawn cup needle roller bearings[8)]

Recently reduction of mounting angle for propeller shafts has been emphasized in order to reduce vibration. Lubrication on the end surfaces of the cross pin (inside bottom of drawn cup) must be improved. The lubrication has been much improved by shaping the inside bottom of the drawn cup as shown in **Fig. 15**[8)].

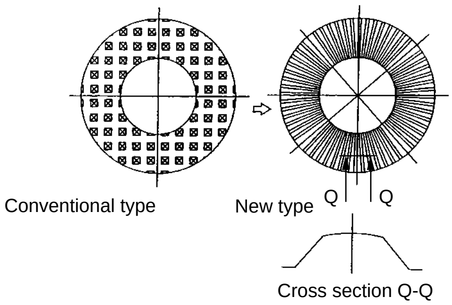


Fig. 15 Design for inside bottom of new drawn cup[8)]

5) Double cardan constant velocity joint (DCJ)

DCJ is a constant velocity joint developed for the propeller shafts of 4WD vehicles etc. requiring low vibration and low noise under high-speed and high-angle usage conditions (see **Fig. 16**)[9)]. In recent years, smaller size, lighter weight, reduced unbalance and more compactness are required.

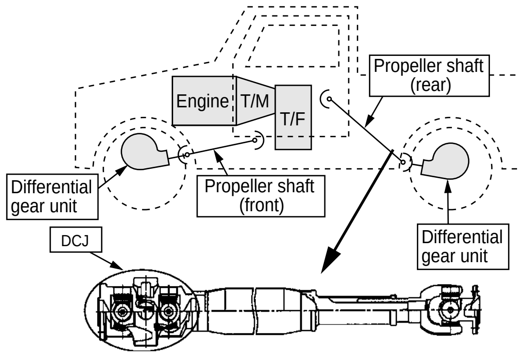


Fig. 16 Layout of propeller shaft[9)]

In order to meet these needs, Koyo has developed and is mass producing a new DCJ. **Figure 17**[9)] shows a comparison of the structure between the new and the conventional joints. Koyo is developing higher strength joints to cope with increasing higher engine torque.

4. Conclusion

It goes without saying that social demands for automobiles will continue to rise. Particularly, research and development on drive trains to improve fuel consumption is making progress.

Intelligent, modulized, innovative technologies have not been mentioned in this paper, but Koyo would focus on attractive product and technology development to meet the increasing demands for the future.

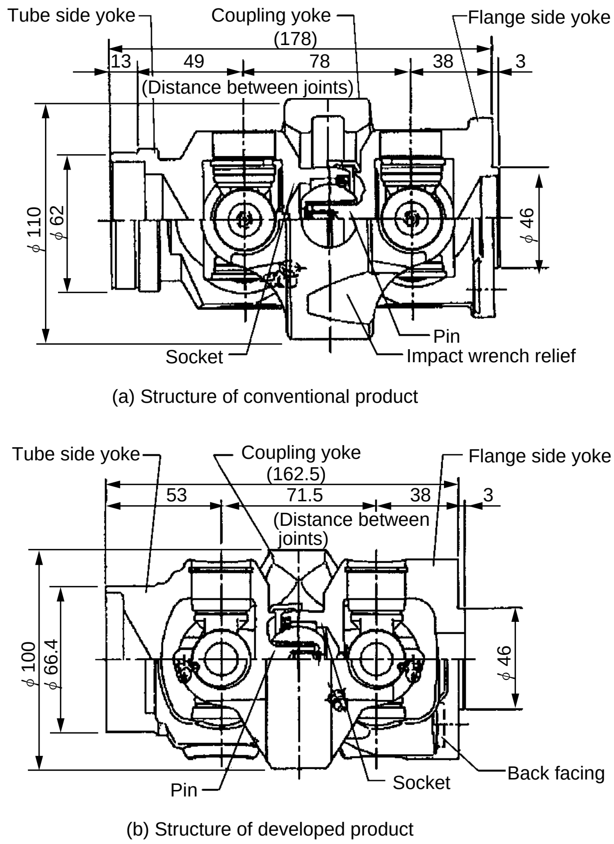


Fig. 17 Cross sections of DCJ[9)]

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