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Plain bearings — Spray nozzle type directed lubrication for tilting pad bearings

Titre manque

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Foreword

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This document was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 7, *Special types of plain bearings*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

These days, rotating machines such as turbines, generators, compressors, pumps, etc. tend to be increasing in speed and reducing in size. Bearings used in such machines can cause large power losses, which not only degrades machine performance but also results in the associated cooling system being larger in size. Directed lubrication type bearings can reduce the power loss significantly. They are energy-saving bearings that can simplify facilities and improve plant efficiency.

Plain bearings — Spray nozzle type directed lubrication for tilting pad bearings

1 Scope

Directed lubrication is an advanced technology that is capable of reducing the power loss and improving the performance of tilting pad type bearings. Unlike flooded lubrication, where the bearing components remain permanently submerged in an oil filled housing, with directed lubrication the components are not submerged and the oil is delivered from an external source directly to the working surfaces of the tilting pads after which it falls freely away to be drained from the bottom of the housing. There are several alternative methods of realising the benefits of directed lubrication in tilting pad bearing designs. As an example, this document specifies a spray nozzle type directed lubrication system where lubricant is supplied to each pad through nozzles mounted between the pads in tilting pad thrust and journal bearings. The design concept of this type of lubrication is described.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbols and abbreviated terms

For the purposes of this document, the following symbols apply.

Table 1 — Symbols and units

Symbol	Explanation	Unit
B_{tc}	Thrust collar width	m
c_p	Specific heat capacity of lubricant	J/(kg·K)
D_d	Diameter of discharge oil hole	m
d_h	Hole diameter of nozzle	m
K_Q	Coefficient of oil flow rate	1
n_h	Number of holes per nozzle	1
n_n	Number of nozzles per bearing	1
P	Power loss	W
p_{en}	Oil supply pressure	Pa
Q	Total oil flow rate	m^3/s
Q_n	Oil flow rate per nozzle	m^3/s
ΔT	Oil temperature rise	K
ρ	Density of lubricant	kg/m^3

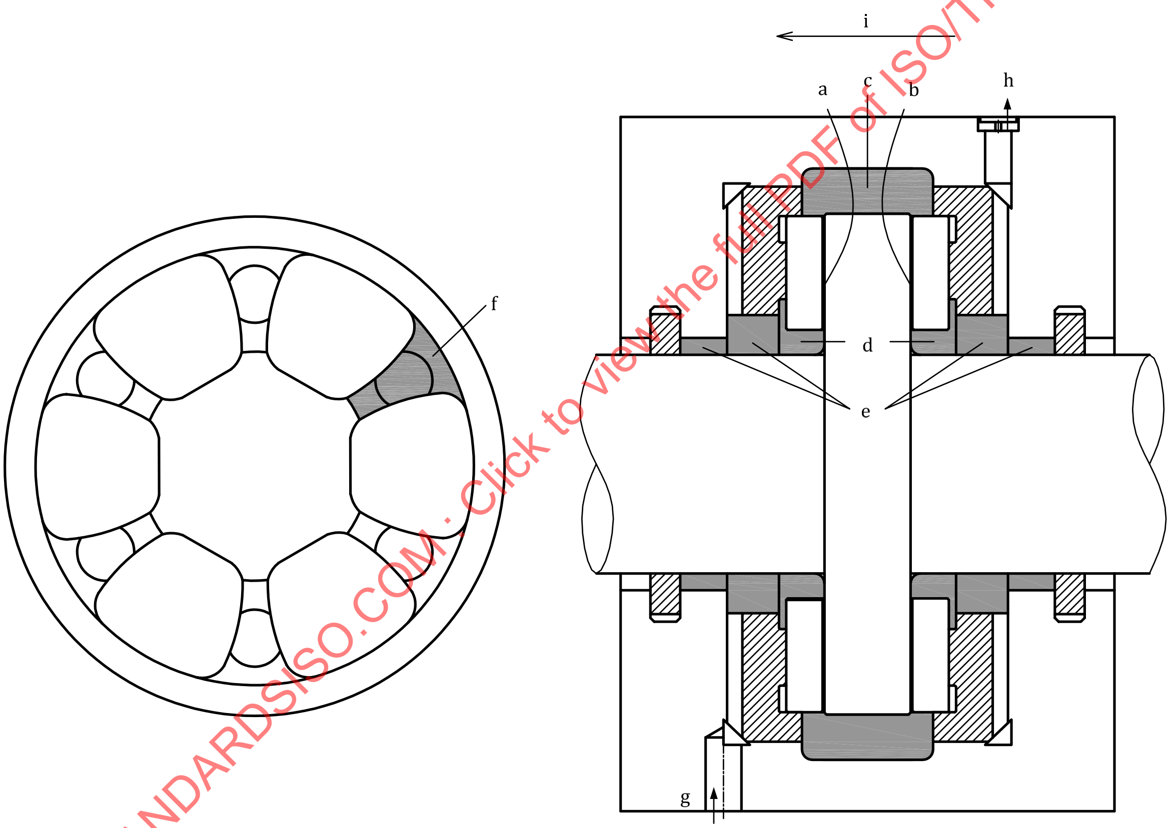
5 Reduction effect of power loss by spray nozzle type directed lubrication systems

The effect of power loss reduction by the spray nozzle type directed lubrication system is shown with regard to tilting pad thrust bearings. The power loss of tilting pad thrust bearings arranged for flooded lubrication consists of shearing losses at the thrust pad surfaces and churning losses from oil in contact with the parts other than the pad surfaces (refer to Figure 1[2][3]).

As the bearing housing of a flooded lubrication type bearing is entirely filled with oil, churning losses cannot be avoided. Particularly at high speed, the churning losses increase rapidly and dominate a majority of the total losses in the bearing (refer to Figure 2[2][3]).

Spray nozzle type directed lubrication bearings supply oil directly to the pad surfaces and are designed to allow all unnecessary oil in the bearing housing to freely flow out. As a result, the churning losses associated with oil coming into contact with parts other than the pad surfaces can be minimized (H3, H4, H5, H6).

Spray nozzle type directed lubrication produces a significant reduction in power loss in the entire bearing.



Key

a H1 shearing loss.

b H2 shearing loss at reverse face.

c H3 churning loss at rim of collar.

d H4 churning loss at inside of pads.

e H5 churning loss along shaft.

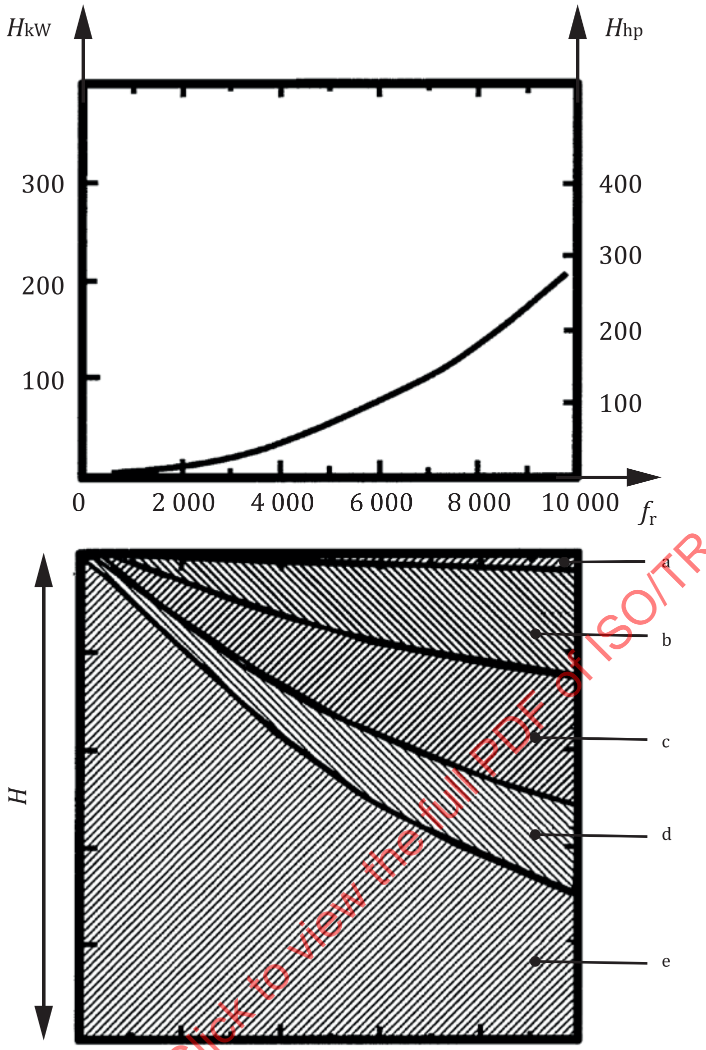
f H6 churning loss between pads.

g Oil inlet.

h Oil outlet.

i Thrust load.

Figure 1 — Components of power loss for flooded lubrication bearings[2][3]



Key

H_{kW} total power loss *H*, expressed in kW

H_{hp} total power loss *H*, expressed in hp

f_r rotational frequency, expressed in min^{-1}

a (H4 + H5)/*H*

b H3/*H*

c H6/*H*

d H2/*H*

e H1/*H*

NOTE These results are based on a study carried out under the following conditions.

— Type: Double thrust assembly (2 rings of 8 pads each)

— Pad size: 60 mm

— Oil: 25 cSt at 60 °C

— Specific load: 3 MPa

— Housing inlet temperature: 50 °C

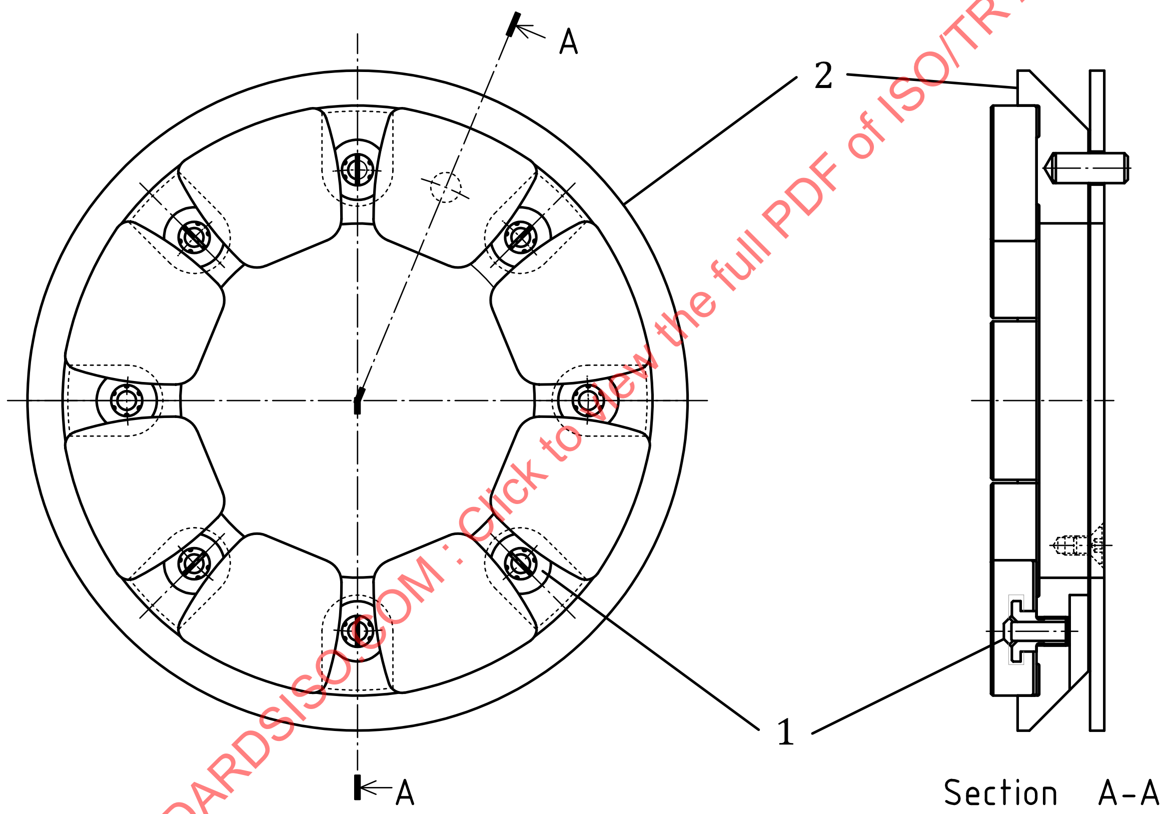
— Housing outlet temperature: 67 °C

Figure 2 — Components of power loss and their variation with speed[2][3]

6 Lubrication system

6.1 Tilting pad thrust bearing

There are two kinds of lubrication systems for tilting pad thrust bearings: a flooded lubrication system and a directed lubrication system. In the flooded lubrication system, lubricant continually fills the inside of the bearing housing. In the spray nozzle type directed lubrication system, lubricant is sprayed from mounted nozzles between the pads to the pad surfaces (refer to Figures 3 and 4). Lubricant is supplied through the oil groove on the back surface of the bearing, led to the nozzles, and then sprayed directly to the thrust collar from the oil supply holes of the nozzles (refer to Figure 4). The nozzles can also act as pad stops, preventing circumferential movement due to rotation of the collar and retaining the pads during assembly and disassembly. The oil sprayed from the oil supply holes ensures ample fresh cooled oil is supplied to the leading edge of each pad and reduces the amount of hot oil carry over from the trailing edge of each preceding pad. The spray nozzle type directed lubrication system delivers the oil required for oil film formation directly to the thrust collar surface and eliminates the need to maintain unnecessary oil in the bearing housing.

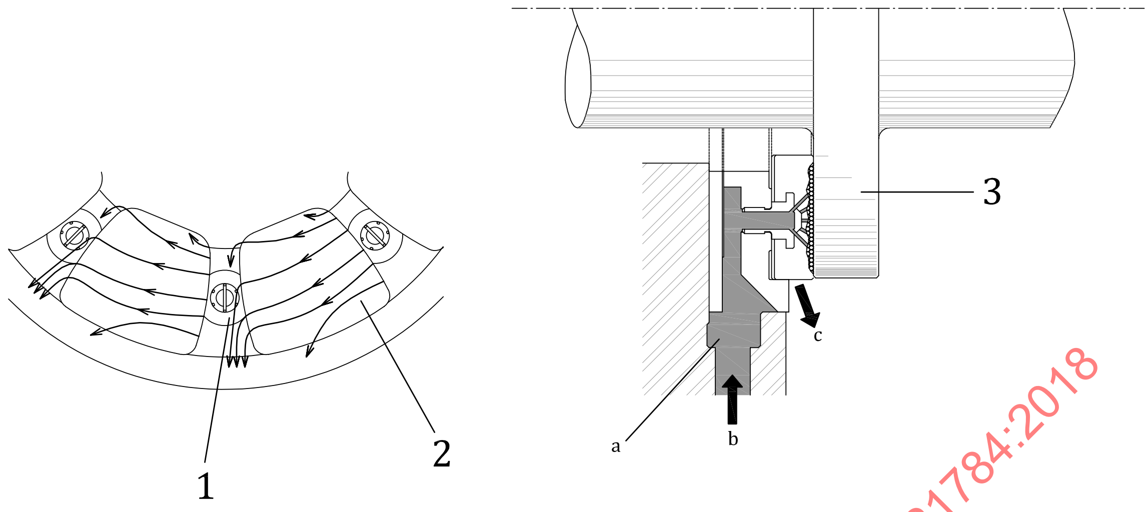


Key

1 nozzle (pad stop)

2 carrier ring

Figure 3 — Spray nozzle type directed lubrication system for a tilting pad thrust bearing



Key

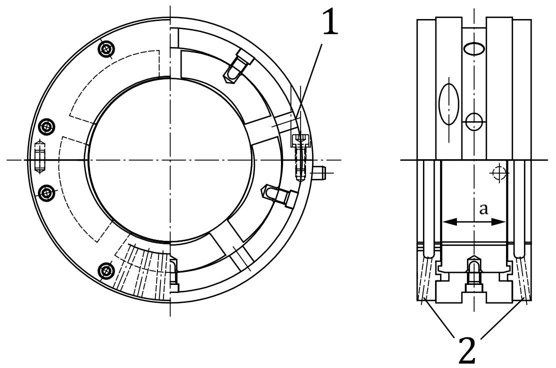
1 nozzle (pad stop)
2 pad
3 collar
a Oil inlet.
b Oil supply.
c Oil discharge.

Figure 4 — Oil sprayed from the oil supply hole of the nozzle

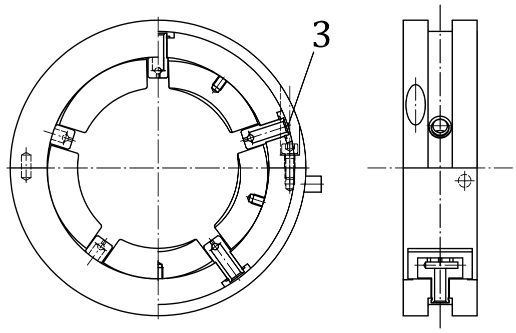
6.2 Tilting pad journal bearing

Like tilting pad thrust bearings, tilting pad journal bearings can also be of the flooded or directed lubrication type. In the flooded lubrication system, oil fills the bearing housing and the working components are kept submerged by attaching seal rings at both axial ends of the bearing. In the spray nozzle type directed lubrication system, oil is supplied directly to the shaft surface from nozzles mounted between the pads and the seal rings attached at both ends of the bearing are removed to allow the oil to discharge freely in the axial direction. Figures 5 a) and 5 b) are examples of arrangements.

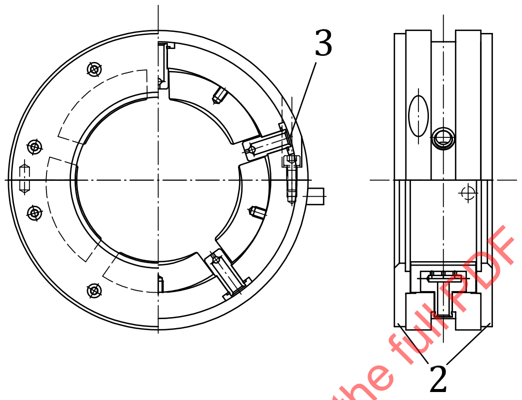
In some applications using nozzle type directed lubrication, seal rings are included, but they have a larger clearance with the shaft than in the case of those used for flooded lubrication. In this case, some oil remains to some extent in the bearing housing. Figure 5 c) shows this type of arrangement.



a) Flooded lubrication



b) Spray nozzle type directed lubrication



c) Spray nozzle type directed lubrication with seal ring

Key

1 oil supply hole

2 seal ring

3 nozzle

a Axial width of pad.

Figure 5 — Lubrication system arrangements for a tilting pad journal bearing

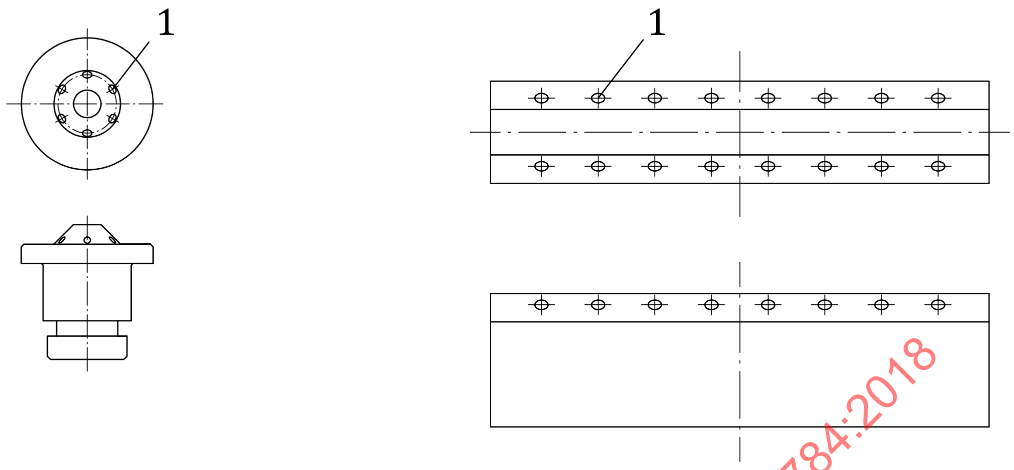
7 Oil supply system of spray nozzle type directed lubrication

7.1 General

For the oil supply nozzles mounted between the pads of a directed lubrication type bearing, the nozzle shape, the number of holes per nozzle and the nozzle hole diameter are designed according to the bearing dimension and the oil flow rate.

7.2 Tilting pad thrust bearing

Typical nozzle shapes for a tilting pad thrust bearing are shown in Figure 6. Type A also provides the additional functions of maintaining pad position and preventing detachment of the pads.



a) A type

b) B type

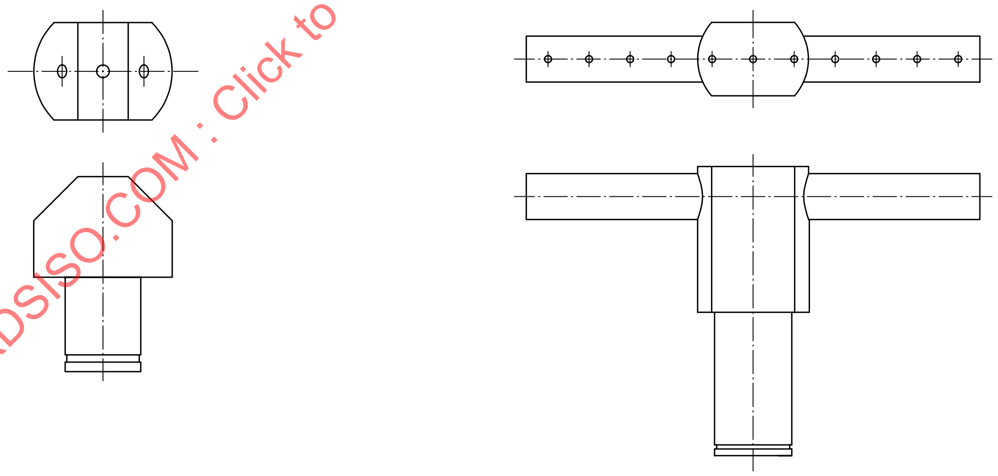
Key

1 hole of nozzle

Figure 6 — Nozzle types for tilting pad thrust bearing

7.3 Tilting pad journal bearing

An example nozzle type for tilting pad journal bearings is shown in Figure 7. It is designed so that the oil sprayed from the nozzle holes spreads over approximately 70 % of the pad entrance width. Type C is recommended when the axial width of pad (refer to Figure 5) is less than approximately 130 mm.



a) C type

b) D type

Figure 7 — Nozzle types for tilting pad journal bearing

7.4 Oil flow

Oil is circulated through the bearing to provide lubrication and to remove the generated heat resulting from friction loss. The oil flow rate is related to the power loss and the temperature rise. In general, to ensure stable operation, it is recommended that the temperature rise between the oil entering and exiting the tilting pad bearing housing be limited to 15 °C to 20 °C. To achieve this, the oil flow rate required to cool the bearing sufficiently is calculated. From the estimated power loss and the desired temperature rise, the required oil flow rate is evaluated using Formula (1).

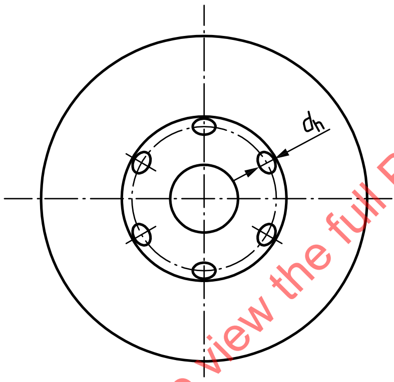
$$Q = \frac{P}{c_p \times \rho \times \Delta T} \tag{1}$$

According to the required oil flow rate, the optimum nozzle type, number of holes and hole diameter (refer to Figure 8) can be designed.

Formulae (2) and (3) relate the sizing and quantity of oil nozzles to the required oil flow rate. Coefficient of oil flow rate K_Q is determined by the spray method details of the nozzle type and the oil flow behaviour.

$$Q_n = n_h \times K_Q \times \frac{\pi {d_h}^2}{4} \times \sqrt{\frac{2p_{en}}{\rho}} \tag{2}$$

$$Q = n_n \times Q_n \tag{3}$$



Key

d_h hole diameter

Figure 8 — Enlarged nozzle of type A

7.5 Oil supply pressure

The oil supply pressure should typically be 0,1 MPa to 0,15 MPa for both thrust bearings and journal bearings.

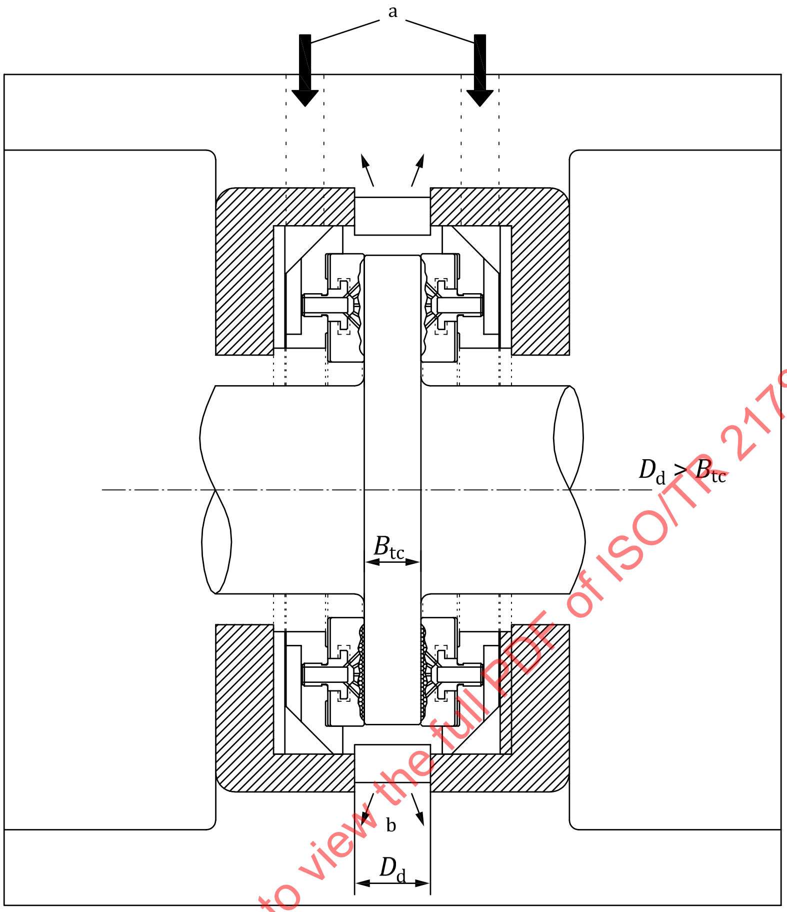
8 Structure of oil inlet and outlet (drainage) on nozzle type directed lubrication

8.1 Tilting pad thrust bearing

Directed lubrication type bearings do not need seal rings on the shaft. Oil inlet holes for each thrust face (load carrying pads and pads of reverse thrust face) should be provided. The size of the oil supply passages should be designed to limit the oil velocity to 3 m/s to prevent a reduction in oil supply pressure at the bearing.

If the diameter of the oil inlet hole is larger than the width of the carrier ring groove, multiple oil supply holes should be prepared so that the oil hole diameter is less than the dimension of the carrier ring groove (refer to Figures 9 and 10).

In the case of directed lubrication type bearings, it is desirable that oil scattered from the thrust collar be discharged from the housing without resistance. The example structure shown in Figure 9 is recommended. The oil discharge velocity should be less than 0,15 m/s by arranging the diameter of the discharge oil hole D_d larger than the thrust collar width B_{tc}.

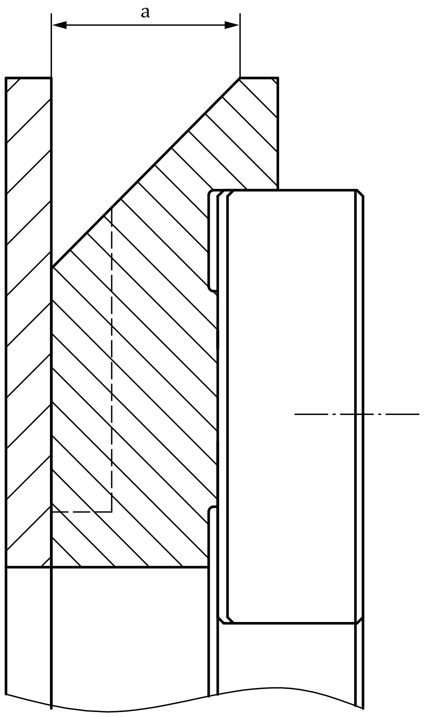


Key

a Oil inlet.

b Oil outlet.

Figure 9 — Structure of oil inlet and outlet (tilting pad thrust bearing)



Key

a Carrier ring groove width.

Figure 10 — Carrier ring groove in detail

8.2 Tilting pad journal bearing

The size of oil inlet passages should be designed to limit the oil velocity to 3 m/s to prevent the reduction of oil supply pressure inside the bearing as in the case of a thrust bearing.

In the case of directed lubrication type bearings with seal rings, the diametral clearance of the seal rings is increased in relation to the diametral clearance of the bearing to facilitate oil discharge from both ends of the bearing (refer to Figure 11 as an example).