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Plain bearings — Lubrication characteristics of crosshead pin bearings for low-speed marine diesel engines

Paliers lisses — Caractéristiques de lubrification des paliers de crosse pour moteurs diesels marins à vitesse faible

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Foreword

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The committee responsible for this document is ISO/TC 123, *Plain bearings*, Subcommittee SC 7, *Special types of plain bearings*.

Introduction

For crosshead pin bearings, with which a shaft oscillates when a load is applied mainly in a downward direction, it is difficult to generate an appropriate lubricating film; therefore, they are subject to unfavourable lubricating conditions. For better lubrication of crosshead pin bearings, which have a high rate of damage, two types of bearing structures are mainly used as oil supply methods for sliding surfaces at present. The characteristics of those bearings are compared and the concept of design approaches is standardized.

Plain bearings — Lubrication characteristics of crosshead pin bearings for low-speed marine diesel engines

1 Scope

This Technical Report specifies lubrication characteristics of grooves and pockets on crosshead pin bearings for low-speed marine diesel engines.

It is applicable to the design of axial oil groove and pocket types as an oil supply method.

2 Crosshead pin bearing and its symbols

The crosshead pin bearing and changes in specific load and angular velocity during one cycle are schematically illustrated in Figures 1 and 2. Table 1 shows the symbols and their descriptions.

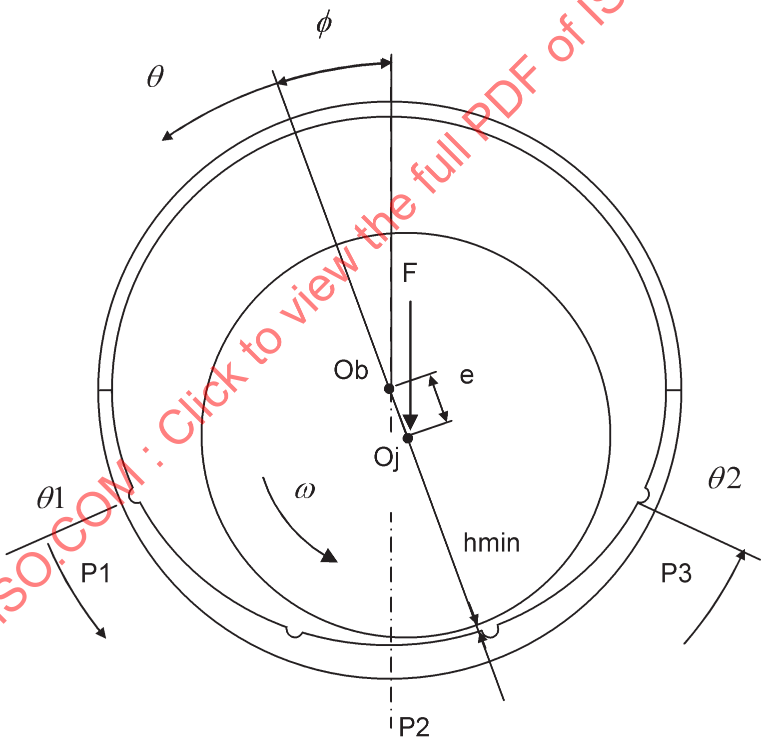


Figure 1 — Crosshead pin bearing

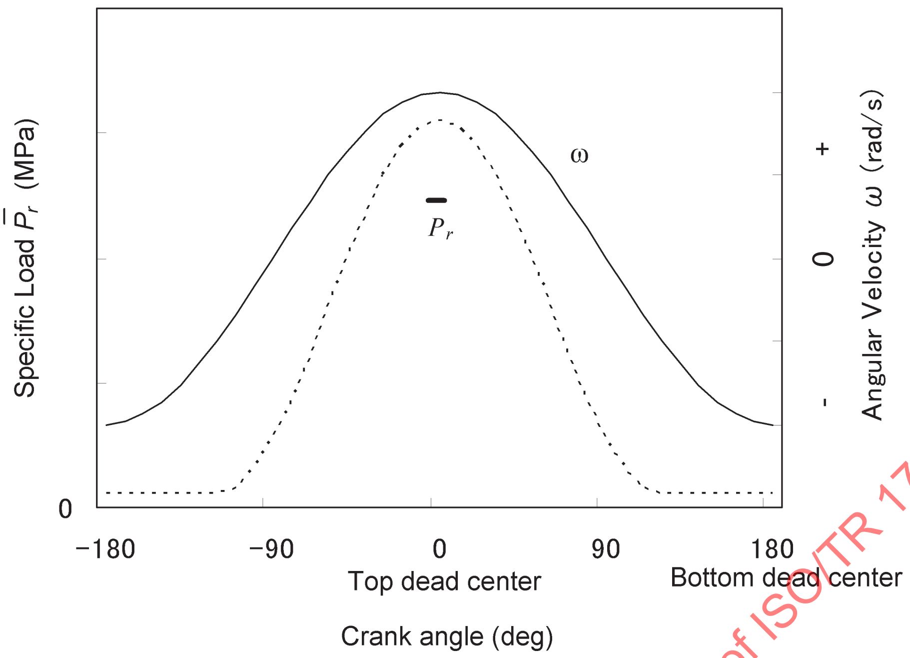


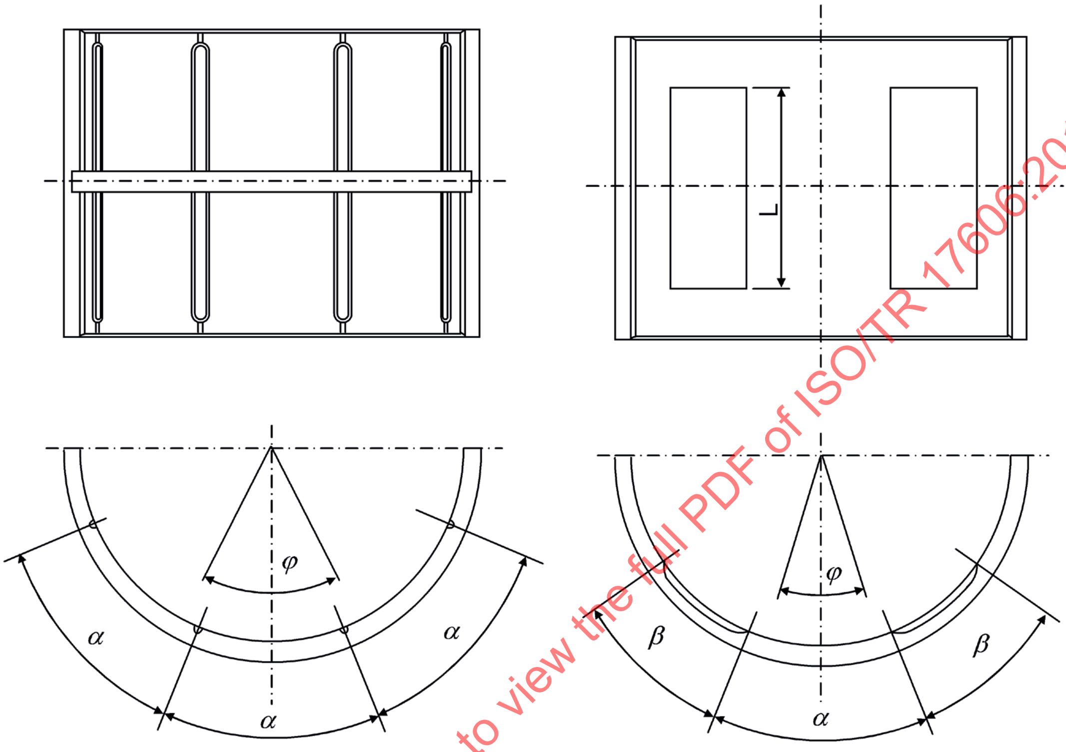
Figure 2 — Changes in specific load and angular velocity during one cycle

Table 1 — Symbols and their descriptions

Symbol	Description
e	eccentricity
hmin	minimum oil film thickness
l	subtended taper length
L	axial width
O_b	center of bearing
O_j	center of journal
p	oil film pressure
P1	pad 1
P2	pad 2
P3	pad 3
$\bar{P}_r$	specific load
r	shaft radius
F	bearing load
α	circumferential pitch angle
β	circumferential width angle
γ	taper depth
φ	oscillation angle
ϕ	attitude angle
θ	circumferential angular coordinate
$\theta 2 - \theta 1$	effective angular extent of bearing arc
ω	angular velocity

3 Oil supply method on bearing sliding surfaces

There are two oil supply methods. One is for bearings with a few (normally four) axial grooves. Oil is supplied to the sliding surface at normal pressure through these oil grooves. The other is for bearings with two oil pockets symmetrically located relative to the central part of each bearing. Oil is supplied to the oil pockets at high pressure to provide a hydrostatic bearing mechanism (see Figure 3).



a) Bearing with axial grooves

b) Bearing with oil pockets

Figure 3 — Bearings with axial grooves and oil pockets

4 Shape of a bearing

4.1 Bearing inside diameter, bearing width, height, circumferential groove, and an upper bearing

The diameter of a crosshead pin is set by consideration of strength design taking into account such as cylinder bore diameter and explosion pressure. The inside diameter of the bearing is based on the diameter of its crosshead pin. The bearing width is set within the allowable specific pressure range for its bearing material in consideration of the durability and strength of the material. Normally, single wide (integral structure) bearings are commonly used with respect to each cylinder. Some bearings may be axially divided into two parts for the reason of production of their bearing materials. The height of the bearing should be set to ensure adequate interference fit. The height measurement method is the same as for smaller sized half-bearings. The crosshead housing can be checked for deformation due to the tightening of the bearing by conducting an assembly test using a housing (it might affect bearing clearance). In the case of a bearing with more than one axial groove, it may be provided with a circumferential groove around (part of) the entire circumference. The upper bearing on the unloaded side is provided with a relatively wide opening to allow the crosshead pin, which is connected to a piston rod, and the crosshead pin bearing to oscillate relative to each other.

4.2 Wall thickness of a bearing and shape of its bore

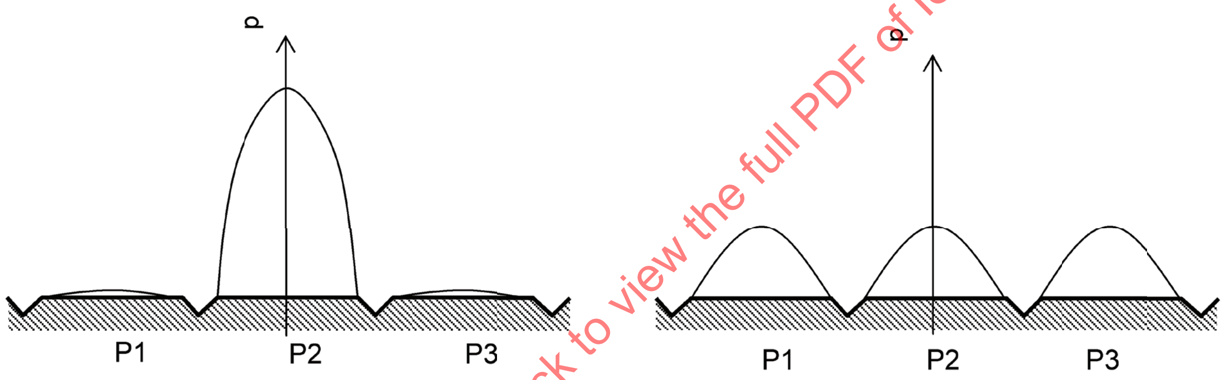
The wall thickness of a bearing is set in consideration of its bore clearance.

4.2.1 Influence of the clearance ratio on the minimum oil film thickness

The clearance ratio is the value of the radial clearance divided by the bearing radius. If the clearance ratio is too low, it has a small wedge effect; it tends to have a relatively small oil film thickness. Conversely, if the clearance ratio is gradually increased, it has a larger wedge effect; it tends to have a larger oil film thickness until the clearance ratio is around 0,000 5. However, if the clearance ratio is too high, oil film pressure is concentrated on the central part of the bearing, resulting in severer lubricating condition; it tends to have a very small oil film thickness.

4.2.2 Influence of the clearance ratio on the maximum oil film pressure

If the clearance ratio becomes higher, the bearing load is concentrated on the central pad on the loaded side and there is an increase in the maximum oil film pressure as a result. If the clearance ratio becomes lower, the bearing load tends to be distributed to some pads on the loaded side and there is a decrease in the maximum oil film pressure as a result (see Figure 4).



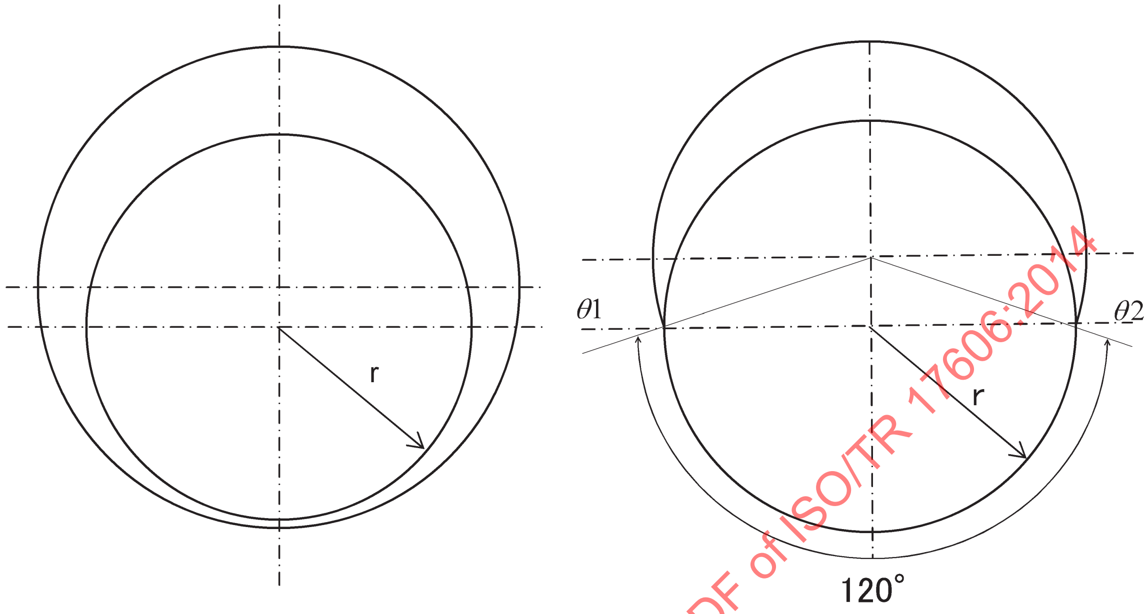
a) Distribution of oil film pressure with high clearance ratio

b) Distribution of oil film pressure with low clearance ratio

Figure 4 — Distributions of oil film pressure

4.2.3 Guideline for bearing design

In consideration of the effects of a clearance ratio on its maximum oil film pressure and minimum oil film thickness, the maximum oil film pressure could be decreased by using a concept of contact arc with a clearance ratio of zero (see Figure 5). When there is a decrease in the minimum oil film thickness as a result of the clearance ratio in the vicinity of zero, the wedge effect could be improved by providing the small and appropriate taper on both ends of the axial oil grooves to increase the minimum oil film thickness.



a) Normal circular bearing with a middle clearance ratio

b) Contact arc (120°) with a clearance ratio of zero

Figure 5 — Normal circular bearing with a middle clearance ratio and contact arc with a clearance ratio of zero

4.3 Oil supply — Lubrication characteristics

4.3.1 Axial oil grooves

4.3.1.1 Influence of oil groove pitch angle and design standards

It is necessary to ensure satisfactory oil film formation by making the oil groove's circumferential pitch angle, α, smaller than the crosshead pin's oscillation angle, ϕ. In recent years, attempts have been made to decrease the maximum oil film pressure at the central pad by widening its circumferential angle range allowing for tendency to increase bearing loads.

4.3.1.2 Cross-sectional shape of an oil groove

The cross-sectional shape of a standard oil groove is semicircular. Oil grooves either with the same cross-sectional shape along the axial direction or with chamfers (bleed groove) at the axial ends of the groove for supplying an appropriate amount of oil to sliding surfaces are commonly used. Both types produce a cooling effect from the introduction of fresh oil through the oil grooves [see Figures 6 a) and b)].

4.3.1.3 Effectiveness of tapered oil grooves

If the clearance ratio becomes lower, the maximum oil film pressure is decreased and the bearing load tends to be distributed to some pads on the loaded side, and there is a decrease in the wedge effect; it might become difficult to maintain an appropriate minimum oil film thickness. By providing the small and appropriate taper on both ends of the axial oil grooves, the wedge effect could be improved to increase the minimum oil film thickness. As a result, the disadvantage of having a smaller wedge effect due to a decreased bearing clearance would be offset to some extent by such tapers at both ends of the oil grooves [see Figure 6 (c)].

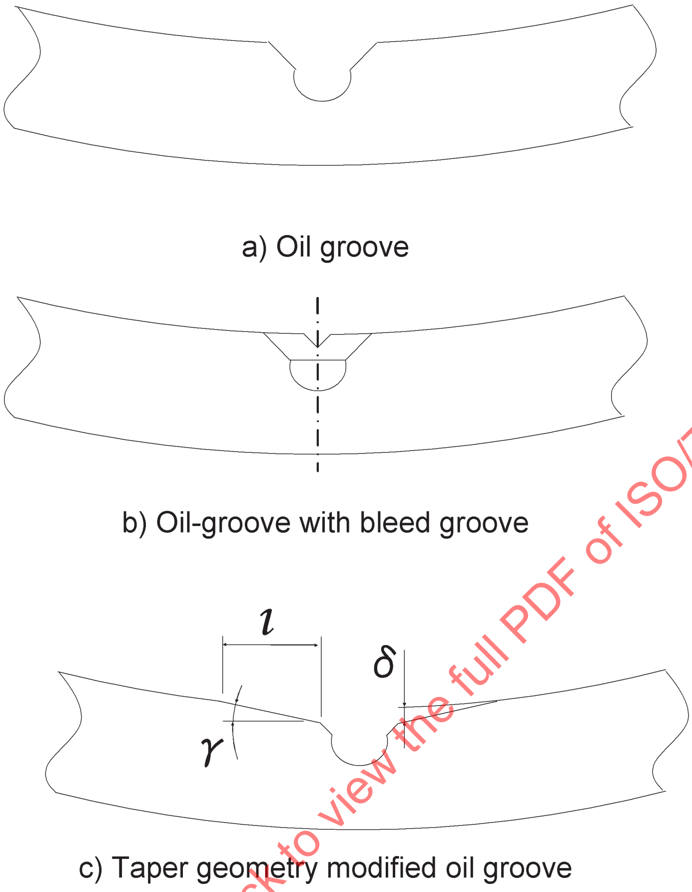


Figure 6 — Cross-sections of 3 types of oil grooves

4.3.2 Oil pocket

4.3.2.1 Influence of oil supply pressure with hydrostatic crosshead pin bearings

The load capability of a bearing is increased by supplying oil to its oil pocket at high pressure due to the recovery of oil film thickness near the bottom dead centre of the piston. However, a high-pressure oil supply mechanism is needed, resulting in increased production costs.

4.3.2.2 Influence of area of oil pocket

For the area of the oil pocket, its axial length L and circumferential width angle, *β,* should be set correctly in consideration of the bearing's load capability. The larger the axial length L, the higher the static pressure. On the other hand, if the circumferential width angle, *β,* becomes too large, there is little increase in the static pressure acting in vertical directions, which are effective in lifting the crosshead pin; conversely, the load capability could become lower.

4.3.2.3 Influence of pitch angle of oil pocket

The pitch angle, *α,* should be set correctly in consideration of the bearing's load capability. There is an increase in the area of the central part of the bearing, which facilitates squeeze action, by increasing the oil pocket's pitch angle, *α*. However, if the pitch angle, *α,* becomes too large, there is little increase in the

