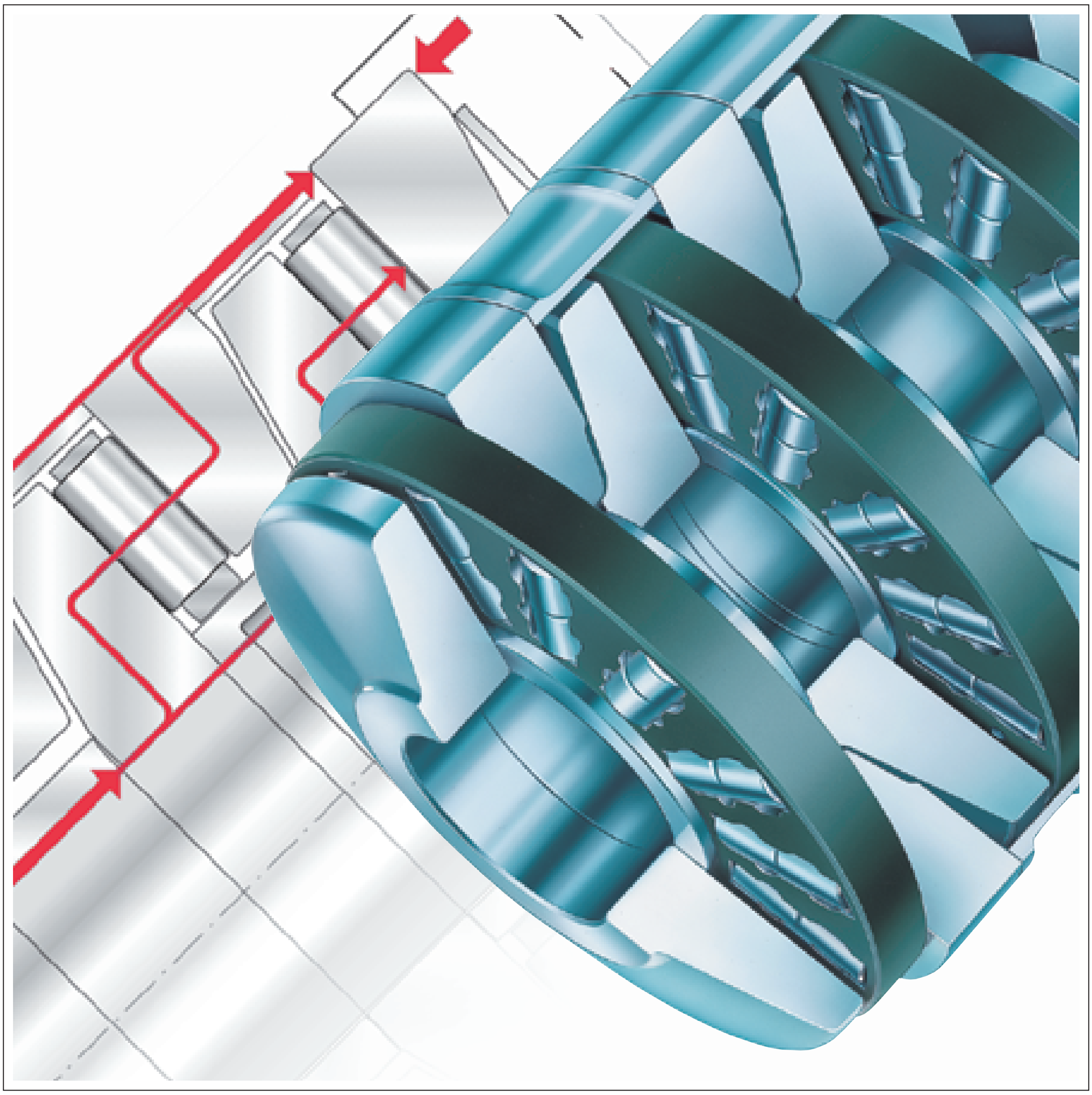

Tandem Bearings in Twin Screw Extruder Gearboxes

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Modern twin screw extruder gearboxes with a high power density such as those used in the processing of thermoplastic materials are machine elements that must provide a high degree of reliability in operation. The tandem bearings supplied by a well-known rolling bearing manufacturer have been used in harsh environments for decades (Figure 1). In spite of increasing demands placed on these bearings, like the requirements for deep foundation drilling equipment or friction welding machines, these products have proven themselves as reliable machine elements. These tandem bearings represent an excellent solution for applications requiring a small radial design envelope, high axial forces and long life.

1 Introduction

INA's tandem bearings are primarily used when reliable support must be provided for high axial forces in a limited radial design envelope. A typical application for tandem bearings is the distribution gear in twin screw extruders (Figure 2).
The power range found in twin screw extruders ranges from approx 2 kW and 16 MW. The back pressure forces are also quite high: they range from 2.5 to 3,400 kN.

Due to the small center distance between the heavily loaded extruder shafts, a tandem bearing is often used in combination with a thrust cylindrical roller bearing (series 894...) having the corresponding load carrying capacity (Figure 2).
The combination of two identical tandem bearings (Figure 3) or two differing tandem bearings is also possible depending on the design envelope and gear application.

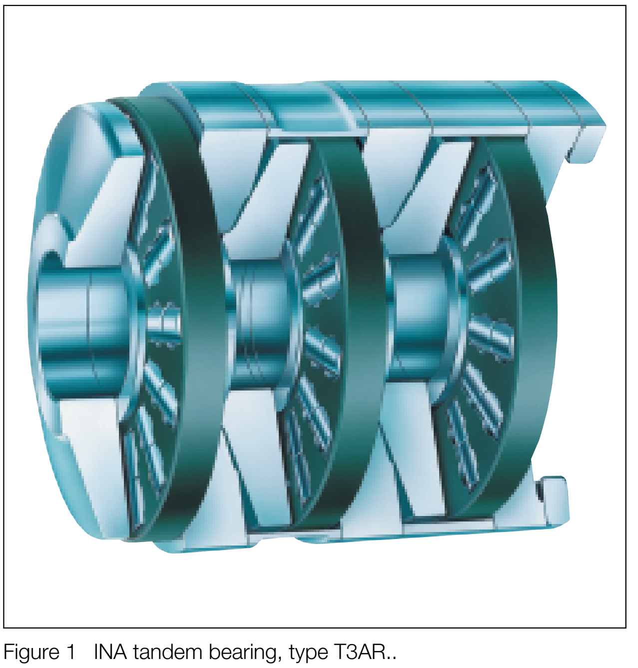

Figure 1 INA tandem bearing, type T3AR..

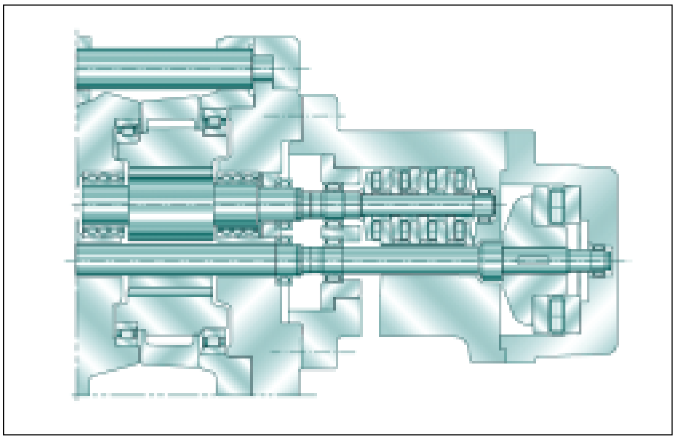

Figure 2 Distribution gear in a twin screw extruder with combination bearing consisting of tandem bearing and thrust cylindrical roller bearing

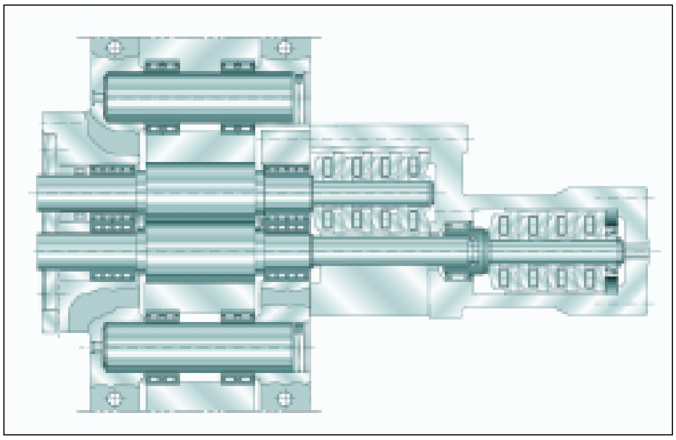

Figure 3 Distribution gear in a twin screw extruder with combination bearing consisting of two identical tandem bearings

2 Tandem Bearing Design

Tandem bearings consist of several coaxially arranged thrust cylindrical roller and cage assemblies. Two, three or four thrust cylindrical roller and cage assemblies can be used, corresponding to product designations T2AR.., T3AR.. and T4AR.. respectively. Six row and eight row tandem bearings (T6AR.. and T8AR..) are also available. These products consist of two triple row and two four row tandem bearings respectively.

The special elastic system of matched rings and washers made from hardened rolling bearing steel ensures that there is an equal load on all rows regardless of the magnitude of the axial load. Benchmarking performed at INA has shown that a comparable competitor product has been designed only for a certain point of operation. Axial loads deviating from this point are not supported equally across all stages.

3 Tandem Bearing Operation

To meet the requirement that all rows support equal portions of the axial forces from the extruder screw regardless of the load ratio C/P (where C is the dynamic load rating [N] and P the dynamic equivalent load [N]), the shaft sleeves and housing sleeves are specially designed so that the same deflection is achieved for each row. The geometry of the rings thus plays an important role in providing the optimum flow of power in the bearing (Figure 4). The shape of shaft washers and housing washers primarily effects the load distribution on the length of the cylindrical rollers. The design of shaft and housing washers allows both components to receive the same polysymmetric deformation. Although the washers under load are subject to elastic deformation, both raceways nonetheless remain almost parallel to each other (Figure 5). Rolling element tilting or edge loading on the rolling elements, which lead to reduced service life, can thus be eliminated.

In addition to the equal deflection on each row mentioned above, in the case of six row and eight row tandem bearings the load distribution between the three row and four row tandem bearings must be achieved corresponding to their load carrying capacity. This can be done by matching the shaft sleeve and the housing sleeve.

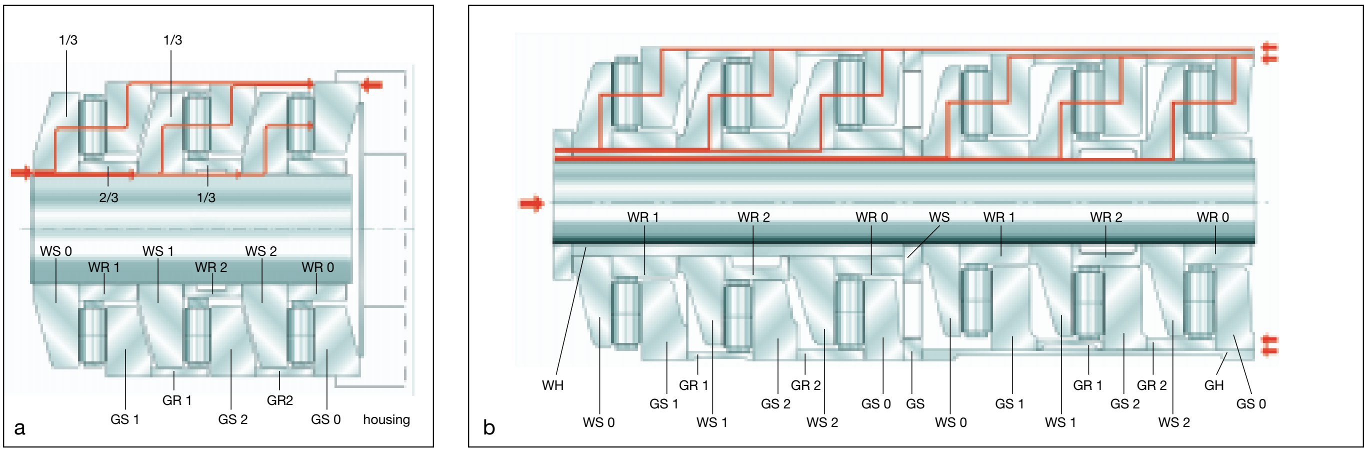

Figure 4 Design and power flow for a three row (a) and six row tandem bearing (b)

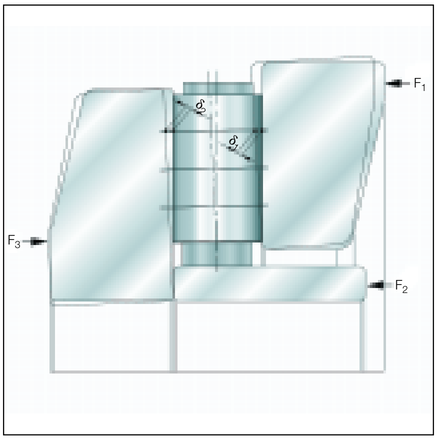

Figure 5 Approximately parallel raceways of shaft and housing washers under load

4 Bearing Selection

Three pieces of information are necessary when selecting a suitable tandem bearing:

- the maximum possible bearing OD
- the desired calculated rating life under operating load and speed
- the maximum screw pressure.

The maximum possible bearing OD results from the intermeshing of two screws in the case of twin screw extruders. In the process, the crest diameter of one screw contacts the root diameter of the other screw. The resulting tight center distance (Figure 2) and the output shaft near the tandem bearing limit the radial design space. The length of a tandem bearing is normally not a crucial factor in bearing selection. For this limited envelope, tandem bearings are available in the 31.5 to 900 mm OD range.

The required calculated rating life under operating load and speed is generally between 20,000 and 40,000 hours for extruder gearboxes. Smaller gearboxes such as those used in extruders for laboratory applications have shorter life requirements. Here, a value of 5,000 hours is sufficient.

Another factor to consider in bearing selection is the maximum screw pressure. Due to the deformation of the components and the resulting stresses, a maximum permissible axial load $F_{a\,max}$ may not be exceeded. The value for $F_{a\,max}$, the dynamic load rating C as well as the static load rating C_0 can usually be found in the tandem bearing delivery drawing.

The value $F_{a\,max}$ refers to the permissible strain on the components (rings, washers, etc.). For this reason, the maximum screw pressure should be known. On the other hand, the dynamic and static load ratings refer to the entire rolling element set. Since the value for $F_{a\,max}$ is always lower than C_0, the static load rating C_0 is not relevant for the selection of a tandem bearing. INA can provide gearbox manufacturers with a tandem bearing data sheet so that all relevant data can be recorded precisely. This allows the optimum bearing solution to be recommended.

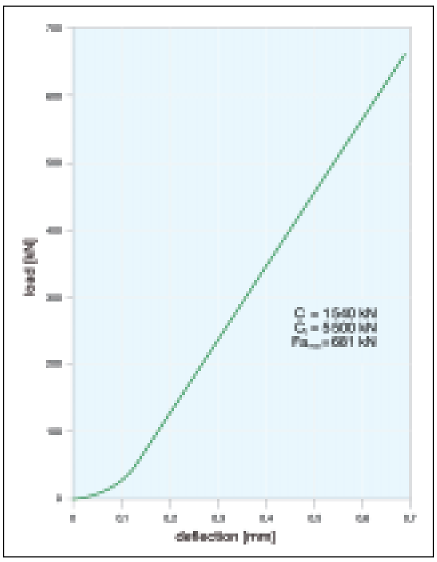

Figure 6 Spring curve for a six row tandem bearing

5 Mounting Tandem Bearings

Tandem bearings are mounted with a loose F7 fit for the housing and f6 for the tandem bearing shaft. A loose fit is necessary to allow the axial shifting (deflection) of the washers, rings and sleeves. The seating surface of the adjacent structure (housing and shaft) should be designed to have a perpendicularity tolerance to DIN ISO 1101 and qualities IT4 to IT7 (depending on the diameter range).

For the mating structure, care should also be taken to ensure that the contact diameter indicated on the delivery drawing is maintained. The contact diameter (support diameter) for the shaft shoulder may not be lower than the diameter indicated, and the contact diameter for the housing must not be exceeded. Insufficient support will not only cause an unequal load distribution but also an increased washer deformation (washers GS 0 and WS 0), which in turn will result in increased strain on the components.

Since tandem bearings are thrust bearings that are not capable of supporting radial loads, it is advisable to provide sufficient radial support. One way to do this is to use needle roller bearings (Figure 2). This will allow potential shaft deflection and associated frictional losses to be reduced, especially in the case of continuous shafts where pinion and tandem bearing are on the same shaft and not separated by a gear coupling.

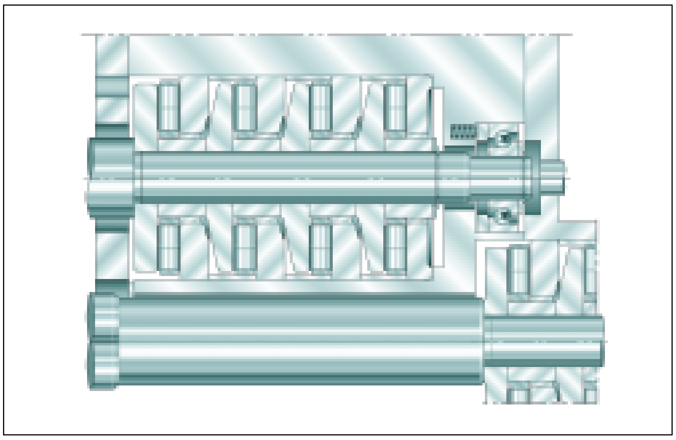

Figure 7 Preloading a tandem bearing with a compression spring

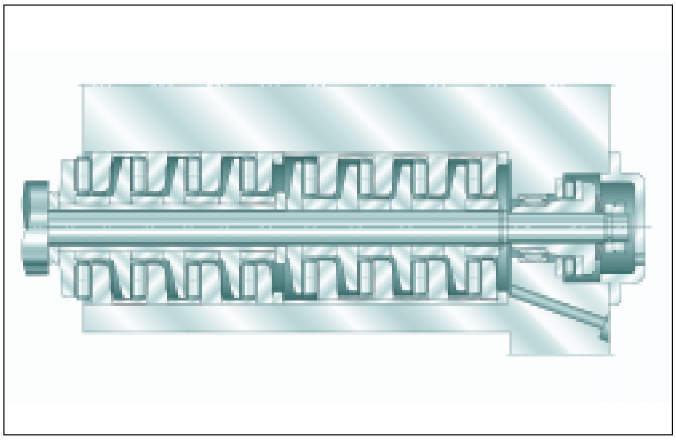

Figure 8 Preloading a tandem bearing with a disk spring

6 Minimum Load for Tandem Bearings

The minimum load or preload for tandem bearings has been defined as one percent of the dynamic load rating C. Two issues are important when dealing with the question of minimum load. The first pertains to the kinematics of the bearing and the other is the deflection behavior.

6.1 Kinematics

Thrust bearings should never run without a certain minimum load. This load prevents rolling bearing slip and the resulting surface damage in the case of acceleration or hesitation. The minimum load F a min for thrust cylindrical roller bearings can be calculated using the formulas given in [1].

6.2 Deflection Behavior

Larger deflection differences can lead to the contact of screw flanks or to premature screw wear. For tandem bearings the spring curve is relatively flat for low loads and does not become linear (Figure 6) until a certain load ratio C/P is reached. The reason for this is that tandem bearings are “softer” than single row thrust cylindrical bearings, whose entire spring curve is in the linear range. To be able to record the deflection path accurately and achieve suitable operating conditions, tandem bearing operation should be within the linear range of their spring curves. Put another way, they should have sufficient preload.

Depending on the size, the preload can be applied in different ways. In general, a compression spring is suitable for small to medium preload forces (Figure 7). For larger tandem bearings, disk springs are preferred for the application of preload forces (Figure 8).

7 Service Life

As is the case for thrust cylindrical roller bearings, the service life of tandem bearings is calculated using the formulas provided in [1]. If required, the extended rating life L naa can also be calculated. The oil temperature required for this calculation can be taken from the oil outlet since experience has shown that lubricant flowing through the bearing is between 5 °C and 15 °C warmer than the inlet temperature.

8 Lubrication and Cooling

In general, circulating oil lubrication should be used to lubricate tandem bearings. The oil is always fed from the back, which means that the lubricant flows through the bearing against the direction of the axial force. The gearbox housing at the end of the tandem bearing must be closed so that the required amount of oil is available (Figures 7 and 8). Although the rotating thrust cylindrical roller and cage assemblies promote oil flow, an additional feed pump must be used in order to achieve a sufficient oil exchange in the bearing. The required amount of oil is calculated using the formulas given in [1]. When calculating the speed dependent frictional torque caused by fluid friction, the number of rows must be considered.

9 Summary

INA tandem bearings provide an optimum solution for applications with the following requirements:

– Small radial design envelope
– Support of high axial loads
– High speeds
– Long service life

Due to the high operational safety, it would be hard to imagine modern extruder gearboxes without this reliable machine element.

Literaturhinweis:

[1] INA Catalog 307: Needle Roller Bearings, Cylindrical Roller Bearings

[2] INA Publication TAL: Tandem Bearings in Large Gearboxes

[3] INA Publication PGM: Rolling Bearings in Large Gearboxes

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