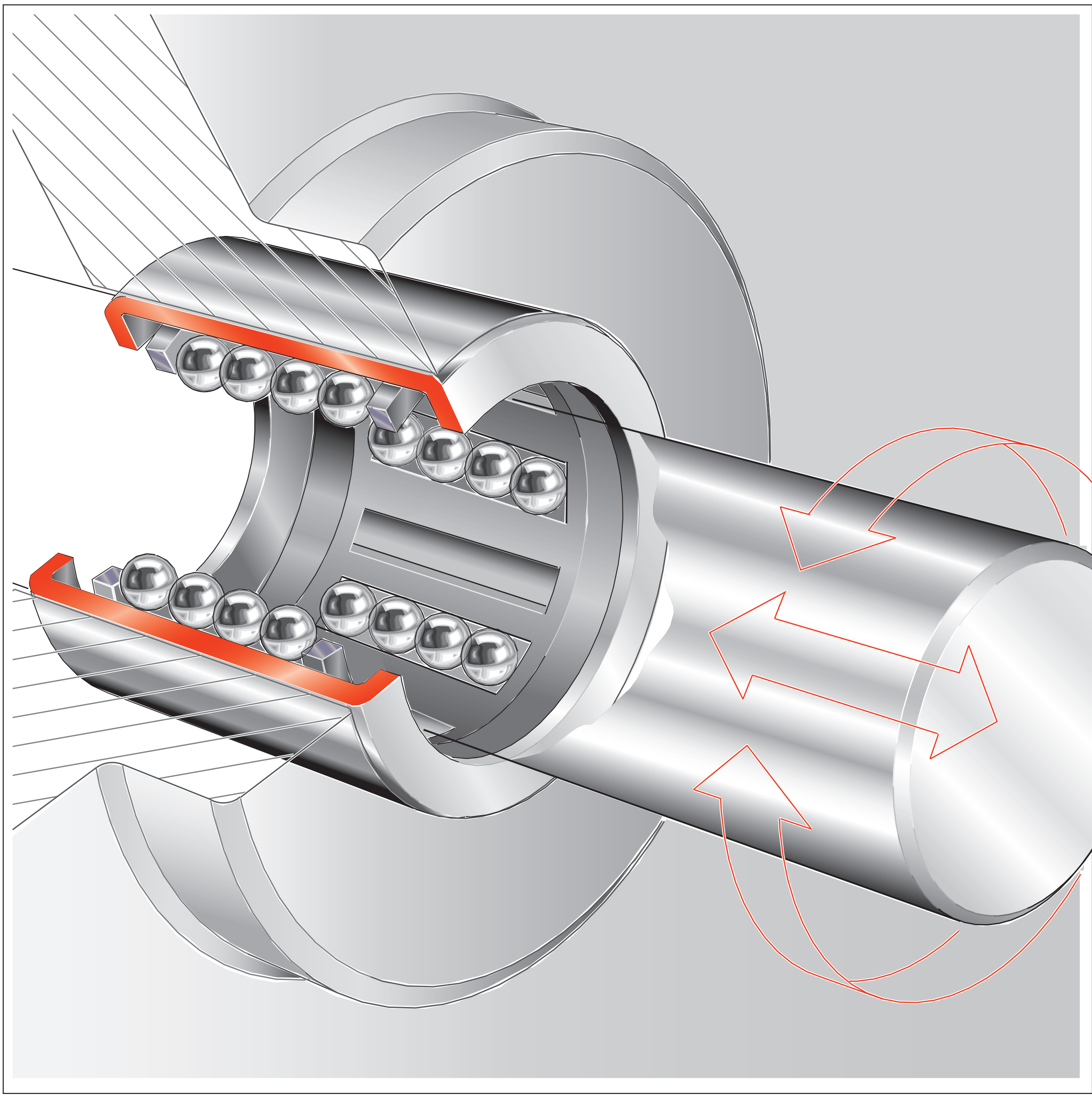


Rolling bearings for rotary and limited linear motion

Series RLF for Shift Rods and Shift Rails

Automotive Product Information API 10

Contents

Requirements

In order to achieve the lowest possible gearshift and synchronisation forces, the gearshift elements in manual automotive gearboxes must be supported by bearing arrangements matched to their function with high precision, smooth operation and low friction while requiring only a very small radial design envelope.

Rolling bearings of series RLF for rotary and limited linear motion are designed to fulfil these requirements. They are now standard solutions for modern shift systems in gearboxes.

Application – Figure 1

Rolling bearings of series RLF:

- are pressed into the gearbox housing
- guide selector shafts, selector rods, round or rectangular section selector rails and selector forks and support the gearshift forces and moments occurring in their operation.

The bearings must:

- allow limited axial displacement travel of the selector rods, rails and forks during the gearshift operation
- allow additional oscillating or swivel motion of the selector shaft due to the externally induced gearshift operation.

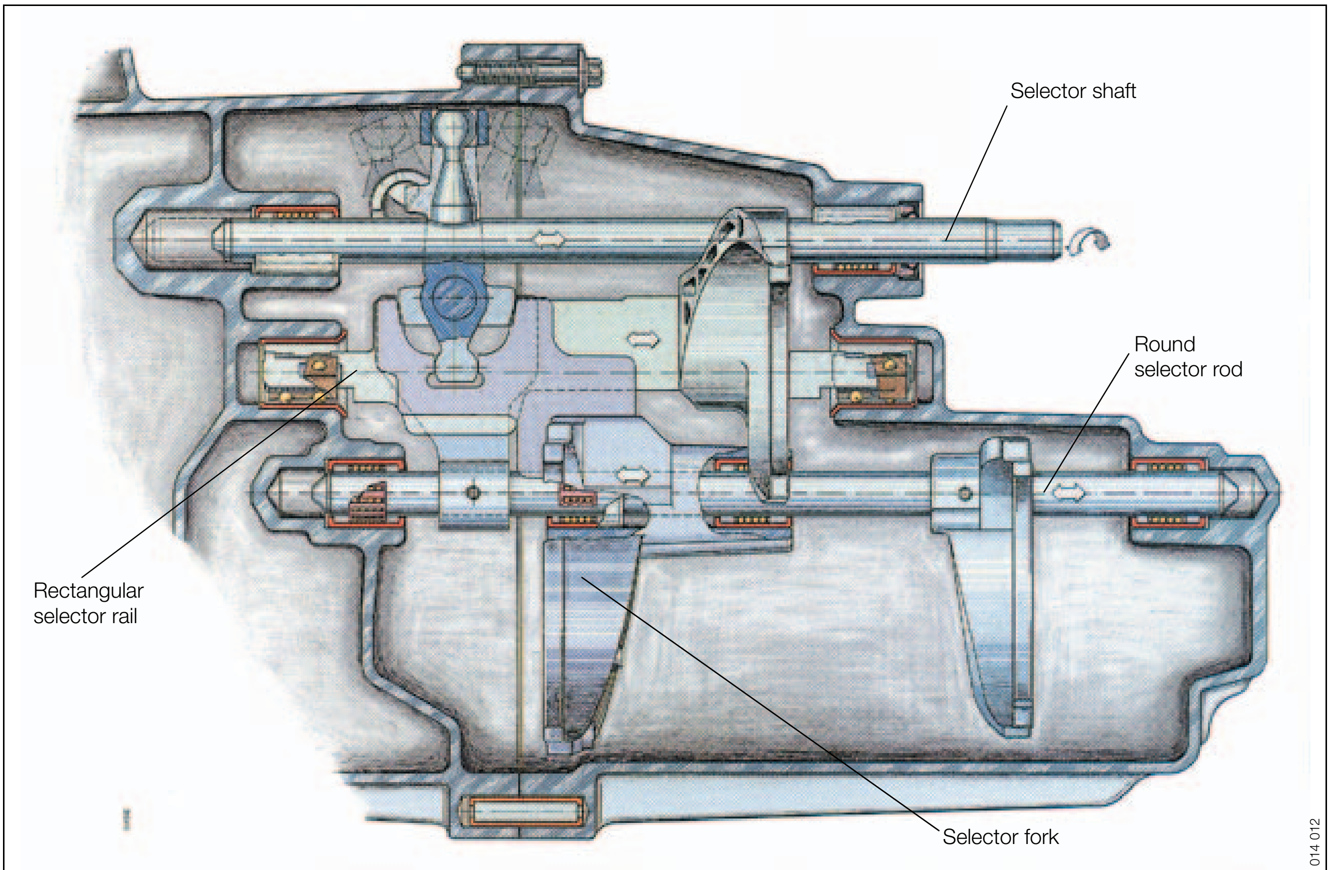


Figure 1 · Bearings for rotary and limited linear motion – application

Types and design

Types – Figure 2 to Figure 7

Bearings of series RLF for manual automotive gearboxes are essentially produced in the following types:

Figure 2: Rolling bearings for rotary and limited linear motion;

Figure 3: Rolling bearings for rotary and limited linear motion;

Figure 4: Rolling bearings for limited rotary and limited linear motion;

Figure 5: Rolling bearings for limited linear motion and torque transmission;

Figure 6: Rolling bearings for limited linear motion and for selector rails of rectangular cross-section;

Figure 7: Rolling bearings for limited linear motion and torque transmission.

Design – Figure 2 to Figure 7

The bearings consist of a drawn cup – the outer ring – and a significantly shorter cage with rolling elements. The drawn cup and ball cage form a self-retaining unit.

Bearings of the type in Figure 6 are two-piece units. In addition to the outer cup, they have an inner sleeve made from steel strip and case hardened on all faces to accommodate the rectangular section selector rail. This elastic, sprung inner sleeve gives clearance-free guidance of the selector rail. The outer cup and inner sleeve with the ball cage must be separated for fitting of the selector rail – see section *Assembly*.

Drawn cup

The drawn cups are designed as an outer raceway for the rolling elements; they are formed and case hardened. Depending on the type, they are manufactured with or without internal ribs.

In bearings of the type in Figure 6 and Figure 7, the outer cup has a funnel-shaped opening at one end – this outer cup is not shown in the type in Figure 7. As a result, the selector rail and preassembled inner part, comprising the inner sleeve and ball cage, can be easily fitted – see section *Assembly*.

Rolling elements

Balls are used as rolling elements. The balls are in accordance with DIN 5 401 and are made from through hardened rolling bearing steel.

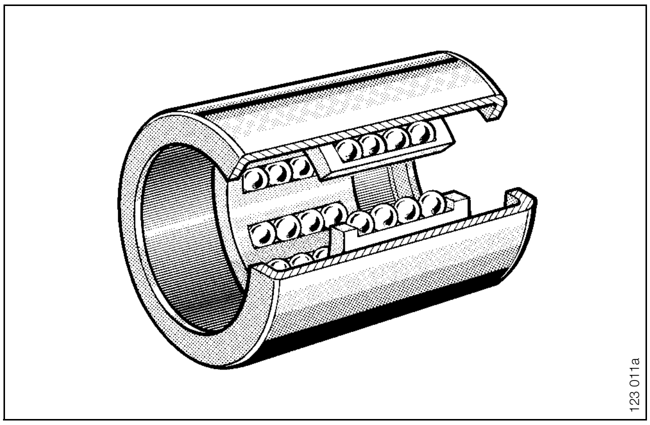


Figure 2 · Rolling bearings for rotary and limited linear motion

Figure 3 · Rolling bearings for rotary and limited linear motion

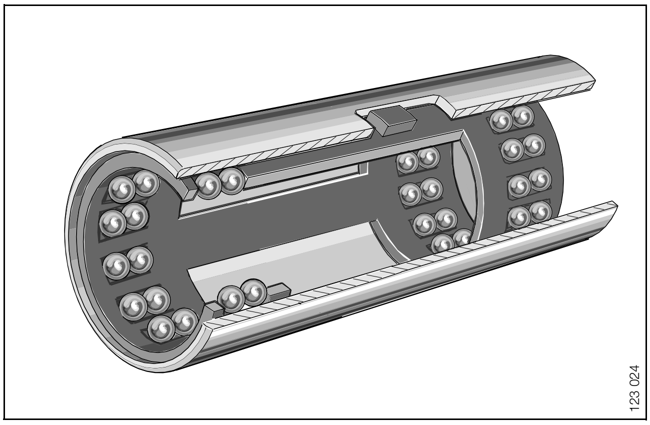


Figure 4 · Rolling bearings for limited rotary and limited linear motion

Cage

The cages are made from steel strip or plastic; the surface of the steel strip is case hardened.

They are either closed or designed to prevent skewing (twisting).

The balls are accommodated in pockets in the cages. The use of rolling elements is matched to the load carrying capacity required – for a lower load carrying capacity, for example, only every second pocket contains a ball. If the maximum basic load ratings of the bearings are to be achieved, all the pockets are filled. For optimum utilisation of the load carrying capacity, the cage pockets are designed with a slight axial offset, so that each rolling element has its own raceway.

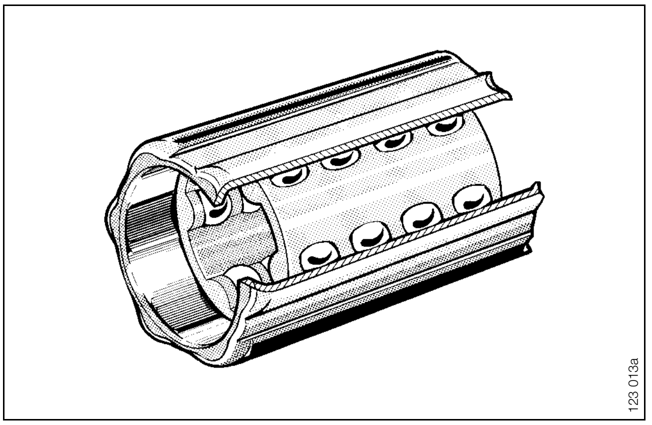


Figure 5 · Rolling bearings for limited linear motion and torque transmission

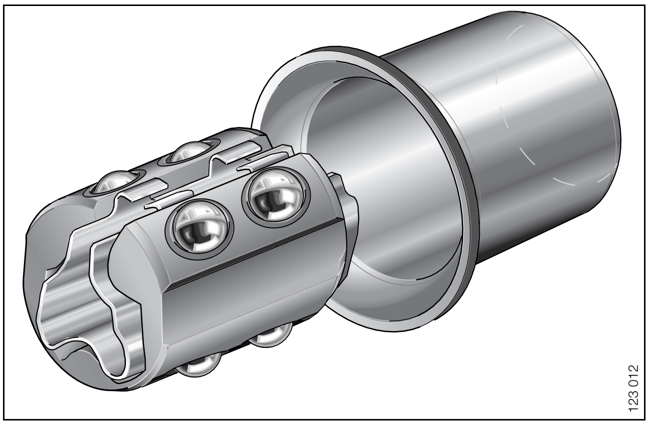


Figure 6 · Rolling bearings for limited linear motion and for selector rails of rectangular cross-section

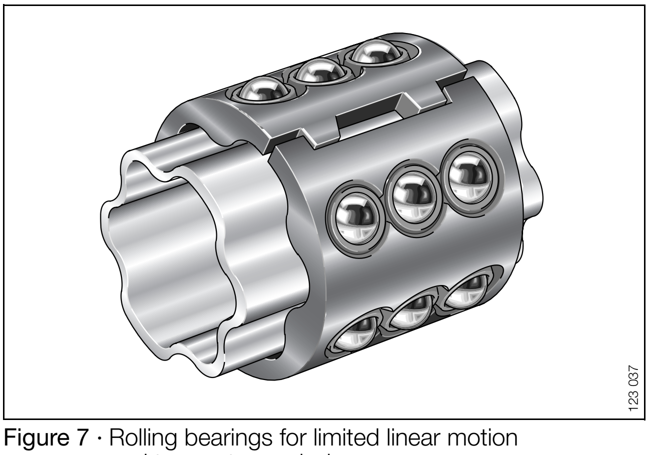


Figure 7 · Rolling bearings for limited linear motion and torque transmission

Cage stroke and shaft stroke – Figure 8

Due to the difference in axial design envelope "h" between the outer cup and the cage, the cage can perform linear motion. The extent of the motion is determined by the free length between the cage and the inner ribs of the outer cup. In outer cups without ribs, the limiting factor is the axial size of the outer cup.

The selector shaft can be displaced axially within the bearing. The maximum displacement travel "H" of the selector shaft – the shaft stroke – corresponds to twice the displacement travel "h" of the cage – the cage stroke:

$H = 2 \times h.$

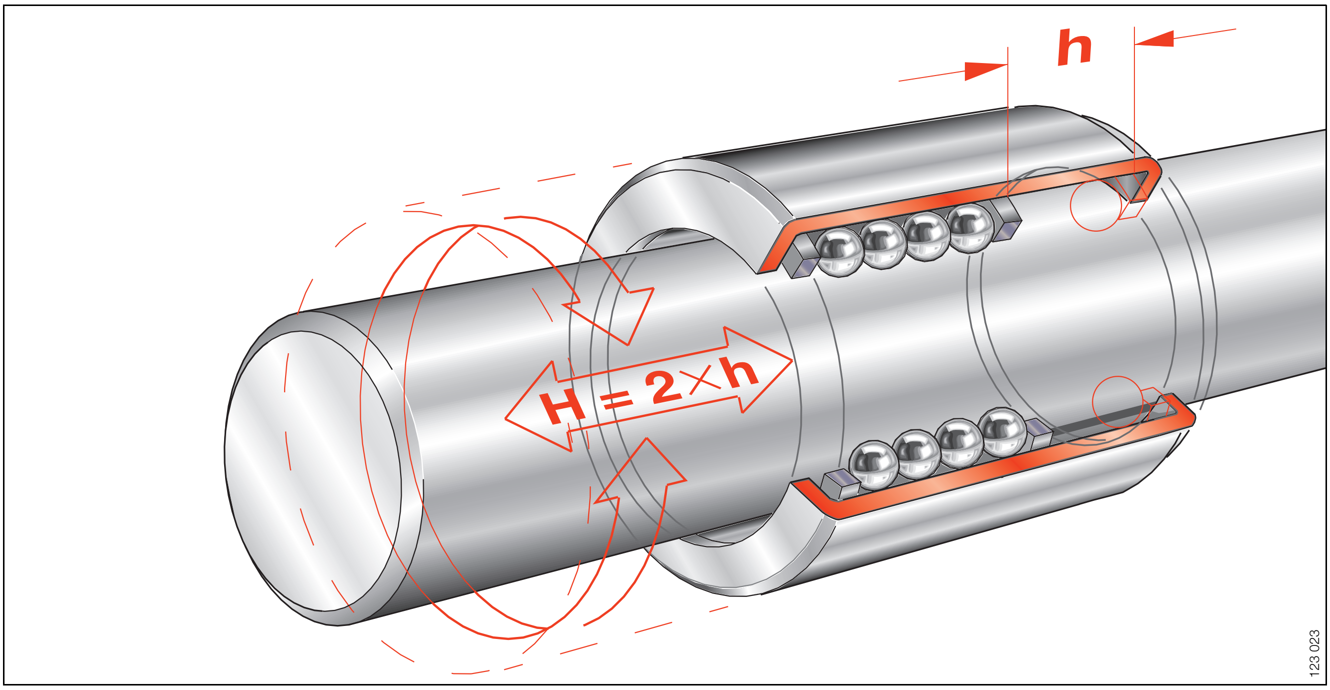


Figure 8 · Cage stroke and shaft stroke

Design of bearing arrangements

Gearbox housing – Figure 9 and Figure 10

In order to fully utilise the load carrying capacity, the thin-walled outer cup – the outer ring of the bearing – must be supported with adequate rigidity in the gearbox housing.

The bore tolerance for the bearing seat should be:

- R7 for aluminium alloy housings
- N6 for steel housings.

The position of the eveloping circle F_W and the quality of the bearing arrangement in the mounted condition is determined by the material and the wall thickness of the adjacent construction as well as the dimensional and geometrical accuracy of the housing bore.

The enveloping circle is the inner inscribed circle of the balls in clearance-free contact with the outer raceway. The enveloping circle is stated in the delivery drawing. A steel ring gauge with the lower bore deviation of the N6 fit is used as a comparator.

RLF bearings have, depending on the size of balls used, an enveloping circle between 2 µm and 7 µm times larger than that of drawn cup needle roller bearings.

Selector shaft/selector rail

Since the rolling elements run directly on the shaft, the shaft must be designed as a rolling element raceway; i.e. the material for the raceway must have the necessary hardness depth – as specified or determined by INA – and a surface hardness of 670 +170 HV.

Materials with a correspondingly high purity level can be used such as:

- through hardening steels, e.g. 100Cr6, or
- case hardening steels, e.g. 16MnCr5.

The surface quality depends on the precision required in the bearing arrangement. It should be between R_z1 and R_z4. The shaft tolerance should be selected such that the smallest possible operating clearance is achieved, e.g. m6. Selector rails with a rectangular section require neither special machining nor surface treatment or hardness.

Lubrication

The bearings can be lubricated with grease or oil. For grease lubrication, greases in accordance with DIN 51825 KP2K are used. If oil lubrication is to be used for bearings with plastic cages, please consult INA.

Load

If the load ratio is $C_0/P_0 \leq 1{,}5$, a precise analysis of the bearing arrangement should be carried out by INA.

Note

Further information is given in *INA Catalogue HR 1*, section *Design of bearing arrangements*.

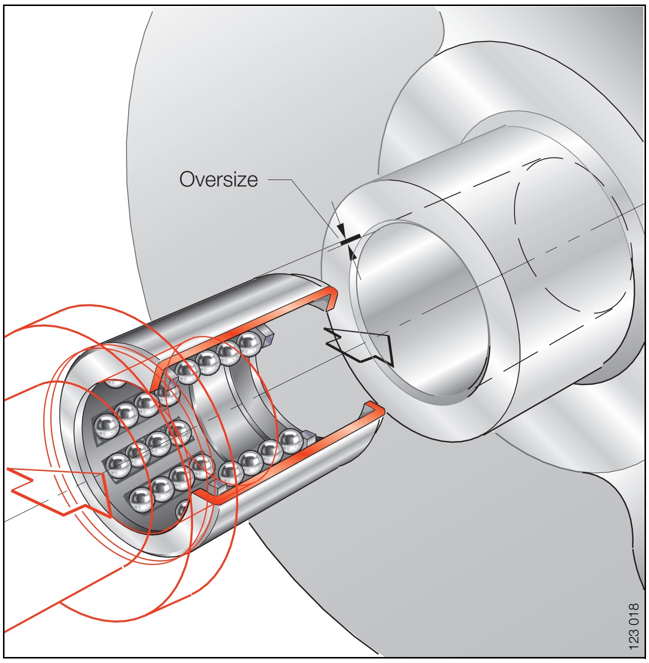


Figure 9 · Outside diameter with oversize

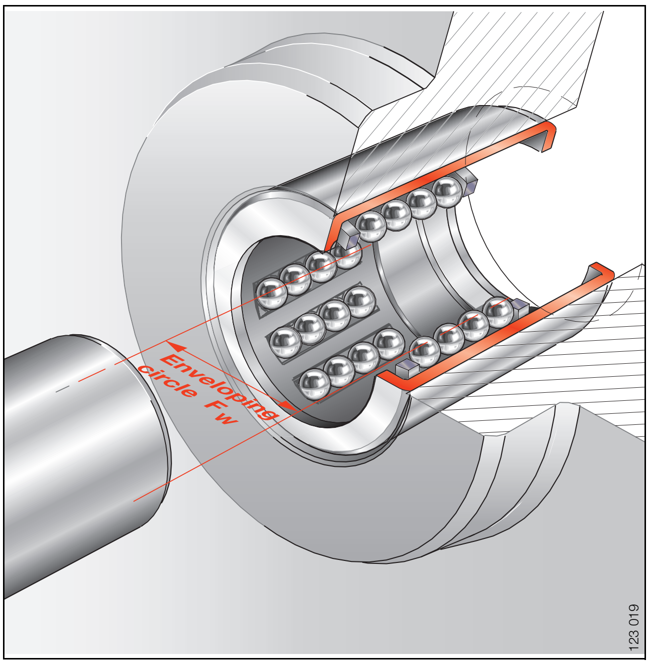


Figure 10 · Enveloping circle diameter F_W in mounted condition

Assembly

Fitting of bearings

RLF bearings are supplied as bulk material in carboard boxes – batch size approx. 250 pieces. The rolling bearings are wrapped in VCI paper and thus have a dry preservative. This paper protects the bearings against corrosion.

⚠ Bearings should only be removed from their original packaging immediately before assembly. The packaging should be closed again immediately:

- the protective vapour phase of the VCI paper is only effective when the packaging is closed.

Bearings should be oiled as soon as they are removed from the packaging.

Perspiration from handling leads to corrosion. Bearings should only be touched with clean, dry hands; cotton gloves should be worn if necessary.

Fitting advice for:

- rolling bearings for rotary and limited linear motion
- rolling bearings for limited rotary and limited linear motion
- rolling bearings for limited linear motion and torque transmission.

The bearings are pressed into the locating bore in the gearbox housing using a pressing-in mandrel or a press – see Figure 9. The collar of the pressing-in mandrel should preferably be located against the end face of the bearing displaying the marking/number.

The bearings must not be tilted during fitting.

After pressing-in, the bearings are axially and radially located; no further means of retention is required.

Fitting advice for:

- rolling bearings for limited linear motion and for selector rails of rectangular cross-section.

In the case of these bearings, the outer cup and the inner sleeve together with the ball cage must be fitted separately (Figure 11 and Figure 12).

Once the outer cup has been pressed into the gearbox housing, the selector rail with the ball cage clipped on is pushed in through the funnel-shaped opening in the outer cup. No further location or adjustment of the bearings is required.

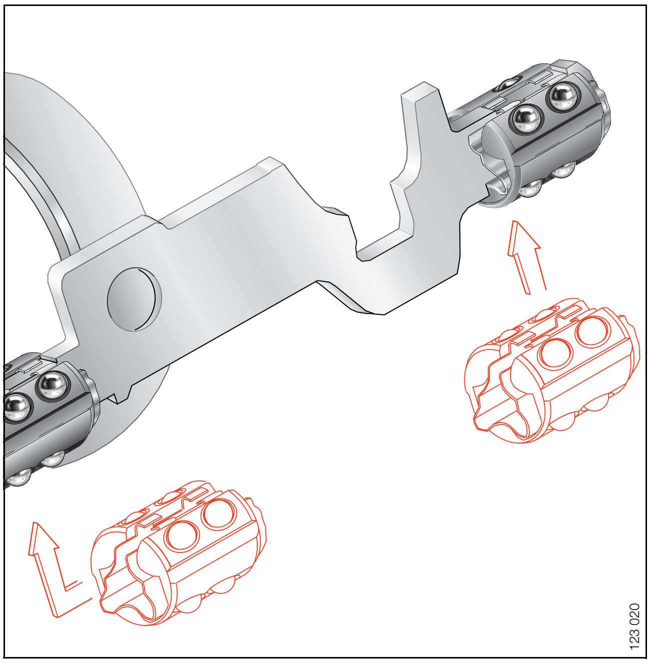


Figure 11 · Pressing in the outer cup and clipping on the ball cage

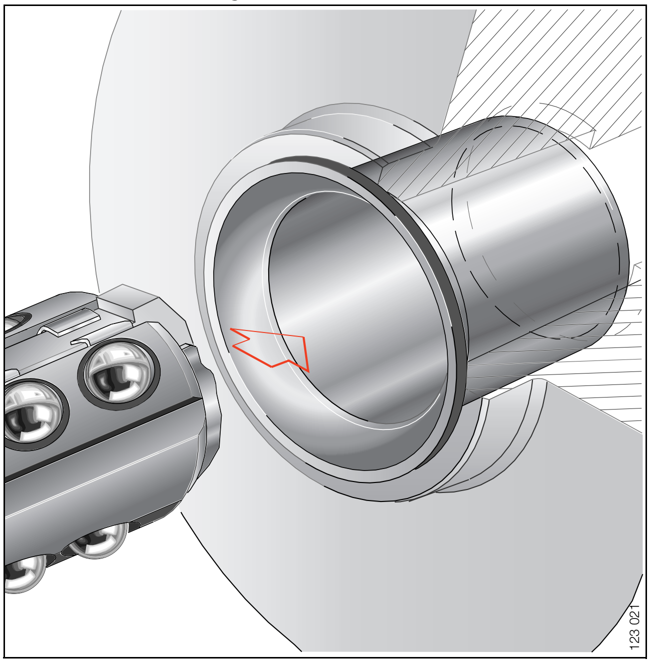


Figure 12 · Fitting the selector rail and ball cage

Gearshift force and moment curve in selector shafts with plain and rolling bearings

The type of bearing arrangement – plain or rolling bearings – influences the force required in selecting and engaging gears and thus the gearshift feel.

In the process of selecting a gear, the effects on the smooth gearshift capability are only slight. In the process of engaging a gear, however, a high level of displacement resistance and frictional torque is undesirable.

Comparison – Figure 13

A comparison is given of the displacement resistance and frictional torque of a selector shaft with the following support arrangements:

① directly in the aluminium alloy gearbox housing or

② in Permaglide® plain bearing bushes PAP P10 or

③ in bearings of series RLF.

Displacement resistance under pure linear motion

The upper curves show the displacement resistance with linear motion of the selector shaft. Measurements were carried out on a loaded selector shaft. Bearing load:

- 160 N
- 450 N.

Displacement resistance under linear motion and overlaid swivel motion

The curves in the centre show the displacement resistance under simultaneously overlaid swivel motion: swivel angle ±30°.

Frictional torque

The lower curves show the frictional torque under pure swivel motion with a swivel angle ±30°.

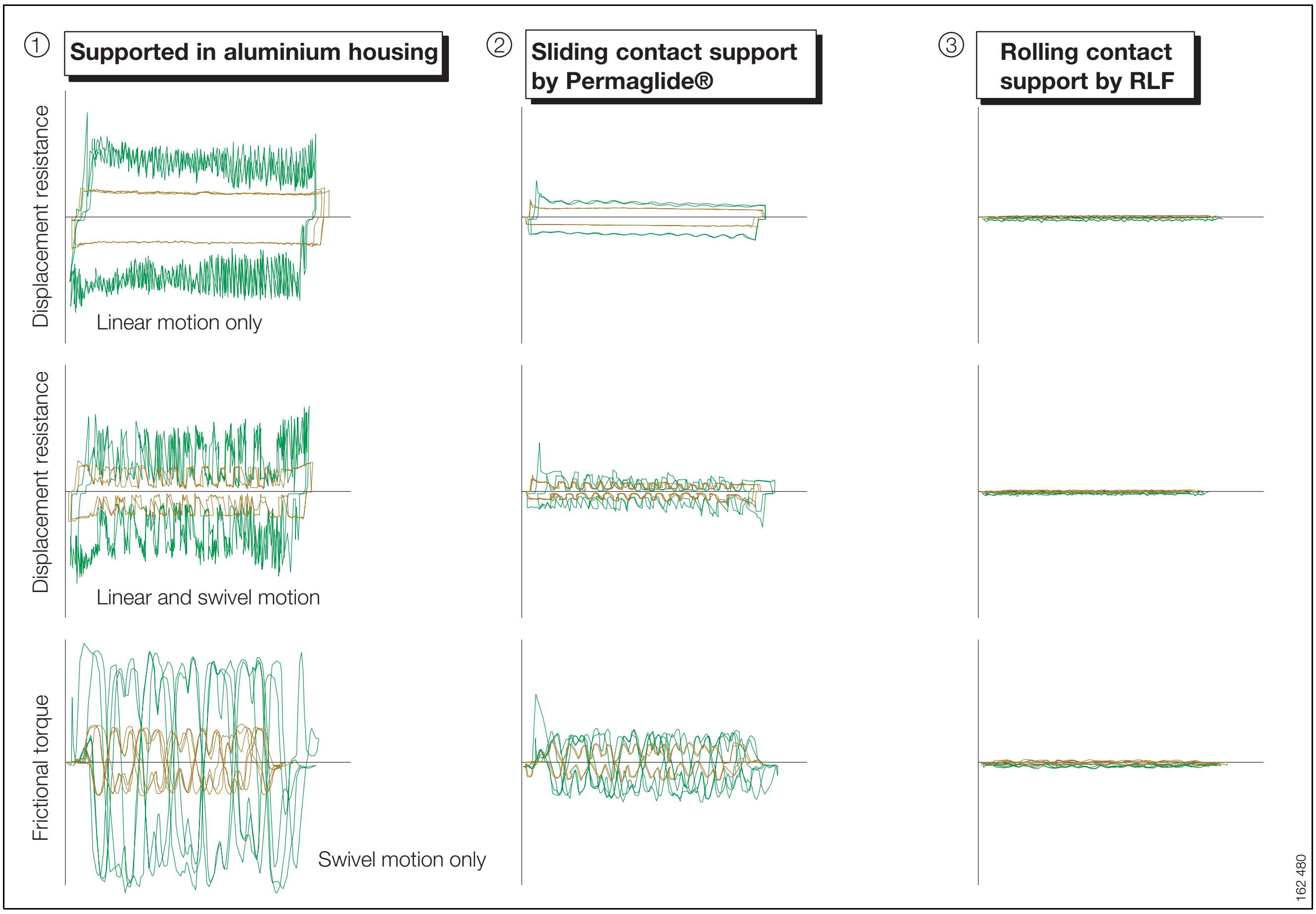


Figure 13 · Displacement resistance and moment curve – comparison

Interpretation of the measurement values

① The values for the displacement resistance and frictional torque are extremely high. Gearshift is thus difficult and does not communicate a positive gearshift feel.

② Significantly improved measurement values are shown by the bearing arrangement with the Permaglide® plain bearing bush. The result is essentially possible due to the favourable p · v value – the product of the specific bearing load and sliding speed. The steep rise in the curve at the start of the measurement process is caused by the stick-slip effect that is typical of plain bearings.

③ The lowest values occur with the rolling bearing arrangement. The smooth, low-friction gearshift process thus contributes to a positive gearshift feel.

Behaviour of the bearing arrangement

The bearing arrangement of a selector shaft should be designed such that the shaft can be moved easily and smoothly and rotated over a certain angle range. By means of these motions, the relevant gate is selected and the corresponding gear is engaged. The relevant type of motion – linear or rotary motion for the selection and engagement operation respectively – is predetermined by the overall design of the gearshift system.

The bearings do not have to transmit gearshift moments when selecting the gate. However, frictional forces must be overcome that result from the mass of the selector shaft, the lever ratios of the adjacent parts and the return spring forces.

Selector shafts supported by rolling bearings ensure that the required function is performed reliably even with lower operating clearance and at low operating temperatures.

Test method

Bearings of series RLF must exhibit certain product characteristics and fulfil precisely defined quality standards. Mechanical test methods are used to check and confirm these requirements. Idealised, theoretical load conditions are replaced in these tests by characteristic loads that are representative of actual driving conditions.

If no customer requirements are stipulated, the conditions correspond to the actual application.

Test conditions

Load dependent on the stress	F_R = 18 N to 941 N
Shaft stroke	s = ± 12,5 mm
Swivel angle of shaft	α = 0/±30°
Displacement speed of speed	v = 3,16 mm/s
Lubricant	Esso gearbox oil ST SAE 85–W90
Lubrication method	Drip feed oil lubrication.

Displacement resistance and frictional torque – Figure 14

Two test bearings are fixed in a locating tube.
A radial ball bearing is positioned centrally over the locating tube. The required radial load is applied to the radial ball bearing by means of suspended weights.

The locating tube is extended without transverse forces to the load cell on which the longitudinal force – the displacement resistance – is measured.

The shaft is rotated by hand and the linear motion is overlaid and recorded by a rotational angle encoder.

The frictional torque of the test bearings is measured at the extension to the load cell with bending beams. The measured frictional torque is, however, reduced by the frictional torque of the radial ball bearing. In the evaluation of the test bearing frictional torque, therefore, the measurement values are corrected by the frictional torque of the radial ball bearing.

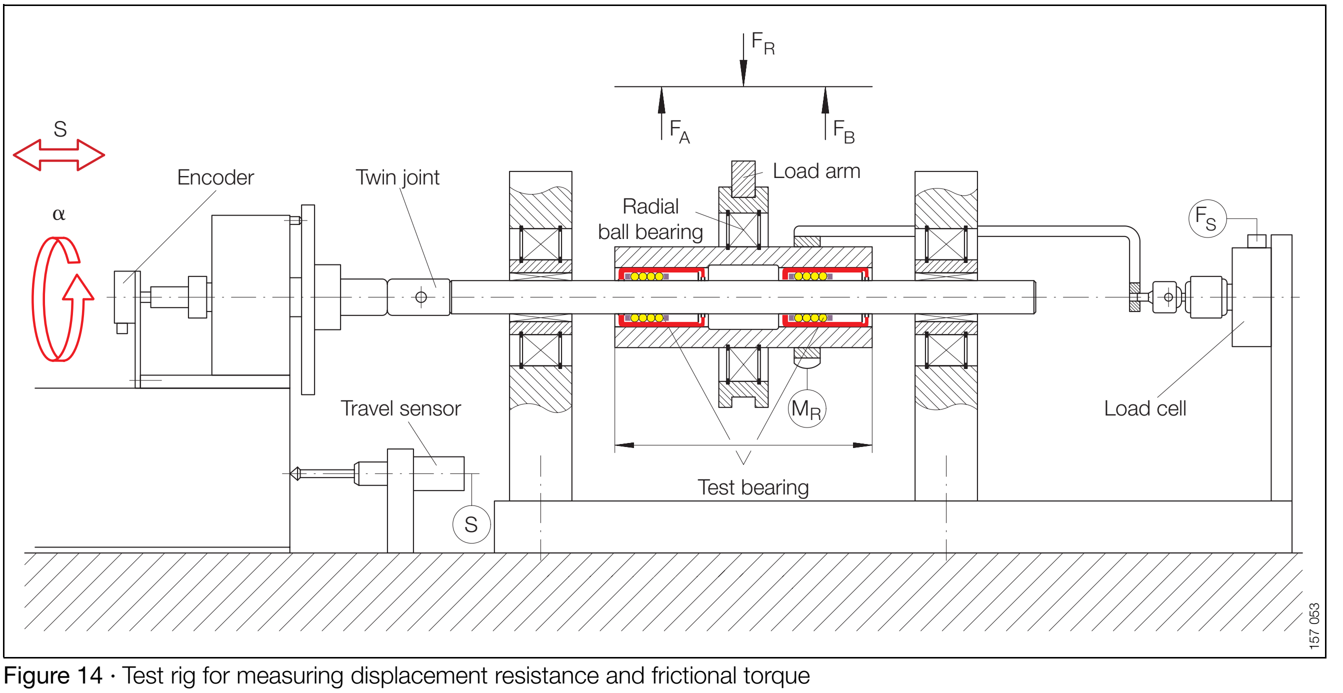


Figure 14 · Test rig for measuring displacement resistance and frictional torque

Failure characteristics

Spalling, indentations

For RLF bearings, the static load safety factor required is only designed for the required operating life.

If the load is higher or if the exposure time – the cycle duration – is longer, damage may occur as shown in Figure 15 and Figure 16.

Such damage is only permissible if it does not impair the function of the bearing, e.g.: if the RLF bearing is used to support selector rails.

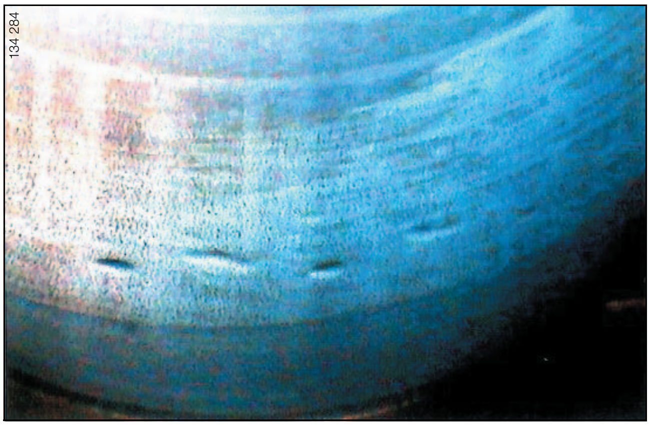


Figure 15 · Fatigue tracks on the drawn cup

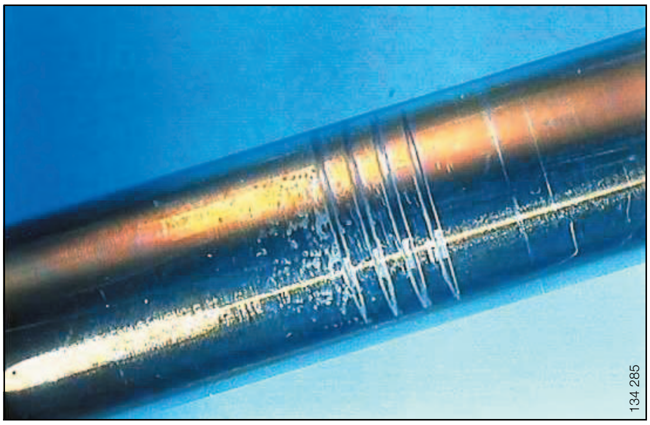


Figure 16 · Fatigue tracks on the shaft

Summary

Bearings of series RLF can be used in a wide range of applications in manual automotive gearboxes.
The various types available and the resulting specific product characteristics give comprehensive advantages for the customer.

Advantages

- Fewer parts are required, since the required rotary and linear motion of the gearshift elements is carried out using a single bearing
- Uniform gearshift force curve due to the use of rolling bearings
- If the ball cage is preloaded, the cage remains fixed in position in the unloaded condition
- Only a low level of gearshift force is required over the whole operating life since the bearing arrangement has low friction and low wear
- Secure and direct gearshift curve by means of a very small operating clearance
- Only minimal space is required
- Suitable for high operating temperatures due to the use of temperature-resistant materials
- No axial retaining elements are necessary since a press fit in the gearbox housing is sufficient
- Easy to fit by pressing the bearing into the gearbox housing
- Economical since production of the bearings has been adapted for high volume manufacture.

Load carrying capacity

If the load ratio is $C/P \leq 1{,}5$, slight indentations may occur on the shaft / drawn cup raceway.

The internal preload in the bearing – between the cage and balls – decreases by approximately 50% at a load cycle time of 10^6 since burnishing occurs on the guide surfaces of the cage crosspieces and wear marks – grooves – may be formed on the balls.

However, the function of the bearings is not significantly impaired at this stage.

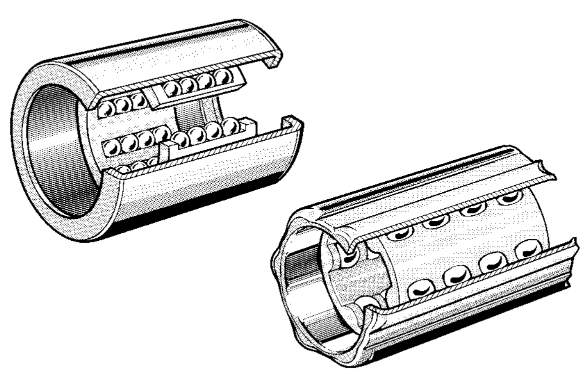
Checklist

Legend

❑ Tick appropriate box

☐ Enter relevant information

1) Attach customer drawing.



RLF – range

Basic functions

Bearing arrangement for:	No	Yes
main or central selector shafts	❑	❑
selector rods	❑	❑
selector rails	❑	❑
selector forks	❑	❑
for rotary motion	❑	❑
for linear motion	❑	❑
for rotary and linear motion	❑	❑

Additional functions / characteristics

	No	Yes
Transmission of torques	❑	❑
Sealed	❑	❑
Anti-corrosion protection	❑	❑

Operating conditions

Bearing load (N)	
Torque to be transmitted (Nm)	
Distance between bearings (mm)[1])	
Shaft stroke (mm)[1])	
or: Mounting position of RLF bearings – horizontal or vertical arrangement of shaft –[1])	
Is gearshift initiated by rotation / displacement of the selector shaft	
Frequency (min^{-1})	
Swivel frequency (min^{-1}) / swivel angle of bearing (°)	
Bearing speed (min^{-1})	

	No	Yes
Are drawings available that describe the function of the gearshift system[1])	❑	❑

Inspection and test conditions / test specifications

	No	Yes
Temperature range (°C)		
Grease lubrication	❑	❑
Oil lubrication	❑	❑
Special test conditions	❑	❑

Adjacent construction

Material / tolerances / surface quality of shaft

Material / tolerances of housing

Available space in housing[1])

Assembly

	No	Yes
Special assembly conditions	❑	❑

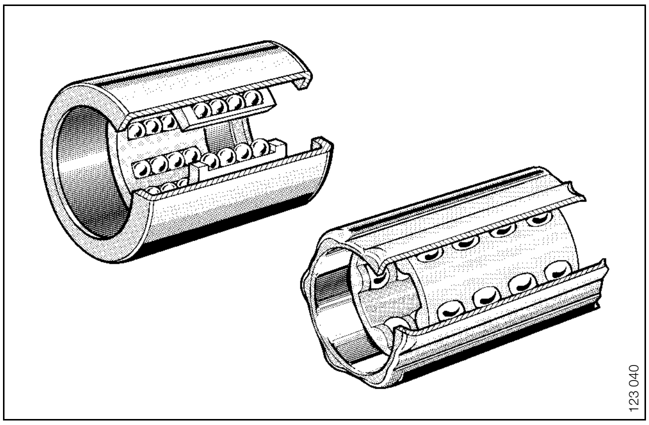
Delivery quantity / delivered condition

Number of RLF bearings per gearbox / costing quantities (pieces)

Special packaging required

Note:
Delivery in cardboard boxes

Dimension list



RLF – range

Dimensions	F- number	Item number
6,000×10,000× 9,000	F-217853.2	000-009-371-341
6,945×23,000×28,000	F-205524-220[1)]	000-000-551-651
12,000×18,000×16,000	F-215109.2	000-001-148-923
12,000×18,000×56,300	F-86934.1[2)]	000-001-495-151
13,000×18,000×20,000	F-216152	000-001-702-670
13,000×25,100×40,800	F-216784[3)]	000-001-548-093
14,000×20,000×21,000	F-228755.3	000-005-092-963
14,000×20,000×21,000	F-228755.1	000-009-679-979
15,000×21,000×16,000	F-226955	000-004-784-260
15,000×21,000×22,000	F-213995.1	000-000-549-290
15,000×21,000×22,000	F-82852	000-000-601-837
15,000×21,000×22,000	F-80574.3	000-006-984-669
15,000×21,000×22,000	F-80574.1	000-000-385-883
15,000×21,000×27,000	F-43174	000-000-180-491
16,000×22,000×20,000	F-203798.1	000-001-707-264
16,000×24,000×25,500	F-212495.1	000-000-388-432
16,000×24,000×26,500	F-206384	000-001-703-145
18,000×24,000×22,000	F-210804	000-000-251-500
18,000×24,000×24,000	FC66880	000-006-004-652
18,000×24,000×26,000	F-218266	000-000-004-987
19,000×23,500×27,500	F-236370	000-010-023-020
19,000×26,000×27,000	F-213256	000-000-193-313
20,000×26,000×27,000	F-235175.2	000-011-363-436
20,000×26,000×30,000	F-20031	000-000-061-492
50,000×69,000×54,000	F-22985.1	000-001-690-477

1) Rolling bearing according to type (Figure 6).
2) Rolling bearing according to type (Figure 4).
3) Rolling bearing according to type (Figure 7).

Reference list

Customer

- BRAUN
- CZ STRAKONICE (SKODA)
- DAIMLER CHRYSLER
- FGP FIAT-GM POWERTRAIN
- FORD
- GEARBOX DEL PRAT (SEAT)
- GETRAG
- GFT GETRAG FORD TRANSMISSION
- GKN SINTER METALS
- GMA GUSTAV MEYER
- HEIDELBERGER DRUCKMASCHINEN
- HYUNDAI MOTOR COMPANY
- SAGAR RICHARDS
- BRONZE ACIOR
- GRAZIANO
- JOHN DEERE WERKE
- KIA MOTORS CORPORATION
- KOCHENDOERFER & KIEP
- LUNKE & SOHN
- NACAM
- OPEL
- PHILIPS
- SELZER
- TREMEC
- VOLKSWAGEN
- ZEULENRODA PRAEZISIONS MASCHINENBAU
- ZF
- ZWN ZAHNRADWERK NEUENSTEIN

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