Kalsi Thrust Bearing

A Low-Friction, High-Capacity, Impact-Resistant Bearing

Thrust Bearing Introduction

The Kalsi Thrust Bearing™ (Fig. 1,2) was developed as a high capacity alternative to plain thrust bushings and roller thrust bearings. The key feature is a unique patented geometry that elastically deflects under load and hydroplanes on a lubricant film during rotation, much like tires on a wet road. This lubricant film dramatically reduces friction, compared to conventional thrust bushings, allowing significantly higher loads and speeds, and providing longer life and reduced bearing-generated heat. Unlike roller thrust bearings, the new Kalsi Bearing™ can tolerate high shock loading without brinelling, thanks to the "squeeze film effect" and a much larger support area.

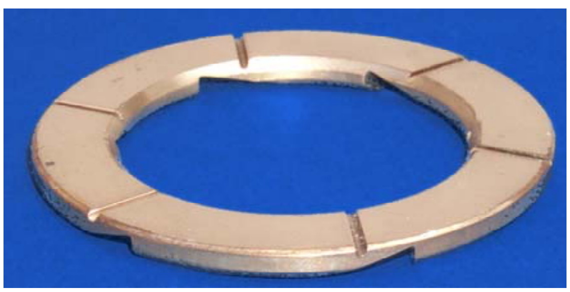

Figure 1

Kalsi Thrust Bearings generate a hydroplaning action to reduce friction and accommodate higher loads and speeds.

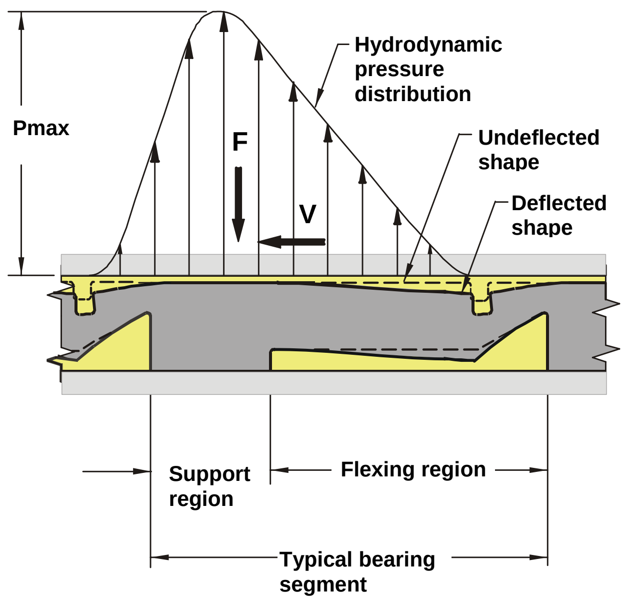

Figure 2

The hydroplaning action is caused by load-induced deflection of the initially flat dynamic surface (exaggerated here for clarity) that creates an efficient hydrodynamic wedging angle.

Benefits Provided by the Kalsi Bearing

- Lower friction resulting in reduced heat generation
- Expanded speed and load combinations
- Increased shock load capacity

This new bearing, although sophisticated in design, is compact and simple in construction. It can be retrofit into existing equipment to provide significant performance advantages in a variety of demanding applications, such as

- Mud motors & turbines,
- Roller cone bits,
- Rotary steerable tools,
- Mud hammer drills,
- Mining & excavating equipment.

Bearing Deflection Lowers Friction by Hydrodynamic Lubrication

The Kalsi Bearing is a relatively thin disk that has a number of repetitive bearing segments that define flexing regions and support regions (Fig. 2). The bearing dynamic surface, which is initially flat, deflects elastically under load, as shown in exaggerated vertical scale in Figure 2. The deflection creates regions of gradual convergence between the bearing and the mating surface that act as efficient hydrodynamic inlets. During rotation, these inlets force lubricant into the dynamic interface, creating a load-supporting interfacial lubricant film that significantly reduces bearing friction, wear, and heat. Friction coefficients are typically in the range of 0.003 to 0.005, which is significantly lower than plain thrust bushings, which operate in a boundary/ mixed lubrication regime.

Kalsi

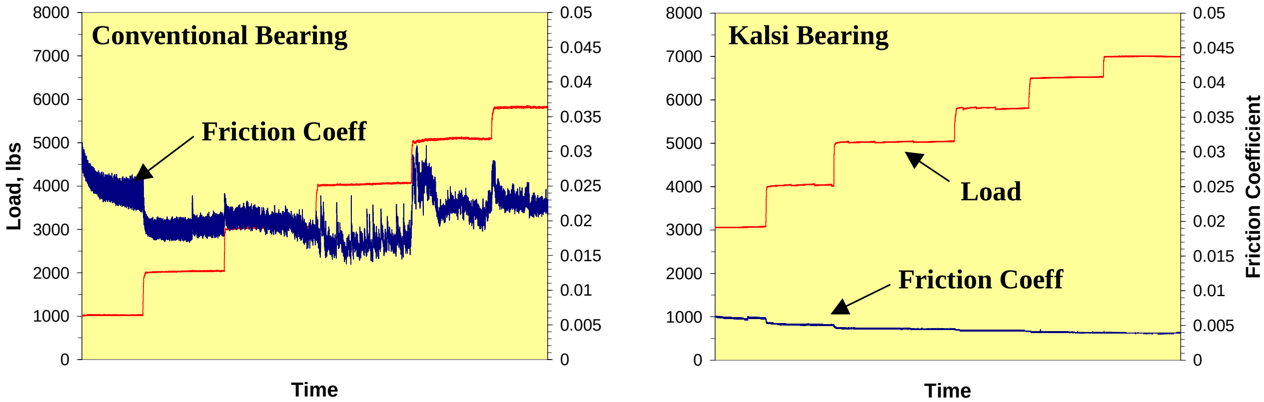

Figure 3

Due to hydrodynamic operation, Kalsi Thrust Bearings have significantly lower friction than a conventional oilfield drill bit thrust bushings, which operate in a boundary/mixed lubrication regime.

The Bearings Are Based on Extensive Analytical and Experimental Research

The Kalsi Bearing design is the result of an intensive development effort spanning several years of rigorous analytical and experimental research. An extensive matrix of finite element and elastohydrodynamic lubrication analyses were performed to quantify the effect of key geometrical features, dimensions, material properties, lubricant viscosities, loads, and operating speed on bearing performance. Various design and operating parameters were then explored experimentally.

Performance characterization tests with oil and grease-type lubricants have confirmed the advantages of the Kalsi Bearing, including reduced friction, cooler operation, and higher operating load and speed capabilities.

The test matrix included variations in bearing design, surface coatings, and two different lubricants: a typical calcium complex grease used in oilfield drill bits, and an ISO 1000 viscosity grade synthetic oil that is used in downhole drilling tools. Loads were varied to bearing unit pressures of over 5,000 psi. Speeds were varied from 30 rpm to 700 rpm. The environmental temperature varied between 150 to 250ºF.

Figure 3 compares the performance of a 1.04” ID x 1.95” OD Kalsi Bearing to an identically-sized silver plated beryllium copper thrust bushing that is used to carry extremely heavy loads in oilfield rotary cone rock bits.

The friction coefficient of the drill bit bushing operating in high-particulate drill bit grease varied from about 0.015 to 0.031 in an erratic fashion. By comparison, the friction coefficient of the Kalsi Bearing over a wide performance range was about 0.004, and was extremely smooth, even at loads that were substantially higher than could be tolerated by the conventional thrust bushing.

In such comparison tests, the temperature of the Kalsi Bearing was 50 to 100°F cooler than that of the conventional thrust bushing. This reduced heat output can be especially significant when elastomeric rotary seals are located near the bearings, because it allows the seals to run cooler.

High Shock Resistance Due to the “Squeeze Film” Effect

When subjected to heavy downhole impact loads, conventional rolling element bearings are prone to fatigue damage and brinelling (e.g. denting) of the race surfaces. Kalsi Thrust Bearings are able to withstand much higher momentary impact loads by virtue of the large dynamic support area and the hydrodynamic lubricating film, which together provide a classical squeeze-film cushioning effect. When a momentary impact causes the lubricant film to be rapidly squeezed, it cannot escape instantaneously. The magnitude and duration of the load determines the reduction in film thickness, and the load that can be supported. In general the Kalsi thrust bearing is able to handle impact loads more than three times the design load limit.

Geometry Options

Kalsi Bearings are available in three different geometry configurations::

- Unidirectional rotation,
- Bidirectional rotation, and
- Floating bidirectional rotation.

Unidirectional Thrust Bearing

The unidirectional bearing (Fig. 1) is designed for applications that have predominantly unidirectional rotation, such as oilfield downhole mud motors. The unidirectional bearing maintains hydrodynamic film in either direction of rotation, but has less thrust capacity in the non-optimum direction. The Kalsi unidirectional thrust bearing achieves the maximum load capacity within the smallest axial space. The flexing regions are established by contoured radial slots that maximize hydrodynamic efficiency in one direction of rotation. When thrust can occur in both axial directions, one clockwise and one counter-clockwise bearing are typically employed.

Bidirectional Thrust Bearing

The Kalsi bidirectional thrust bearing (Fig. 4) has an equally high thrust load capacity in either direction of rotation. Load capacity is about 90% of the capacity of the unidirectional thrust bearing. In applications with similar thrust requirements in both axial directions, the bidirectional bearing simplifies inventory and reduces the potential for installation errors, because both bearings can be identical. Compared to other Kalsi thrust bearings, the bidirectional bearing is more economical to manufacture because the slots that produce the flexing regions are less complicated.

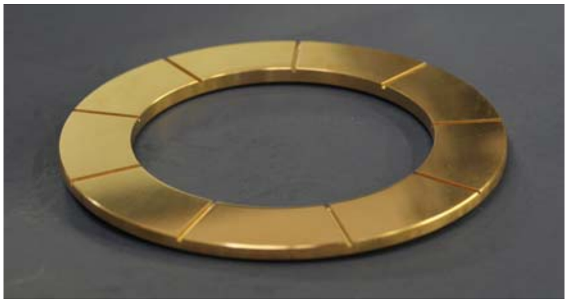

Figure 4

The flexing regions of the bidirectional thrust bearing are established by shallow symmetric slots on the static end of the bearing, As a result, the static end of the bearing (not shown) has a castellated appearance. This bearing was manufactured from beryllium copper.

Floating Bidirectional Thrust Bearing

The floating thrust bearing (Fig. 5) provides redundant dynamic surfaces that increase reliability, reduce operating temperature and simplify installation. The bearing is sandwiched between two dynamic races, and slips relative to both, providing hydrodynamic lubrication at both dynamic interfaces. In testing, the floating thrust bearing runs 30 to 50°F cooler than the non-floating bearings.

The slots of the floating bearing are more expensive to machine than the slots of the non-floating designs, but the bearing implementation is more economical because—unlike the non-floating bearing configurations—no special anti-rotation features (pins, static surface roughening, low friction coatings) are required to prevent slippage at the wrong interface. The floating design also eliminates the potential for installation error, because the bearing cannot be installed backwards.

The floating bearing requires slightly more axial space than the unidirectional and bidirectional non-floating configurations.

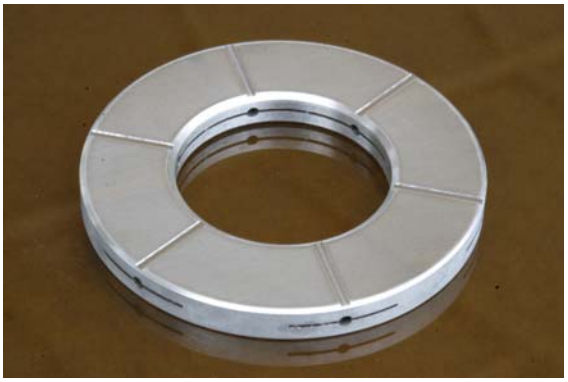

Figure 5

The Kalsi Floating Thrust Bearing has two dynamic surfaces. The flexing regions are established by symmetric slots that extend radially through the bearing body. This example was manufactured from steel.

Low Breakout Friction Coating

An optional coating is available that reduces the breakout friction coefficient to 0.12 or lower with bearing loads as high as 3,000 psi and dwell times up to 24 hours. The coating reduces operating temperature, and improves reliability by inhibiting asperity wear and galling under extreme loads. Low breakout friction also eliminates the need for anti-rotation features, simplifying implementation.

Bearing Selection and Implementation

Kalsi Thrust Bearings are custom-designed for the envelope constraints and load requirements of each application using coupled elastohydrodynamic analysis software. The bearings are available in an assortment of materials, including beryllium copper, steel, and spinodally hardened copper-nickel-tin alloy. Kalsi bearings are typically run against carburized or Stellite 6 overlaid steel counter-faces. Silver-plating of the counter-face is sometimes employed with non-ferrous Kalsi Thrust Bearings for added over-load protection. Experienced Kalsi Engineering personnel are available to provide thrust bearing technical support and implementation guidance.

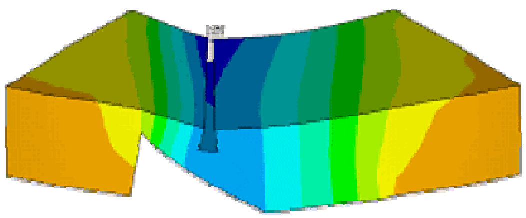

Figure 6

This figure shows elastic deformation of a unidirectional thrust bearing under static load, as predicted by finite element analysis. Deflection is exaggerated, making the static wedge clearly visible. Upon rotation, the static wedge initiates interfacial hydrodynamic pressure. This pressure alters bearing deflection, and the resulting dynamic wedge shape dictates lubricant film thickness and thrust load capacity. The Kalsi design methodology accounts for these static and dynamic effects..

Company Background

Kalsi Engineering, Inc. was founded in 1978 to provide engineering services in the areas of research and development, design, analysis and testing of mechanical equipment and structures. Our facilities (Fig. 7) are located in the Houston, Texas metropolitan area. The founder of the company, M. S. Kalsi, was the director of research and development for a well-known valve manufacturer prior to starting Kalsi Engineering. He became interested in the field of hydrodynamic lubrication while pursuing his masters and doctorate degrees. His fundamental research in this area led to the basic lubrication concept now employed by the Kalsi Bearing product line. The product has been developed using state-of-the-art analysis techniques and rigorous testing.

The Kalsi Engineering staff has an outstanding and diverse engineering background, with a record of accomplishments in developing innovative, practical and cost effective solutions to mechanical engineering problems in a wide range of applications in the power generation, oilfield, petrochemical, aerospace, defense, manufacturing and mining industries. The company's core capabilities include structural, fluid and thermal analysis, mechanical design and product development, tribology, and mechanical and flow testing.

Kalsi Engineering is recognized worldwide for technical excellence. Our numerous industry milestones, guidelines, technical publications, new products and patents continue to provide long-term benefits to our clients and to the industries we serve. Visit our website at www.kalsi.com for additional information.

Figure 7

Kalsi Engineering's facilities in Sugar Land, Texas house our consulting engineering offices, mechanical testing laboratory, flow loop, and seal and Bearing operations. Our highly experienced mechanical engineers have a variety of complementary skills and industry backgrounds. We are well versed in classical solid mechanics/stress analysis and thermo-fluid analysis, and use state of the art design, analysis and testing software to support our activities.

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