17. PLAIN BEARINGS

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17. Plain bearings

In many cases the rolling bearings are not able to match the requirements that are demanded from them, despite wide variety of types, versions and sizes. Some features of rolling bearings disqualify them from being taken into account in the phase of defining construction principles. This features are, among others, big weight, large cross-section (bearing-closed pair size), dimension limitations (dimension series), relatively difficult mounting and dismounting and housing conditions (interacting parts), necessity for continuous or periodical supervision – additional lubrication, and relatively high price, especially of bearings with more complex construction. In the last years another branch of bearing mounting has been considerably developed, namely plain bearings, which find even more application in all branches of modern industry.

One can divide them into two essential groups:

- spherical plain bearings – this group is represented by **GE**-type spherical plain bearings and rod ends of **SA**- and **SI**-type – load is carried by the pair of own friction surfaces of these bearings
- slide bearings – one of the friction surfaces always belongs to the device interacting with the bearing – many variants are available, beginning with **TUP** and **TUF** sliding sleeves through to **TUW** sliding washers and sliding plates of various shapes and sizes.

17.1. Spherical plain bearings

Owing to their structure – rolling elements have been substituted for sliding elements, self-alignment: they are adapted for carrying very heavy loads. They carry out fixing, oscillatory, tilting and self-aligning movements. They have found application wherever rolling bearings were not able to fulfill their tasks properly as a result of too heavy loads.

There are many variants of plain bearings on account of structure and type of implemented materials. Key feature of spherical plain bearings is that both working surfaces (friction surfaces) belong to the bearing.

17.1.1. Maintenance and material used (interacting pairs)

- steel/steel – minimal supervision is necessary
- steel/sintered bronze – service-free
- steel/PTFE fabric – service-free (PTFE – teflon)
- steel/PTFE composite service-free (PTFE – teflon)
- chromium/PTFE composite – service-free (PTFE – teflon)
- steel/special bronze – service-free.

Fig.57 Radial spherical plain bearing

17.1.2. Dimension series

GE.. + (designation behind the size)

- **..ES** – standard (steel/steel)
- **..ES2RS** – standard (steel/steel) sealed version
- **..HS** – increased contact angle (steel/steel)
- **..HS2RS** – increased contact angle (steel/steel) sealed version
- **..ECR** – standard (chromium/composite)
- **..ECR2RS** – standard (chromium/composite) sealed version
- **..HCR** – increased contact angle (chromium/composite)
- **..HCR2RS** – increased contact angle (chromium/composite) sealed version
- **..QCR** – big sizes (chromium/PTFE fabric) split outer ring

GW.. - thrust bearings

Non-standard sizes are marked by the **X**-letter behind the bearing symbol.

For standard application **ES** basic-makes of bearings (also available in the sealed **..ES2RS** version) are recommended. However, one should not forget that contact angle in the sealed bearings is considerably limited. In case of very high and changing loads bearings with increased contact angle (**HS**-type, also available in the sealed version: **HS2RS**) are recommended. Service-free **CR**-series bearings are more and more popular, where conventional friction pairs have been replaced with the chromium/PTFE composite pair. Bearings of biggest sizes of **QCE**-series, on account of mounting procedure, have a two-piece outer ring connected with bolts.

17.2. Rod ends

Fig.58 Rod end with a threaded mandrel of SA- (SAL)-type

17.2.1. Dimension series

- **SA..** – "male" rod end, right-hand thread
- **SAL..** – "male" rod end, left-hand thread
- **SI..** – "female" rod end, right-hand thread
- **SIL..** – "female" rod end, left-hand thread.

17.2.2. Designation of friction pairs

- **T/K** – steel/PTFE (wrap for smaller bearings and soaked fabric for bigger bearings)
- **SS/M** – acid resistant steel / brass.

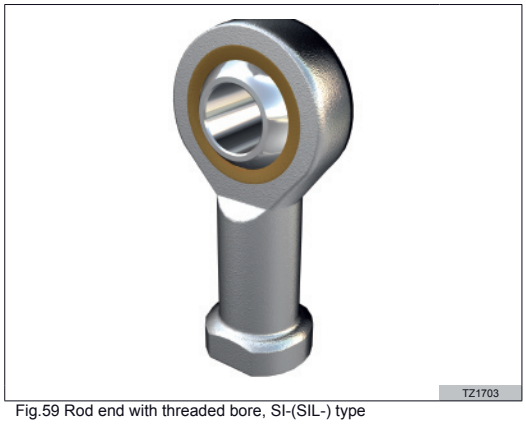

Fig.59 Rod end with threaded bore, SI-(SIL-) type

Rod ends with built-in plain bearings are ready-to-mount parts and can be quickly and easily fixed to the interacting machine elements. The wide variety of engineering solutions basing on the one hand on implementing various plain bearings (various materials of friction pairs) and on the other hand on various assembly options (internal or external threads, right-hand or left-hand threads) enable lots of construction solutions. Standard make (T/K) bases on the friction pair steel/PTFE (wrap or soaked fabric in larger bearings). For heavy-duty operation SS/M rod ends are most suitable, where special, acid resistant steel and brass constitute the friction pair.

17.3. Sliding sleeves and sliding washers of TUP-, TUF- and TUW-type

17.3.1. Basic series

- **TUP1..TUP2..** – sliding sleeves
- **TUF1..** – sliding sleeves with a flange
- **TUW1..TUW2..** – sliding washers

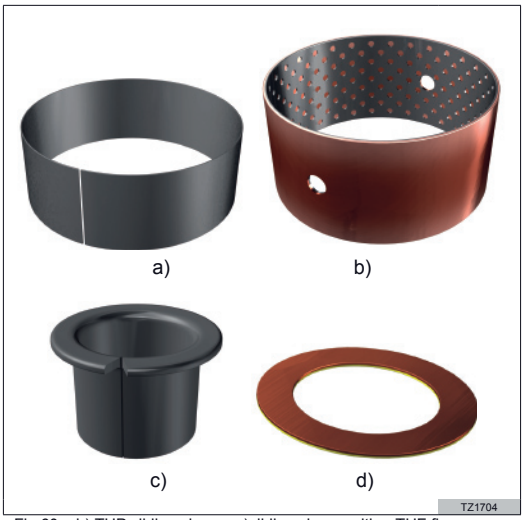

Fig.60 a,b) TUP sliding sleeve, c)sliding sleeve with a TUF flange, d) TUW sliding washer

Development of tribology – science, that treats (among others) friction problems – has largely contributed to the development of plain bearings. Owing to the new technology of laminar composite and polymer materials plain bearings have nearly limitless application.

New materials, that friction surfaces are made of , have lent bearings invaluable features:

- small resistance to motion (small moment of friction, small friction coefficient)
- high wear resistance
- ability to carry planned load
- vibration damping
- easiness of mechanical processing of sliding surfaces.

Additional, equally essential features:

- simple structure
- minimal cross-section
- availability of all shapes and sizes
- selection of friction surfaces depending on requirements
- service-free operation
- low price.

17.3.2. Material structure

17.3.2.a UF-1 Composite based on polytetrafluorethylene (PTFE)

- PTFE with lead press-molded in the porous bronze layer
- porous bronze
- base material – steel
- covering with zinc and electrolytic covering with copper.

UF-1 consists of three layers of materials: inside steel layer, combined with the porous bronze layer, using thermal method, soaked and interlaced with polymer. The surface of the polymer layer is smoothened to the depth of bronze cavities is a mix of PTFE and lead ca. 0,01-0,03 mm thick.

Application characteristics

- low oil demand or even no necessity of lubrication where it is difficult to apply it or in cases it is not used at all
- low friction coefficient, slow wear and tear, long life
- it can carry load on the whole surface keeping elasticity and plasticity
- it can be used in temperatures between -195°C and +280°C
- low level of vibration, noise and environmental pollution
- creating a thin PTEE-lead layer, preventing metal surface from tarnishing
- decreased level of hardness of the interacting surface is required
- compact and lightweight construction
- resistance to oil and water
- low thermal expansion
- good heat conduction at high dimensional stability
- when using special metal for covering - it keeps resistant to gases and various types of industrial grease
- increased tolerance to dust and dirt.

Grindability

UF-1 has a very low friction coefficient, which is within the range of 0,03 – 0,20, and drops at higher load and lower velocities. At trace oil amounts the friction coefficient for UF-1 may be lower than 0,05 despite low load and high velocity.

Wear

UF-1 is relatively easy to wear-in. Initial value (of the friction surface) amounts to 0,010 ~ 0,02 mm, whereas one part of PTFE surface is carried on the interacting surface, creating a translucent layer, which acts as a protecting grease, protecting the interacting surface, too.

Chemical properties

UF-1 surface is resistant to most chemical agents. Outside and inside steel surface is subject to oxidation and may be covered with thin protection layer. In case of exposing to corrosive influence UF-1 is electrolytically protected with lead, nickel, cadmium or chromium.

Limiting loads

Limiting loads for UF-1 may reach up to 140MPa with constant loads. If we want to increase its longevity, we shall decrease loads down to 56MPa with dynamic and changing loads.

Limiting PV coefficient

Product of load and sliding velocity is called PV-value of a bearing. It is a very important coefficient when choosing material for making a bearing, which at the same time allows to foresee the operation time. Of course, the longer bearings' longevity is required, the lower value of PV-coefficient should be. Moreover, various types of loads may act upon the sleeve longevity and limiting PV value.

Other factors

Besides load, limiting PV value and longevity under conditions of constant PV value the following issues play an important role: interacting material, its hardness and surface, as well as surrounding temperature. For example, when the UF-1 sleeve turns with the velocity V=1[m/s] in the room temperature, PV coefficient equals 1,2 [m/s MPa], and when temperature rises to 100°C, limiting PV amounts to 0,72 [m/s MPa], and in the temperature of 200°C, limiting PV is limited to 0,24 [ms/ MPa].

17.3.2.b UF-2 composite based on polyoxymethylene (POM)

- POM with many cavities arranged spirally and filled with plastic grease before assembly
- porous bronze
- base material – steel
- electrolytical covering with copper.

UF-2 consists of three material layers: inside steel layer is combined thermally with porous bronze layer, soaked and covered with modified polymers (polyacetale) with the surface of spiral furrows for delivering grease.

Diameter of furrows ranges between 2,5 mm and 3 mm and their depth between 0,3 mm and 0,5 mm. Before application furrows are filled with oil or another lubricating substance.

Characteristics and range of applications

Modified UF-2 surface lends special features to plain bearings. Furrows made in the working surface allow to use optimally even the smallest amount of grease, what significantly increases the longevity of bearings and ensures nearly service-free operation. In case of limiting the grease amount or lack of lubrication limiting PV values drop substantially, what essentially reduces the application of these bearings under such conditions. Bearings with UF-2 admixture are successfully applied in the so-called hybrid connections with rolling bearings, especially with spherical and cylindrical roller bearings. They can be mounted between the shaft and the rolling bearing or between the housing and the rolling bearing. Such solutions are recommended especially in case of changing loads and rotary velocity. Plain bearings significantly reduce wear and tear of rolling bearings during start-up, frequent stops and resumptions of operation, and improve rotational parameters of the system.

Loads

Loads of the sleeve made of UF-2 material can even reach 140MPa, under condition that they are constant and rotary velocity is relatively low. However, to increase longevity of bearings, the permissible load should be reduced.

Longevity

Longevity depends directly on PV value. If PV amounts to, e.g. 2,5, longevity equals about 200 hours, and if PV is 0,1, longevity may exceed 1000 hours. Additional lubrication of bearings made of UF-2 is recommended in the mid-life, e.g. if PV is 2,5, than one shall lubricate the bearing every 100 hours.

Bearing longevity also depends on surrounding temperature, hardness and structure of interacting surface.