SMOOTH SLIDING

Consulting company providing engineering services on issues related to sliding bearings

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RadiaLock™ - Design of Crush Height for Reliable Press Fit of High Performance Bearings

1. Introduction

A firmly tightened bearing has uniform contact with the housing surface, which fulfills the following functions [1]:

- prevents bearing fretting and spinning in the housing during operation
- provides maximum heat transfer through the contacting surfaces
- increases the rigidity of the housing

Fig.1 depicts a bearing installed in the housing. When the bearing is assembled and the two parts of the housing are tightened, a compression stress σ in the circumference direction of the bearing back is formed. The stress causes the bearing to press to the housing surface at a contact pressure P. The value of the radial contact pressure P determines the ability of the bearing to transfer the heat produced by friction.

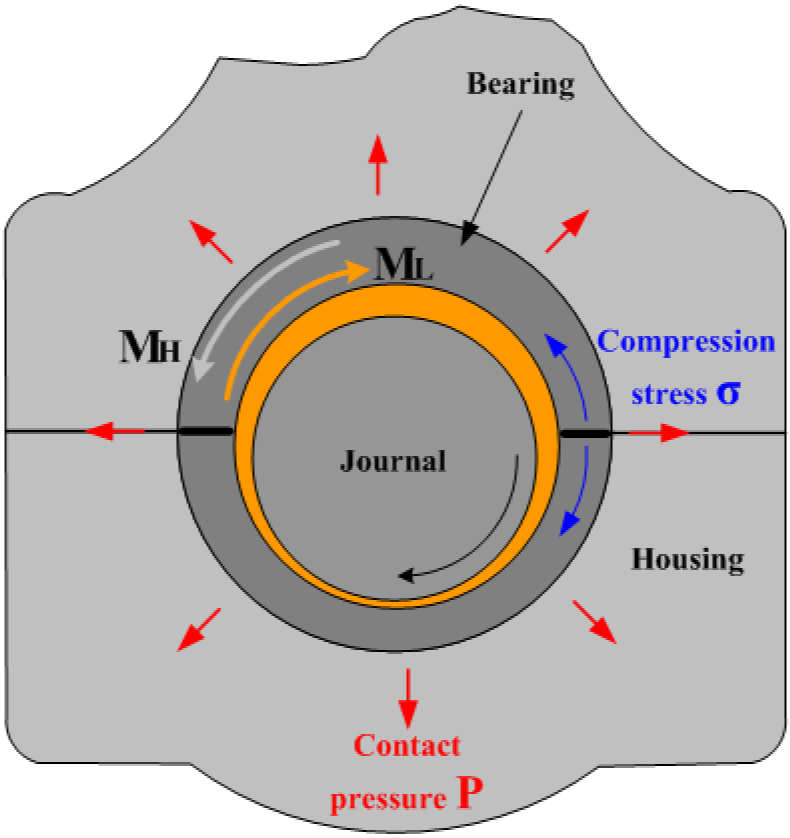

Fig. 1 Bearing assembly

The contact pressure also produces a friction between the bearing back and the housing surface which contradicts the friction generated by the journal rotating in the bearing (ML). The torque of the friction force formed between the bearing back and the housing MH prevents the bearing from shifting in the housing.
High performance bearings working at heavy loads, high rotation speeds and increased temperatures should be installed with a higher contact pressure. This provides better heat transfer and secures the bearing more tightly in the housing.

2. Crush Height

In order to achieve a required contact pressure, the outside diameter of an engine bearing is produced greater than the diameter of its housing. Such installation technique is called press fit (or interference fit). The difference between the diameters is called interference.
The difference between the diameters affects the amount of elastic compression of the bearing installed in the housing, and determines the value of the contact pressure P of the bearing.

Since direct measurement of the bearing circumference is a difficult task, another parameter characterizing the bearing press fit is commonly measured - crush height.

Crush height is the difference between the outside circumferential length of a half bearing (one half shell) and half of the housing circumference [1] measured at a certain press load.
Fig.2 illustrates a device for measuring crush height.

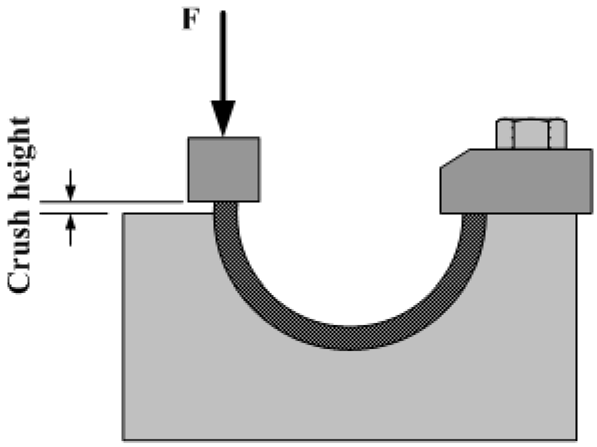

Fig. 2 Device for measuring crush height

The tested bearing is installed in the gauge block and pressed with a predetermined force F. The force is proportional to the cross-section area of the bearing wall.
The optimal value for crush height is dependent on the bearing diameter, housing material (modulus of elasticity and thermal expansion), housing dimensions and stricture (rigidity), and temperature.

3. Design of RadiaLock™ - The Optimal Crush Height for High Performance Bearings

A universal value of crush height suitable for all kinds of bearings and housings does not exist, since the required minimum contact pressure depends on the housing material, housing rigidity (dimensions and shape), bearing thickness and temperature.
For common street car engine bearings, the minimum value of contact pressure providing reliable operation of a medium loaded bearing at moderate rotation speed is about 1200 psi.

However more severe conditions of high performance engines require a higher minimum level of contact pressure - at least 1500 psi. The maximum value of crush height is determined by the level of compression stress, which should not exceed 65,000 psi.

The contact pressure and compression stress may be calculated by the method described in [2]. Fig.3 depicts the results of contact pressure calculations as a function of crush height for three different housing materials: steel, aluminum and titanium. High performance connecting rods, depending upon application, are routinely made from one of these materials. These materials have different values of stiffness (modulus of elasticity). The stiffness of aluminum is about a third that of steel, the stiffness of titanium is half that of steel.
The calculations illustrated in Fig 3 were performed with King high performance connecting rod bearing CR 807XPN.
According to the calculation results, a contact pressure of 1500 psi is achieved at the crush height value of 0.004” in the steel housing, and 0.0052” in the aluminum housing. The diameter of the housing in the calculations was assumed 1” greater than the outside diameter of the bearing.

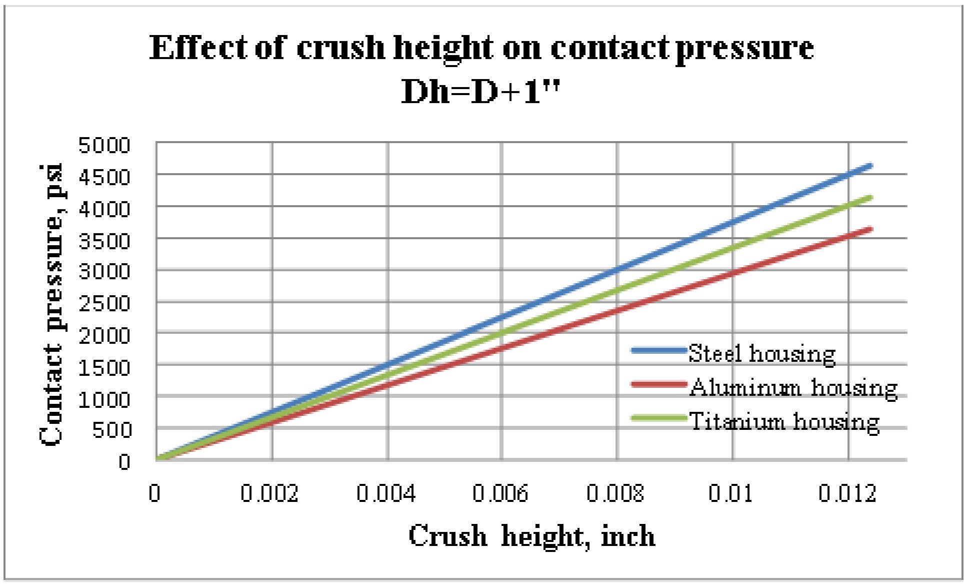

Fig. 3

However the calculation results did not take into account a temperature increase. The crush height is measured at a normal ambient temperature, but the bearing together with its housing heat up during bearing operation. If bearing and housing are made of materials with different coefficients of thermal expansion, the effective crush height (interference) will be different from that measured at room temperature.
The most significant difference between the thermal expansions of the bearing and housing is realized when the housing is made of aluminum.

Fig.4 shows the effect of temperature on the contact pressure of the bearing (CR 807XPN) in an aluminum housing.

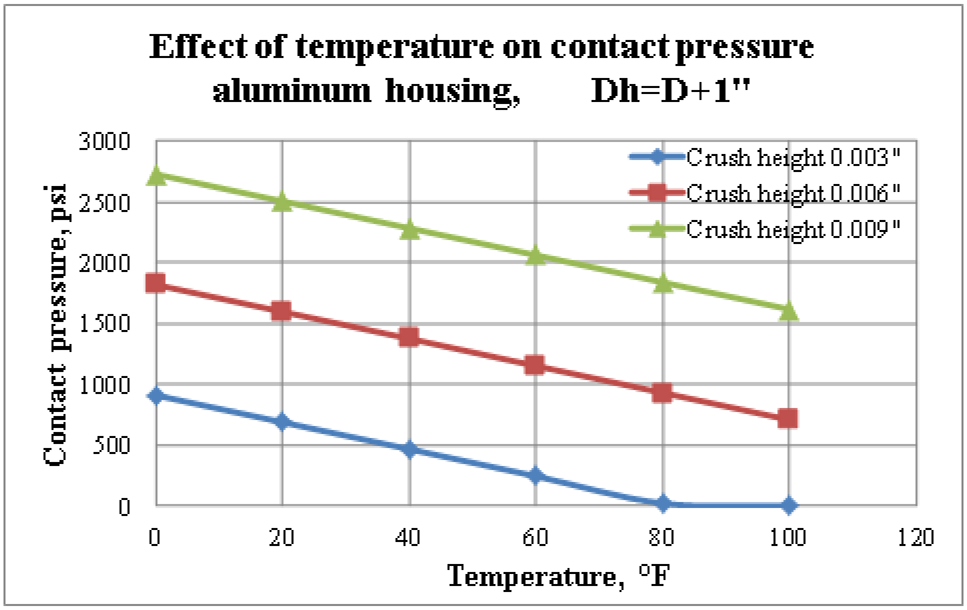

Fig. 4

The graph shows that the required level of contact pressure in the heated aluminum housing may be achieved only if the crush height is not less than 0.009".

Another factor affecting contact pressure is the rigidity of the bearing housing, determined by the housing dimensions and shape. Fig.5 presents the calculation results of the effect of the housing diameter on the contact pressure of the bearing in housings made of three different materials. The calculations are made for crush height ch = 0.005".

The graph shows that the steel housing provides the required contact pressure even at a diameter as low as 1.25 of the bearing diameter. The contact pressure 1500 psi in a titanium housing is achieved at its diameter greater than 1.4 of the bearing diameter. The diameter of an aluminum housing should be at least 1.75 of the bearing diameter.

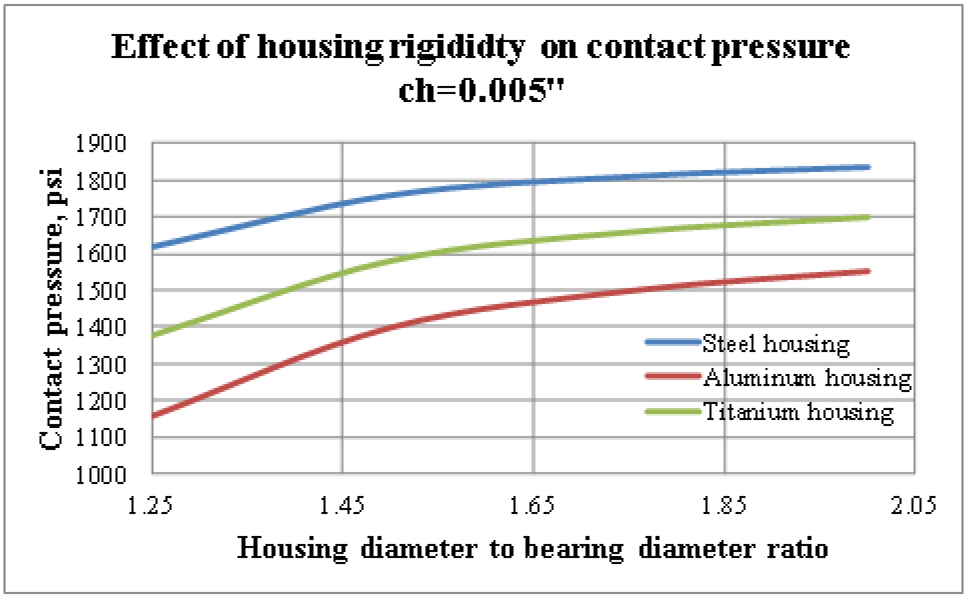

Fig. 5

A tighter contact between bearing and housing may also be obtained by an increase of the thickness of the bearing steel back.

The effect of bearing thickness on contact pressure is shown in Fig.6.

The required minimum value of 1500 psi pressure in a steel housing is achieved with a bearing whose steel back is thicker than 0.047", whereas the bearing back thickness in an aluminum housing should be at least 0.077" and 0.057" in titanium housing.

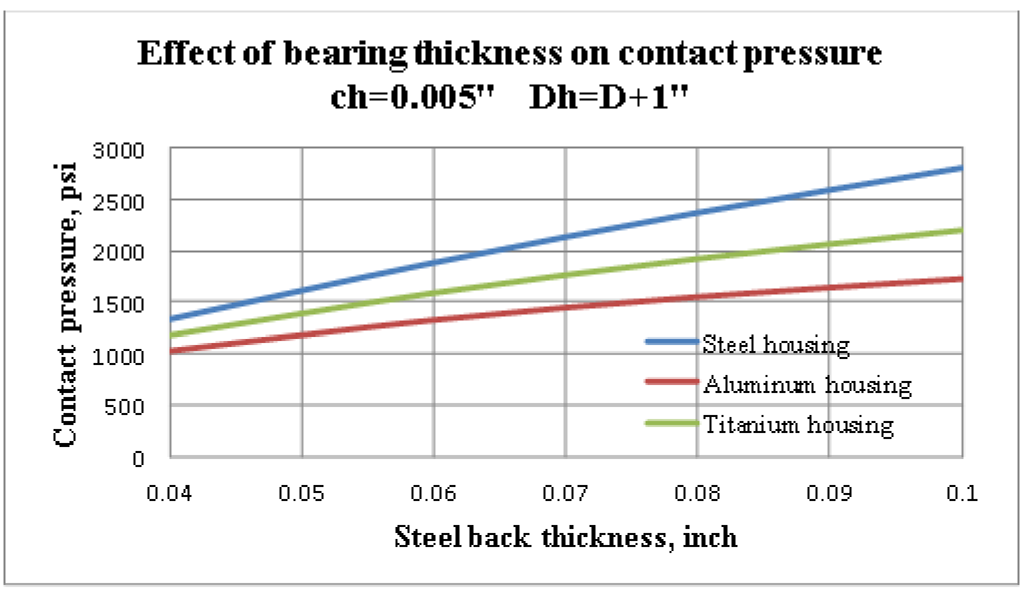

Fig. 6

Thus, the design of crush height in a high performance bearing should take into account not only severe operating conditions (heavy load and high rotation speed), but also the housing parameters (material, shape, dimensions), bearing dimensions and the ambient working temperature.

However, there are limits to the minimum amount of crush height as well as the maximum amount of crush height. When a bearing with excessive crush height is installed and tightened in the housing, the material in the region of the parting line exerts an inward displacement which reduces the gap between the journal and the bearing surfaces in this area. The change of bearing profile at the parting line region results in the formation of peak oil film pressure, which may cause fatigue of the bearing material [3].

A bearing affected with fatigue cracks in the area of crush relief is shown in Fig.7.
The compression stress in the bearing was 72,300 psi which is greater than the maximum value of 65,000 psi.

Fig. 7 Fatigue cracks in the crush relief area

4. Spinning prevention

One of the functions of press fit is to prevent bearing movement (spinning or fretting) within the housing.
According to Fig.1, such movement may be possible if the torque of the friction force applied to the bearing by the rotating journal ML becomes greater than the torque of the friction force retaining the bearing in the housing MH.
Engine bearings operate mostly in a regime of hydrodynamic lubrication [4]. The value of hydrodynamic friction torque developed using King high performance bearing CR 807XPN was

calculated assuming the use of 15W50 oil, and a wide range of rotation speeds, oil clearances and eccentricity.

The calculations were performed using software developed by King Engine Bearings. This software is capable of calculating loads, friction forces, minimum oil film thickness, oil temperature rise, energy loss, oil flow rate and other thermodynamic, dynamic and hydrodynamic parameters for each bearing of an engine at any angular position of the crankshaft.

The maximum value of hydrodynamic friction torque ML resulted in a value of approximately 2 ft*lb.

The torque MH required to spin the bearing in the housing is about 100 ft*lb (corresponds to the contact pressure of 2630 psi).

Thus the safety factor is about 50 - sufficiently large enough to prevent spinning. Even if lubrication turned to mixed regime, the journal friction torque will be much lower than the torque keeping the bearing from spinning in the housing.

5. Conclusions – RadiaLock™ Protocol

- High performance bearings should be installed with a higher contact pressure that provides better heat transfer and prevents the bearing from shifting in the housing.
- The minimum value of crush height providing the required level of contact pressure in high performance bearings may be calculated.
- Lower stiffness of aluminum and titanium housings, and their thermal expansion rates that are different from steel, should be taken into account in the calculations of contact pressure.
- At the same amount of crush height, a greater contact pressure is obtained in bearings with a thicker steel back and in more rigid housings (housings with a greater outside dimension).
- The torque required to spin a bearing in its housing should be at least 50 times greater than the torque developed by the hydrodynamic friction.
- Excessive crush height causes an inward displacement of the bearing in the region of the parting line, which may result in increased localized pressure causing fatigue of the bearing material in the crush relief area.

6. References

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[2] J.E. Shigley (1986), Mechanical engineering design, McGraw-Hill Book Company.
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[4] Dmitri Kopeliovich (2013), Hydrodynamic journal bearing, SubsTech (Substances&Technologies), Available from http://www.substech.com/dokuwiki/doku.php?id=hydrodynamic_journal_bearing