Innovation in Motion

Hydrostatic Jacking Pocket Position of 4-Lobe Bearings

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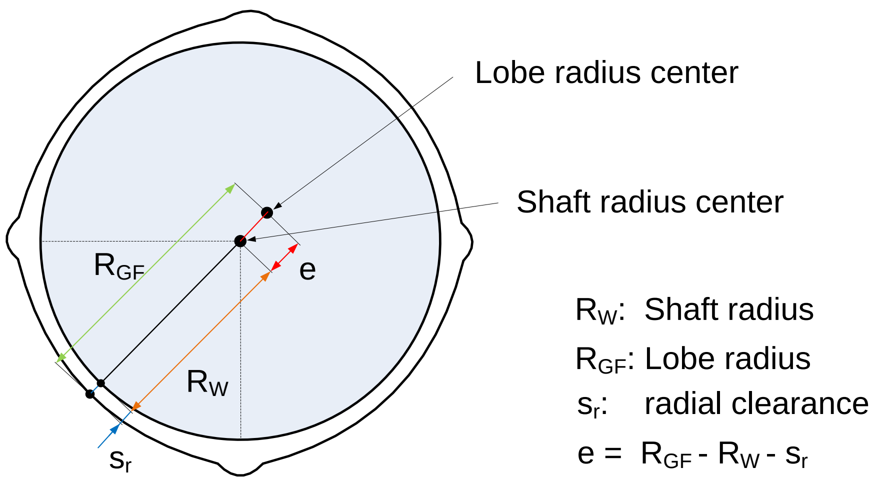
In a variety of 4-lobe journal bearing applications, hydrostatic lifting is used to prevent damage during the start-up or run-out phase. The design of hydrostatic pockets depends very much on the operating conditions and the geometry of the bearing. However, the efficiency/performance ratio can be optimized by a correct positioning of the lifting pockets and resulting in an improvement of the whole design of the hydraulic system. Consequently, the acquisition and operating costs are reduced, and the start-up and run-out behaviour are optimized.

1 Introduction

Compared to cylindrical-bore bearings, four-lobe bearings have a better dynamic behavior, are less expensive than tilting pad bearings and thus offer a more favorable solution for high-speed shafts applications such as turbo gearboxes or compressors. Their suitability for high-speed machines is due to the fact that the shaft and sliding surface circumference are not circularly parallel to each other, the center of the sliding surface is eccentric to that of the bearing, see Fig. 1; this is referred to as profiling or preload.



$$Preload = 1 - \frac{s_r}{s_r + e} \quad (0\ at\ parallel\ shaft\ and\ Lobe\ contour)$$

Fig 1 – Preload and Profiling

The lobe radius must not to be mixed with the bore radius. The bore radius is half of the nominal diameter $\left(\frac{DN}{2}\right)$ and can be described as follows:

$$R_B = R_{GF} - e\ oder\quad R_B = R_W + s_r$$

2 Position of hydrostatic bore

In applications where hydrostatic lifting is required, four-lobe bearings are usually designed with two hydrostatic pockets, see Fig. 2. Each pocket forms an angle of approx. 25° to 45° to the vertical direction. The aim of this article is to determine the optimal position, as the exact position has not yet been defined; rather, the angles take on values based on experience.

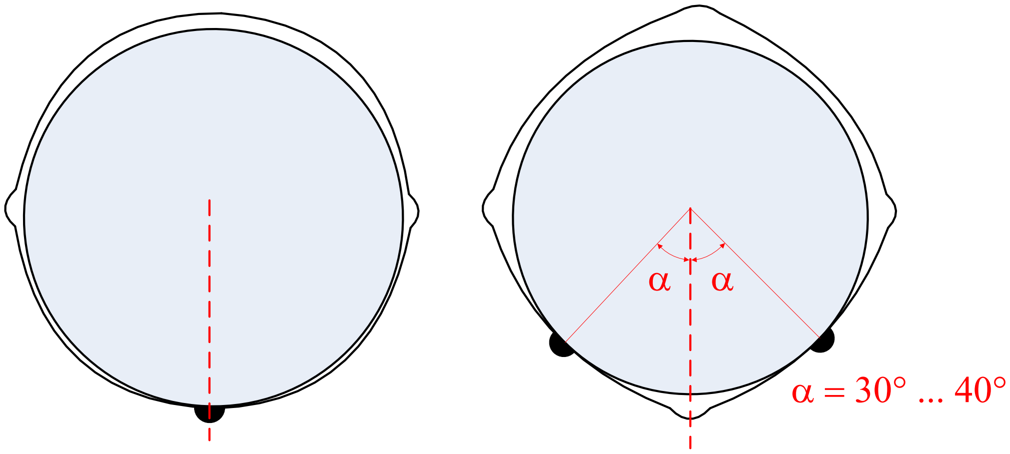


Fig 2 – Hydrostatic lifting of 4-lobe bearings

Diameter	Position of bore
140 mm	40 °
200 mm	35 °
315 mm	40 °
335 mm	40 °

Tab 1 Values of Miba Construction Team

3 Optimization of the position of hydrostatic lifting bores

The bearing engineer or designer should be provided with a template of the exact position of hydrostatic pockets for the different bearing dimensions from which the optimum lift can be expected. This should apply to any bearing diameter and be done analytically using trigonometric relationships.

The bores should be placed at the point where the shaft and the sliding surface would touch during standstill. Because of the small gap between the initially contacting shaft and the sliding surface, the contact points and their immediate surrounding represent the greatest possible resistance, which defines the smallest required lifting pressure and volume flow and consequently minimum required pump performance.

These contact points are determined by estimating an angle on the sliding surface at which the vertical distance to the next point on the centered shaft is the smallest, see Figs. 2 and 3.

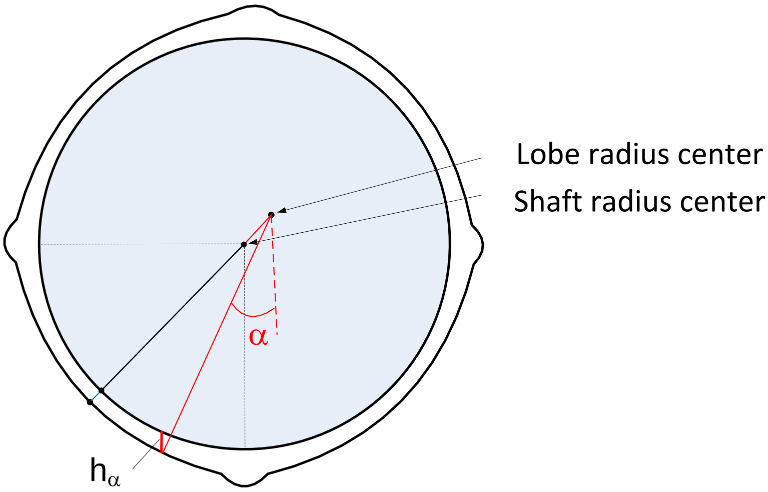


Fig 2 – Hydrostatic lifting of 4-lobe bearings

The mentioned distances are calculated for all angles between 25° and 45° and compared with each other using the minimum value $h_{\alpha,\ minimal}$. Here $h_{\alpha,\ minimal}$ depends on the bearing bore radius R_{GF}, the eccentricity of curvature e, the shaft radius R_W and the clearance Sr. The bearing bore radius R_{GF} includes the nominal dimension of the bearing on the one hand and the preload on the other.

A functional relationship between α and h_α can be obtained with the help of the following geometry:

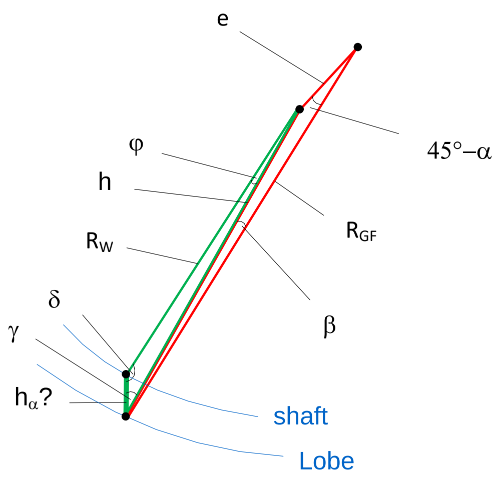


Fig 3 – Geometry to determine hα = f(α)

If this is divided into two triangles (Figs. 3 and 4) and the following sizes are given:

Slip surface radius R_{GF}
Eccentricity e
Clearance Sr

the distance h_α for each angle can be calculated via trigonometric relations by the following steps:

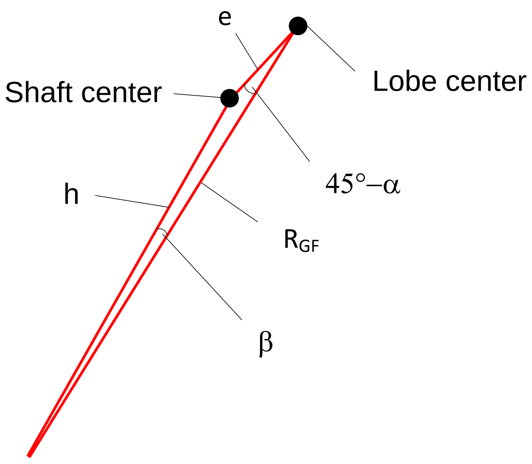


Fig 3.1: Triangle 1

$$h = \sqrt{e^2 + R_{GF}^2 - 2eR_{GF}\cos\left(\frac{\pi}{4} - \alpha\right)}$$ **(Gl. 1)**

$$\beta = \cos^{-1}\left(\frac{h^2 + R_{GL}^2 - e^2}{2hR_{GF}}\right)$$ **(Gl. 2)**

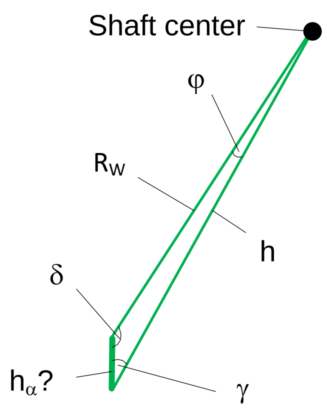


Fig 3.2: Triangle 2

$$\gamma = \alpha - \beta$$ **(Gl. 3)**

$$\delta = \pi - \sin^{-1}\left(\frac{h}{R_W}\sin\gamma\right),$$ **(Gl. 4)**

$$R_W = R_{GF} - s_r - e$$

$$\varphi = \pi - \delta - \gamma \qquad \text{(Gl. 5)}$$

$$h_\alpha = \frac{\sin\varphi}{\sin\gamma} R_W \qquad \text{(Gl. 6)}$$

That is how, any bearing clearance in the range of

Sr = 0.8 ‰ ... 2.25 ‰

a series of distances h_α as a function of the angle

= 25° … 45°

can be assigned.

4 Results

Each series includes a minimum distance $h_{\alpha,\ minimum}$, which finally represents the respective optimal position of the hydrostatic bore, as graphically illustrated in Fig. 4 and 5 using the example of nominal diameter DN 160 and 355

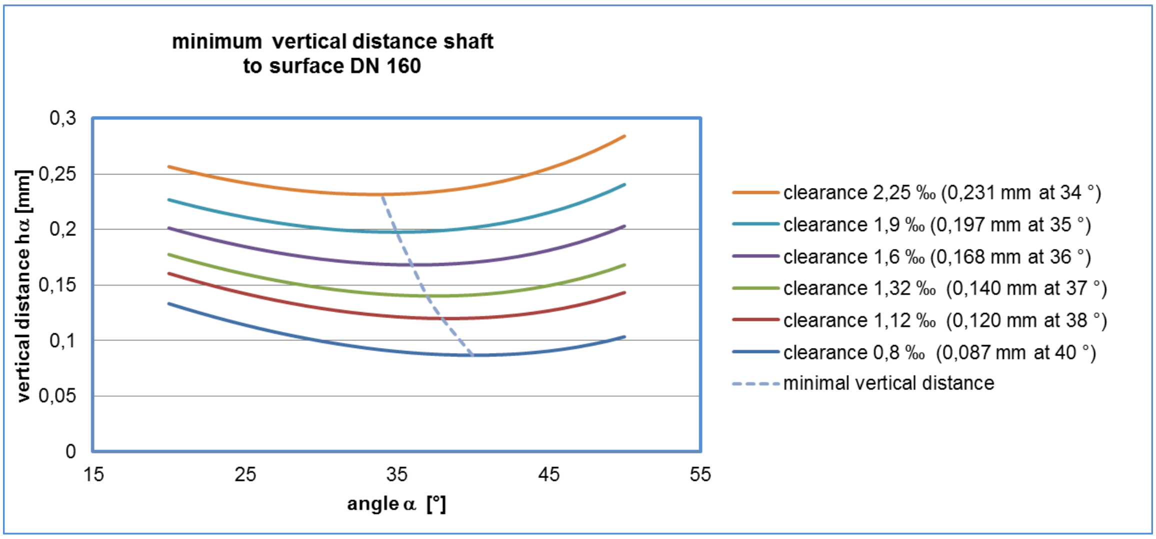


Fig 4: Position of hydrostatic pockets for DN 160

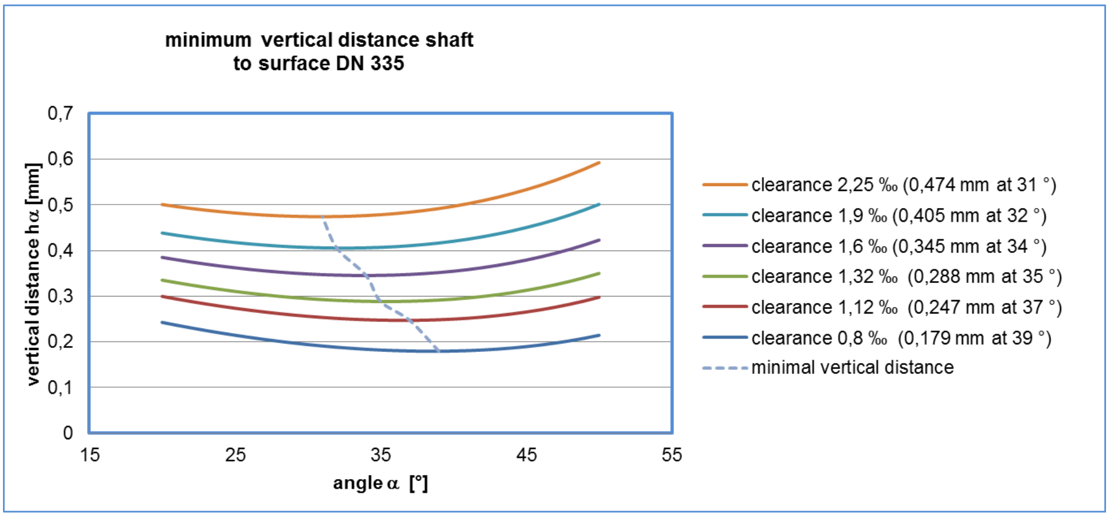


Fig 5: Position of hydrostatic pockets for DN 355

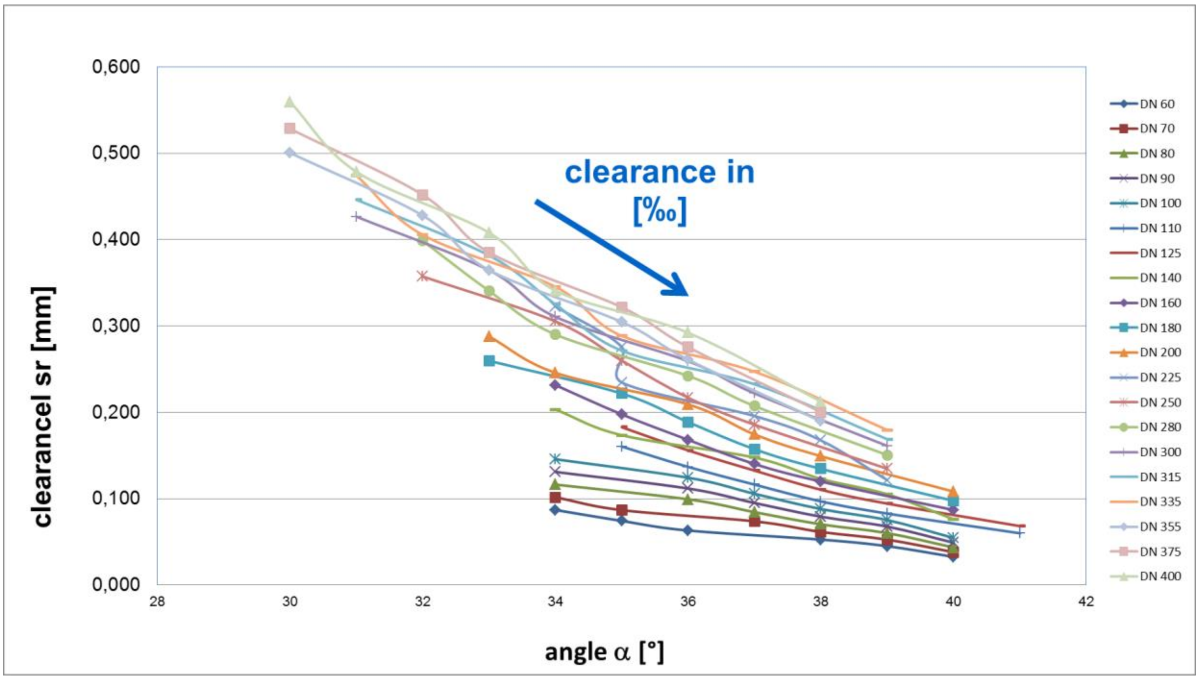


Fig 5: Optimal position of hydrostatic pockets depending in Sr and size

Diameter	Bore Position
from DN 60 to DN110	37 °
from DN 125 to DN250	35 °
from DN 280 to DN400	34 °

Tab 2: Proposed positions for Miba Bearings

5 Summary

In this study, the optimal position of hydrostatic lifting pockets in four-lobe journal bearings was investigated using an analytical approach. This was defined via the contact point or via the minimum vertical distance $h_{\alpha,minimal}$ between shaft and running surface. $h_{\alpha,minimal}$ depends primarily on the clearance Sr, which in turn is designed according to the occurring speed. In quite a few cases, however, bearings have to be operated under several speeds for different time intervals, depending on the application. As a rule, however, there is a position for all bearing clearances for each bearing size, averaged on the basis of experience. The optimum position of hydrostatic pockets must be selected again and again according to the speed and clearance. In practice, this is time-consuming, but very accurate. Furthermore, $h_{\alpha,minimal}$ depends on the preload value but also on the bearing size. The larger the bearing, the smaller the angle for positioning of the hydrostatic pocket.

For more information please contact Miba Industrial Bearings: Mibg_sales@miba.com

Miba Industrial Bearings produces hydrodynamic bearings and labyrinth seals for use in critical centrifugal equipment, such as turbines, compressors, gear boxes and industrial pumps. Established over 100 years ago; Miba Industrial Bearings provides a center of excellence in bearing design, repair, troubleshooting and analysis as well as reversed engineering solutions.

Authors

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Thilo Koch studied mechanical engineering at the university in Clausthal, Germany. He specialized in dynamic mechanical systems, vibration theory (rotor dynamics) and tribology (plain bearings). He gained 35 years of experience in the traditional slide bearing market as manager for the R&D, design and technical sales department. He is an expert in exploring new market opportunities and developing new products for examples for wind energy, steel work or automotive applications.

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After graduating as an engineer at the Technical University of Clausthal, Germany he started at the Institute of Tribology and Conversion Machinery as a scientific assistant, teaching and researching on hydraulics for oil and gas and turbomachinery as well as tribology and plain bearings' hydrodynamics. In 2010 having graduated with doctoral degree, he started working in the R&D, application simulation and calculation department for Zollern Plain Bearing Technology and then joined Miba Industrial Bearing in 2019.