



BSI Standards Publication

Plain bearings — Hydrostatic plain journal bearings with drainage grooves under steady-state conditions

Part 1: Calculation of oil-lubricated plain journal bearings with drainage grooves

National foreword

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The UK participation in its preparation was entrusted to Technical Committee MCE/12, Plain bearings.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Plain bearings — Hydrostatic plain journal bearings with drainage grooves under steady-state conditions —

Part 1: Calculation of oil-lubricated plain journal bearings with drainage grooves

*Paliers lisses — Paliers lisses radiaux hydrostatiques avec rainures
d'écoulement fonctionnant en régime stationnaire —*

*Partie 1: Calcul pour la lubrification des paliers lisses radiaux avec
rainures d'écoulement*



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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 document 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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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 123, *Plain bearings*, Subcommittee SC 8, *Calculation methods for plain bearings and their applications*.

This third edition cancels and replaces the second edition (ISO 12167-1:2016), which has been technically revised.

The main changes are as follows:

- subclause titles have been added;
- symbols have been corrected and added in [Table 1](#);
- calculation values in [Annex B](#) have been corrected;
- adjustments have been made according to ISO/IEC Directives, Part 2:2021;
- typographical errors have been corrected.

A list of all parts in the ISO 12167 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.

Introduction

Hydrostatic bearings use external lubrication to support pressure on the bearings; thus, they are less prone to wear and tear, run quietly, and have a wide useable speed, as well as high stiffness and damping capacity. These properties also demonstrate the special importance of plain journal bearings in different fields of application such as in machine tools.

Basic calculations described in this document may be applied to bearings with different numbers of recesses and different width/diameter ratios for identical recess geometry.

Oil is fed to each bearing recess by means of a common pump with a constant pumping pressure (system $p_{\text{en}} = \text{constant}$) and through preceding linear restrictors, e.g. capillaries.

In this document, only bearings with oil drainage grooves between the recesses are taken into account. As compared to bearings without oil drainage grooves, this type needs higher power with the same stiffness behaviour.

Equivalent calculation procedures that enable operating conditions to be estimated and checked against acceptable conditions may also be used.

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Plain bearings — Hydrostatic plain journal bearings with drainage grooves under steady-state conditions —

Part 1:

Calculation of oil-lubricated plain journal bearings with drainage grooves

1 Scope

This document specifies the calculation procedures to calculate and assess a given bearing design, as well as to design a bearing as a function of some optional parameters. This document contains the design of the required lubrication system including the calculation of the restrictor data.

This document applies to hydrostatic plain journal bearings under steady-state conditions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

[ISO 12167-2:2021](#), *Plain bearings — Hydrostatic plain journal bearings with drainage grooves under steady-state conditions — Part 2: Characteristic values for the calculation of oil-lubricated plain journal bearings with drainage grooves*

3 Terms and definitions

No terms and definitions are listed in this document.

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

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

4 Symbols

Symbols and units are defined in [Table 1](#).

Table 1 — Symbols

Symbol	Term	Unit
a	Inertia factor	1
A_{lan}	Land area	m ²
A_{lan}^*	Relative land area	1
A_p	Recess area	m ²
b	Width perpendicular to the direction of flow	m
b_{ax}	Width of axial outlet $\left[b_{ax} = \frac{\pi \times D}{Z} - (l_c + b_G) \right]$	m

Symbol	Term	Unit
b_c	Width of circumferential outlet ($b_c = B - l_{ax}$)	m
b_G	Width of drainage groove	m
B	Bearing width	m
c	Stiffness coefficient	N/m
c_p	Specific heat capacity of the lubricant (p is a constant)	J/kg·K
C_R	Radial clearance	m
d_{cp}	Diameter of capillaries	m
D	Bearing diameter (D_J : shaft; D_B : bearing; $D \approx D_J \approx D_B$)	m
e	Eccentricity (shaft displacement)	m
f	Relative film thickness [$f = h/C_R$]	1
$f_{en,i}$	Relative film thickness at $\varphi = \varphi'_{1,i}$	1
$f_{ex,i}$	Relative film thickness at $\varphi = \varphi'_{2,i}$	1
F	Load-carrying capacity (load)	N
F_i	Radial force in recess i	N
F_h	Horizontal component of the resultant force of recesses	N
F_v	Vertical component of the resultant force of recesses	N
F^*	Characteristic value of load-carrying capacity	1
F_{eff}^*	Characteristic value of effective load-carrying capacity	1
$F_{eff,0}^*$	Characteristic value of effective load-carrying capacity for $N = 0$	1
h	Local lubricant film thickness (clearance gap height)	m
h_{en}	Oil film thickness at entrance edge of recess	m
h_{ex}	Oil film thickness at exit edge of recess	m
h_{min}	Minimum lubricant film thickness (minimum clearance gap height)	m
h_p	Depth of recess	m
i (index)	Consecutive number	1
k	Exponent	1
K_{rot}	Speed-dependent parameter	1
$K_{rot,nom}$	Normalized speed-dependent parameter	1
l	Length in the direction of flow	m
l_{ax}	Axial land length	m
l_c	Circumferential land length	m
l_{cp}	Length of capillaries	m
N	Rotational frequency (speed)	s ⁻¹
opt (index)	optimum	1
p	Recess pressure, general	Pa
$\bar{p}$	Specific bearing load [$\bar{p} = F/(B \times D)$]	Pa
p_{en}	Feed pressure (pumping pressure)	Pa
p_i	Pressure in recess i	Pa
p_i^*	Pressure ratio in recess i	1
$p_{i,0}$	Pressure in recess i , when $\varepsilon = 0$	Pa
p_{max}	Maximum pressure in recess	Pa
p_{min}	Minimum pressure in recess	Pa

Symbol	Term	Unit
P^*	Power ratio	1
P_f	Frictional power	W
$P_{f,lan}$	Frictional power in land area	W
$P_{f,p}$	Frictional power in recess area	W
P_f^*	Characteristic value for the frictional power	1
$P_{f,lan}^*$	Characteristic value for the frictional power in land area	1
$P_{f,p}^*$	Characteristic value for the frictional power in recess area	1
P_p	Pumping power	W
P_{tot}	Total power	W
P_{tot}^*	Characteristic value of total power	1
Q	Lubricant flow rate (for complete bearing)	m ³ /s
Q^*	Lubricant flow rate parameter	1
Q_{ax}	Lubricant flow rate from recess in the axial direction	m ³ /s
$Q_{cp,i}$	Lubricant flow rate from capillary into recess i	m ³ /s
Q_{en}	Inlet lubricant flow rate into recess in the circumferential direction	m ³ /s
Q_{ex}	Outlet lubricant flow rate from recess in the circumferential direction	m ³ /s
R_{cp}	Flow resistance of capillaries	Pa·s/m ³
$R_{lan, ax}$	Flow resistance of one axial land $\left(R_{lan, ax} = \frac{12 \times \eta \times l_{ax}}{b_{ax} \times C_R^3} \right)$	Pa·s/m ³
$R_{lan, c}$	Flow resistance of one circumferential land $\left(R_{lan, c} = \frac{12 \times \eta \times l_c}{b_c \times C_R^3} \right)$	Pa·s/m ³
$R_{p, 0}$	Flow resistance of one recess, when $\varepsilon = 0$	Pa·s/m ³
Re	Reynolds number	1
Re_{cp}	Reynolds number in capillaries	1
Re_p	Reynolds number in recess	1
So	Sommerfeld number	1
T	Temperature	°C
T_B	Mean temperature in the bearings; see Formula (15)	°C
T_{cp}	Temperature in capillaries	°C
T_{en}	Inlet temperature	°C
u	Flow velocity	m/s
U	Circumferential speed	m/s
$\bar{w}$	Average velocity in restrictor	m/s
Z	Number of recesses	1
α	Position of first recess related to recess centre measured from load direction; see Figure A.3	rad
β	Attitude angle of shaft	°
γ	Exponent in viscosity formula	1
Δp_{lan}	Pressure difference in land area	Pa
ΔT	Temperature difference	K
ΔT_B	Mean temperature difference in the bearings	K
ΔT_{cp}	Temperature difference in capillaries	K
ε	Relative eccentricity	1

Symbol	Term	Unit
η	Dynamic viscosity	Pa·s
η_B	Dynamic viscosity for $T = T_B$	Pa·s
η_{cp}	Dynamic viscosity in capillaries	Pa·s
η_{40}	Dynamic viscosity at 40 °C	Pa·s
κ	Resistance ratio	1
ξ	Restrictor ratio	1
π_f	Relative frictional pressure	1
$\pi_{f,opt}$	Optimum relative frictional pressure	1
ρ	Density	kg/m ³
τ	Shearing stress	N/m ²
φ	Angular coordinate measured from radius opposite to eccentricity, e ; see Figure A.3	rad
φ_F	Angle of resultant force of recesses	rad
φ_G	Angle between the centre of land and the centre of drainage groove	rad
ψ	Relative bearing clearance	1
ψ_{opt}	Optimum relative bearing clearance	1
ω	Angular velocity ($\omega = 2 \times \pi \times N$)	s ⁻¹

5 Bases of calculation and boundary conditions

Calculation in accordance with this document is the mathematical determination of the operational parameters of hydrostatic plain journal bearings as a function of operating conditions, bearing geometry and lubrication data. This means the determination of eccentricities, load-carrying capacity, stiffness, required feed pressure, oil flow rate, frictional and pumping power, and temperature rise. Besides the hydrostatic pressure build up, the influence of hydrodynamic effects is also approximated.

Reynolds equation furnishes the theoretical basis for the calculation of hydrostatic bearings. In most practical cases of application, it is, however, possible to arrive at sufficiently exact results by approximation.

The approximation used in this document is based on two basic formulae intended to describe the flow through the bearing lands, which can be derived from Reynolds equation when special boundary conditions are observed. The Hagen-Poiseuille law describes the pressure flow in a parallel clearance gap and the Couette formula the drag flow in the bearing clearance gap caused by shaft rotation. A detailed presentation of the theoretical background of the calculation procedure is included in [Annex A](#). An example of the calculation procedure is given in [Annex B](#).

The following important premises are applicable to the calculation procedures described in this document:

- a) all lubricant flows in the lubrication clearance gap are laminar;
- b) the lubricant adheres completely to the sliding surfaces;
- c) the lubricant is an incompressible Newtonian fluid;
- d) in the whole lubrication clearance gap, as well as in the preceding restrictors, the lubricant is partially isoviscous;
- e) a lubrication clearance gap completely filled with lubricant is the basis of frictional behaviour;
- f) fluctuations of pressure in the lubricant film normal to the sliding surfaces do not take place;
- g) bearing and journal have completely rigid surfaces;