Trends Regarding Rolling Bearings for Steering Systems

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Many bearings are used in the columns, gears and pumps of steering systems. This report presents the types and characteristics of the bearings fitted into each part.

1. Introduction

Vehicles have three basic functions: moving, turning and stopping. Turning is the job of the steering system. Steering systems are mechanisms by which turning displacement of the steering wheel is converted to turning of the tires via the steering gear. Various types of rolling bearings are used in the various rotational mechanisms of the steering system.

This report presents the types of bearings used in the various parts of steering systems and trends regarding such bearings.

2. Types of Steering Systems

Rack-and-pinion type steering is generally used for passenger cars and recreation vehicles, while ball-screw type steering is used for industrial machinery such as trucks and forklifts. Both types include manual and power assistance types.

The steering system from the steering wheel to the tires consists of the following components:

- Steering column
- Steering joint
- Steering gear

In the case of power steering, the following are added:

- Hydraulic pump, reservoir tank
- High-/low-pressure hoses

Bearings are used in the steering column, steering gear and pump.

3. Required Performance of Bearings in Various Parts

The performance required of bearings differs somewhat according to the part in which the bearing is used. Excessive axial play must be avoided for parts that affect steering feeling, such as the steering column and steering gear.

3.1 Bearings for Steering Columns

A ball bearing is used on the upper side, and a needle roller bearing or a ball bearing is used on the lower side as column shaft support bearings (Fig. 1). In some cases a bushing is used on the lower side. Pipe material is generally used for the housing (column tube). Bearings are tight-fitted into the housing and loose-fitted onto the shaft. Because pipe material is used for the housing, there is a wide tolerance of bore diameter, and the bearing must be used under conditions such that the bore roundness has not been accurately machined. Ball bearings and needle roller bearings are used as shown below.

3.1.1 Ball Bearings for Steering Columns

In the case of column ball bearings, because the radial and axial play of the steering wheel should be minimized, the residual radial clearance of the bearing after mounting must be set slightly negative. Because thin-walled raceway ball bearings are used due to limited space, housing bore diameter accuracy can easily affect outer ring roundness and hence rotational feeling.

Good conductivity is sometimes required for upper side bearings. In the case of ball-screw type steering, current for the horn is grounded via the upper bearing and steering gear. In the case of rack-and-pinion type steering, there are numerous couplings from the steering wheel to the gear that impede grounding, and in some cases the horn will not blow because of insufficient grounding of current for the horn.

Two methods are used to improve conductivity: filling the bearing with conductive grease, and using a wired conductive bearing (Fig. 2). In the case of the former, conductivity is sometimes lost due to deterioration of the grease, so the latter, which maintains stable conductivity, is often used. Conductivity characteristics are shown in Fig. 3, and conductive durability is shown in Fig. 4.

As for the design of conductive bearings, a wire is placed in a groove provided on the outer ring and is held in place by spring force. The position is stabilized by a groove provided on the inner ring wire contact area.
3. 1. 2 Needle Roller Bearings for Steering Columns

Needle roller bearings with rubber case (Fig. 5) are used to minimize radial play of the steering wheel. These bearings use a rubber case and outer ring with a slit. By providing interference between the shaft and roller internal contact diameter after mounting to create a constant light pre-load, the radial clearance can be reduced to zero.

3. 2 Bearings for the Steering Gear

Steering gear bearings are divided into those for rack-and-pinion type steering and those for ball-screw type steering. In the case of power steering, bearings are also used in the torsion bar, as will be explained later.

3. 2. 1 Bearings for Rack-and-Pinion Type Steering Gears

Two bearings are used for gear support (Fig. 6). In some cases two angular contact ball bearings are used, but generally one of them is a deep groove ball bearing and the other a drawn cup needle roller bearing (Fig. 7). Axial and radial loads are produced by gear reaction. Axial load is supported by the ball bearing. In order to minimize axial play of the deep groove ball bearing for the purpose of eliminating steering wheel play, radial clearance after the bearing is mounted is set to negative clearance. If axial play has to be further reduced, four-point contact ball bearings are sometimes used (Fig. 8). If the deep groove ball bearing is replaced with a four-point contact ball bearing, the axial clearance at the same radial clearance can be reduced to 1/4 or less (Fig. 9). No matter what type of ball bearings are used, the axial load being placed on the bearing is usually high, and therefore thorough consideration should be given to the allowable axial load of the bearing.
3.2.2 Bearings for Ball-Screw Type Steering Gears

The ball-screw and sector shaft are shown separately in Fig. 10.

(1) Ball screw

The ball-screw section is configured so that axial and radial loads produced by gear reaction are supported by angular contact ball bearings, which have a 45° contact angle to increase axial load carrying capacity (Fig. 11). In some cases four-point contact ball bearings are used instead of angular contact ball bearings. Unlike that used in the rack-and-pinion type, this four-point contact ball bearing (Fig. 12) has a 45° contact angle with separated outer ring in order to enhance axial load carrying capacity. Because of space restrictions, the shaft may take on the role of the inner ring.

(2) Sector shaft

Needle roller bearings (Fig. 13) are used because the housing cannot be made large in the diameter direction. There is a large radial load on the sector shaft, and skewing particular to needle roller bearings (inclination of the needle rotation axis relative to the bearing center axis) can be expected, increasing the bearing's internal axial load. Because bearing drop-out from the housing and outer ring rib breakage are therefore possible, proper consideration must be given to these problems when studying specifications.
3. 2. 3 Torsion Bar Bearings

Drawn cup full complement cylindrical roller bearings or deep groove ball bearings are used for this part. If there is no problem with steering feeling or noise, a drawn cup full complement cylindrical roller bearing (Fig. 14) may be used. The configuration with a drawn cup full complement cylindrical roller bearing is shown in Fig. 6. Drawn cup full complement cylindrical roller bearings consist of an outer ring and rollers, and because they are assembled so that the rollers do not drop out by adjusting the diameter and number of rollers, they are easy to handle and are more economical than deep groove ball bearings. If the clearance after assembly is a source of noise, deep groove ball bearings are used and clearance after assembling is made negative.

3. 3 Pump Bearings

Ball bearings are used for pulley support of the engine-driven hydraulic pump (vane pump), which serves as the power source for hydraulic power steering. The configuration is shown in Fig. 15. The side of the bearing facing the pulley is exposed to the air in the engine bay, so the bearing must be sealed. Furthermore, the bearing must have a small running torque in order to minimize energy loss (i.e., improve fuel consumption). A very light contact type RD seal is therefore used (Fig. 16).

The pump is mounted near the road surface in the engine bay, so a contact type RKB seal is used so that muddy water cannot get into the bearing if it gets on the bearing from the pulley side (Fig. 17).

4. Bearings for Electric Power Steering (EPS)

Electric power steering (EPS), which uses an electric motor as its power source, is now being used increasingly in the place of engine-driven hydraulic power steering because it reduces energy loss. There are two types of EPS: a column-

Fig. 13 Needle roller bearing for sector shaft

Fig. 14 Drawn cup cylindrical roller bearing

Fig. 15 Hydraulic pump (vane type)

Fig. 16 RD sealed type ball bearing for pump

Fig. 17 RKB sealed type ball bearing for pump

type EPS used for compact cars, and a pinion-type EPS used for vehicles requiring large output power.35

(1) Column type EPS

Regarding the features of column type EPS (Fig. 18), because the motor, reduction gear and other parts composing the power assist mechanism are concentrated on the column, a manual steering system can be converted to a power system merely by changing the column unit. Basically, only the motor and reduction mechanism are added, and therefore column type EPS is much lighter and more compact than a conventional hydraulic power steering system. These features are particularly important for subcompact cars, which have little space under the hood and stringent weight requirements. This is the only type of power steering system with the motor and reduction mechanism in the passenger room.35

The configuration of the motor and reduction gear are shown in Fig. 19. Two bearings are used for worm shaft support, and ball bearings are used for the motor. The two bearings are pre-loaded to minimize play of the worm shaft, and pre-load is applied from the outer ring side of the motor side bearing, and axial and radial loads produced by reaction
of the worm gear are supported by the two bearings. Quiet operation is especially important because the motor is located in the passenger room, and sufficient consideration must be given to noise regarding these bearings.

Fig. 18 System layout of column type EPS

Fig. 19 Gear Ass'y of column type EPS

(2) Pinion type EPS
In the case of pinion type EPS, the motor is connected directly to the pinion shaft via the reduction gear. Gears mesh in two places on the pinion shaft, and therefore allowable bearing axial load must be studied carefully when deciding bearing specifications.

5. Future Trends of Bearings for Steering Systems
The need for lower cost and the switch to EPS place new demands on bearings, as described in the following section.

(1) Press type bearings for steering columns
Ball bearings used for columns are the thin-walled section type, so costs are higher than those of standard thickness types. In order to reduce such costs, press type ball bearings (Fig. 20) are being used increasingly, primarily in countries outside of Japan. Because these bearings are the angular contact type, they are used under pre-load and are able to reduce axial play. The area surrounding the bearings requires a pre-load construction, and this should be taken into consideration when determining total column specifications. An example bearing assembly is shown in Fig. 21.

Fig. 20 Press type bearing for column

Fig. 21 Example of column structure for press type bearings

(2) Bearings for pinion type electric power steering motors
A high axial load is applied to the motor's gear output side bearing, and a four-point contact ball bearing is sometimes used (Fig. 22) for this position in order to minimize axial play without resorting to a pre-load construction. The steering gear parts in which a four-point contact ball bearing has been used have traditionally required only low-speed rotation, and therefore noise was not a problem. However, such bearings used in motors must operate at high speeds, and therefore noise characteristics must be improved. In the future, machining precision must be improved in accordance with the requirements for this part.

Fig. 22 Structural drawing of four-point contact ball bearing for power steering motor

6. Conclusion
This completes the explanation of trends regarding rolling bearings for steering systems. As the demand for more compact, fuel-efficient automobiles increases, the demand for EPS is also increasing. Bearings play a vital role in such EPS systems, and improvements in the precision, cost, etc., of bearings must continue.

References