TECHNICAL SPECIFICATION

ISO/TS 31657-4

First edition

Plain bearings — Hydrodynamic plain journal bearings under steady-state conditions —

Part 4: Permissible operational parameters for calculation of multi-lobed and tilting pad journal bearings

PROOF/ÉPREUVE

Reference number
ISO/TS 31657-4:2020(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 123, *Plain bearings*, Subcommittee SC 8, *Calculation methods for plain bearings and their applications*.

A list of all parts in the ISO/TS 31657 series can be found on the ISO website.

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.

 PROOF/ÉPREUVE

Plain bearings — Hydrodynamic plain journal bearings under steady-state conditions —

Part 4:
Permissible operational parameters for calculation of multi-lobed and tilting pad journal bearings

1 Scope

This document establishes the permissible operational parameters in terms of guide values for the calculation of selected multi-lobed and tilting-pad journal bearings.

In order to attain a sufficient operational safety of multi-lobed and tilting-pad journal bearings by the calculation according to ISO/TS 31657-1, it is necessary for the operational characteristic value h_{min} to be significantly above the permissible operating parameter $h_{lim,tr}$ and for the permissible operating parameters T_{lim} and p_{lim} not to be exceeded by the calculated operational characteristic values T_{max} and p_{max}.

The guide values represent geometrically and technologically founded operational limiting values in the tribological system of plain bearings.

They are empirical values that enable sufficient operational safety even in the event of smaller disturbing influences (see ISO/TS 31657-1). The empirical values indicated can be modified for special application areas.

NOTE The explanations for the symbols and calculation examples are contained in ISO/TS 31657-1.

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 Operational guide values for start-up and run-down

The minimum lubricant film thickness, h_{min}, is calculated for the operating point. Its size primarily determines the requirements for the lubricant with respect to its cleanliness and defines the fineness of the oil filter to be used.

At the transition of a hydrodynamic plain bearing into mixed friction, the minimum lubricant film thickness, h_{min}, at the transition sliding speed, U_{tr}, attains the value $h_{min,tr}$.

In the range $0 < U < U_{tr}$ the load percentage carried by solid body contact increases significantly with decreasing rotational frequency.

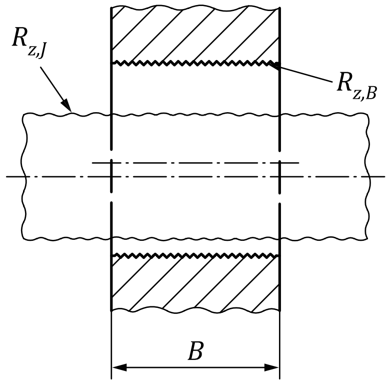
It depends on the energy density occurring in the contact area whether a permissible fine wear occurs on the sliding surfaces or a further roughening affecting the functional capability.

For this reason, there is a close relationship between the limit values $h_{\mathrm{lim,tr}}$ and $U_{\mathrm{lim,tr}}$ on the one hand and the specific bearing load, $\bar{p}_{\mathrm{tr}}$, present at the transition on the other hand.

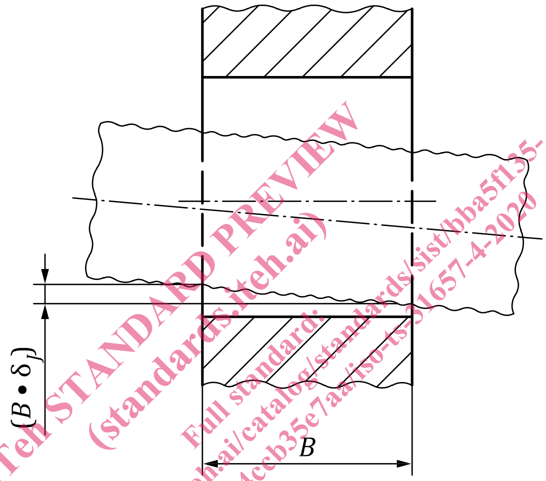
The minimum admissible lubricant film thickness at transition to mixed friction, $h_{\mathrm{lim,tr}}$, is derived according to Figure 1 from the roughness of journal and bearing and the misalignments and deformations occurring in the lubrication gap[8][9]:

$$h_{\mathrm{lim,tr}} = 1{,}5 \cdot R_{\mathrm{z,J}} + 0{,}5 \cdot R_{\mathrm{z,B}} + 0{,}5 \cdot B \cdot \delta_{\mathrm{J}} \cdot \frac{\pi}{180^\circ} + 0{,}5 \cdot f_{\mathrm{J}} \tag{1}$$

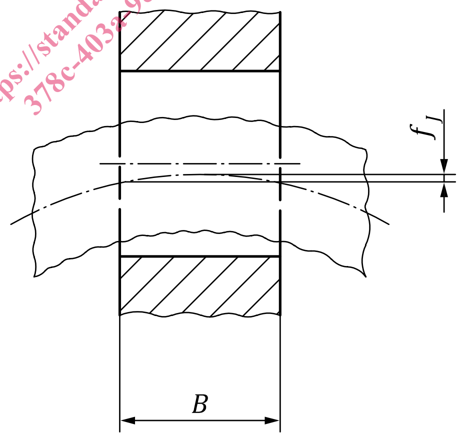
After completing a running in process, significantly smaller permissible lubricant film thicknesses can result due to smoothing and adaptation of the journal and bearing in the load zones, than were determined according to Formula (1). This presupposes the choice of a running in a compatible material pairing and optimal running in operating values.



a) Roughness



b) Misalignment



c) Bending

Figure 1 — Influences on the minimum permissible lubricant film thickness

When selecting the materials for the journal and bearing, favourable sliding and running in conditions are to be ensured in the mixed friction area by means of a sufficient hardness difference.

For soft bearing materials (lead-tin alloys and lead bronzes), a hardness difference between bearing and journal material of about 100 HB has proven effective[10].

In the case of harder bearing materials (tin bronzes), the journal shall be up to 5 times harder than the bearing material[10].

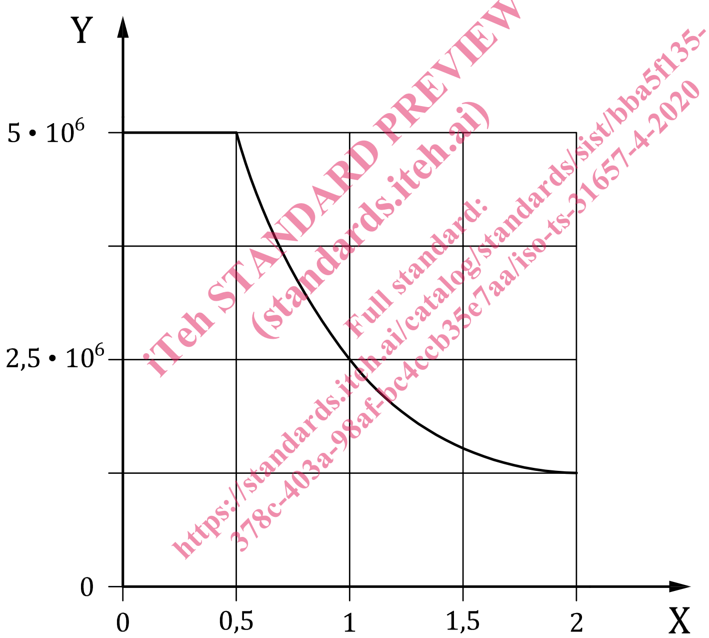
Crucial for the operational safety at the transition to mixed friction is the present circumferential speed at transition to mixed friction, U_{tr}. Presupposing normal run-down times (no exceeding gyrating masses), it should not be greater than $U_{lim,tr}$ = 2 m/s.

The limit values permissible at $h_{lim,tr}$ for sliding velocity, $U_{lim,tr}$, and specific bearing load, $\bar{p}_{lim,tr}$, are then as given in Formula (2), also shown in Figure 2[9]:

$$\begin{aligned} &\bar{p}_{lim,tr} \cdot U_{lim,tr} = 2{,}5 \cdot 10^6 \text{ N/(s·m)} \\ &\text{for } \bar{p}_{lim,tr} \le 5 \cdot 10^6 \text{ N/m}^2 \text{ and } U_{lim,tr} \le 2 \text{ m/s} \end{aligned} \quad (2)$$

In many application cases, the value $\bar{p}_{tr}$, present in the range $U < U_{tr}$, differs from that present in the operating point, $\bar{p}$, as usually $\bar{p}_{tr} < \bar{p}$.

If the specific bearing load at the start-up or the shut-down is $\bar{p}_{tr} > \bar{p}_{lim,tr}$, a hydrostatic jacking should be provided in order to prevent impermissible high wear or even destruction.



Key

X $U_{lim,tr}$, in m/s

Y $\bar{p}_{lim,tr}$, in N/m²

Figure 2 — Permissible values for the specific bearing load, $\bar{p}_{lim,tr}$, depending on the sliding speed, $U_{lim,tr}$, at transition to mixed friction at operating temperature

5 Operational guide values for avoiding thermal and mechanical overloading

In nominal operation at $h_{min} >> h_{lim,tr}$, maximum value of pressure and temperature occur on the sliding surfaces, which have to be tolerated by the materials and lubricants used in continuous operation without damage.

The strength of the bearing materials depends on the temperature. Therefore, the limit values, p_{lim}, for the nominal operation (see Table 1) can only be given in relation to the limit value, T_{lim}, for the maximum lubricant film temperature.

Table 1 — Temperature-dependent maximum admissible lubricant film pressure for different bearing materials

Bearing material group[a]	p_{lim} (at T_{lim}) N/mm^2
Lead alloys	16 (100 °C) to 25 (50 °C)
Tin alloys	25 (130 °C) to 40 (50 °C)
Copper alloys (bronzes)	25 (150 °C) to 50 (50 °C)

[a] For materials, see ISO 4381, ISO 4382-1, ISO 4382-2 and ISO 4383.

In the case of composite bearings with soft bearing metals (lead, tin alloys), these limit values also depend on the thickness of the bearing metal layer and on the constructive design of the supporting body.

Higher load values can be approved for thin layers. On the other hand, the adaptability to deformations and misalignments of the shaft is reduced. This must then be compensated by the design and installation of the supporting body.

The indicated maximum values of p_{lim} apply to lubrication with mineral oils. At higher operating temperatures, special lubricants shall be used if necessary. As a rule, the compatibility of the bearing material and lubricant shall be ensured.

Multi-lobed and tilting-pad journal bearings are generally operated with forced-feed circulatory lubrication. The ageing of the lubricants is generally accelerated at high temperatures. Only a small part of the total amount of lubricant available for the bearing lubrication is located in the lubrication gap subject to high thermal loads, with the result that both the maximum temperature and the ratio between total lubricant volume and lubricant flow rate, i.e. the circulation time, is relevant to the ageing of the lubricant.

6 Operational guide values for the bearing clearance

To be able to fulfil special requirements with respect to the guiding accuracy and/or cooling, in addition to the bearing clearance, C_{R}, the profile factor, K_{P} or the gap ratio, $h^*_{0,\max}$, can also be selected, with the result that an appropriate combination of both values permits an extensive optimisation of the operating performance.

The value of the optimal relative bearing clearance, ψ, depends primarily on the circumferential velocity at nominal speed, as this is relevant to the heating. However, large bearings can have smaller relative clearances, with the result that the diameter of the shaft also influences the choice of bearing clearance.

This is taken into account if we determine the relative bearing clearance as a function of the rotational speed, N:

$$\psi = 0{,}001 \cdot \left(\frac{N[s^{-1}]}{10} \right)^{1/4} \quad (3)$$

In the case of multi-lobed journal bearings, the stability and cooling improve as the gap ratio increases in the tabulated range. The bearing load carrying capacity declines on the other hand.

