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Instantaneous Squeeze Force in the Case of the Narrow Sliding Radial Bearing Exposed to Shocks and Vibrations

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Abstract: *Theoretical and experimental research is presented regarding the behavior of narrow radial HD bearings in high loading conditions. We determined relationship of carrying capacity in dimensional form for narrow radial HD bearings exposed to shocks and vibrations, the determining relationships of the lubricating minimum thickness in relation to the dynamic loading and pressure distribution from the film to be lubricated in five places of the bearing's body. Details on the measuring accomplishments and the experimental results are recorded in relation to the results obtained.*
In the very short time of the shock, we consider only the approach movement between spindle and bushing on direction of the center line, without the rotation of the spindle (the case of the non-rotating bearing), such that the effect of the lubricating expulsion be prevalent in achieving load-bearing capacity.

Keywords: *lubricating expulsion, pressure distribution, shock amplitude.*

1 INTRODUCTION

The behavior of narrow radial HD bearings in high loading conditions the difficulty lies in solving it to Reynolds' equation¸ the equation of elastic deformations of the spindle and bushing surfaces¸ the equation of energy and the equation of lubricating density and viscosity variation with pressure¸ all these together form a non-linear integral and differential system.

We consider only the approach movement between spindle and bushing on direction of the center line, without the rotation of the spindle (the case of the non-rotating bearing), such that the effect of the lubricating expulsion be prevalent in achieving load-bearing capacity [1],[5].

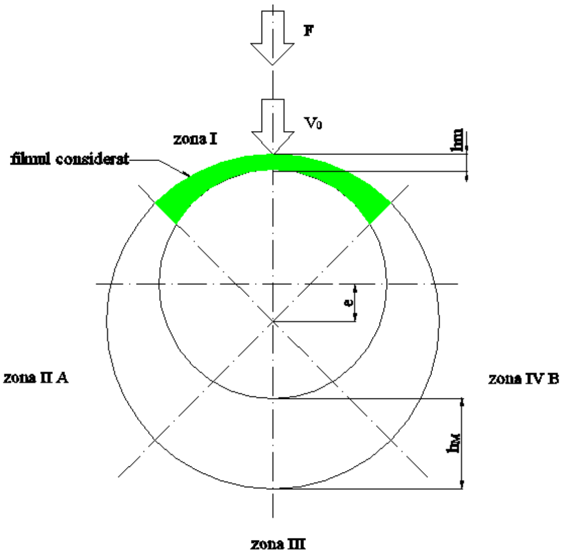

Fig. 1. The lubricating expulsion effect under shock

Area I represent area that opposes real the closing motion, the geometry of the lubricant film will be approximated with a constant thickness surface, on the basis of the rectangular model of infinite length, equal to the minimum thickness of the lubricating film under the condition of static loading,

Notations used: L- length of bearing (m); D- journal diameter (m); H - weight launching height (m); F- dynamically loading (N); G- static loading (N); p- pressure (Pa); η- viscosity of lubricant (Ns/m^2); h- fluid film thickness (m); Fs_ad - instantaneous squeeze force; c$_i$ – time of shock (sec.); A$_i$, B$_i$, C$_i$ – dimensional form of instantaneous squeeze force, in (N).

The circumferential pressure distribution is

$$p(\theta)=\frac{12\eta VB^2}{J^3(1-\varepsilon\cos\theta)^3}, \tag{1.1}$$

where V is the bearing speed at the time before impact and V$_0$ is the bearing speed at the time after impact and θ is the angular coordinate:

$$V=-\frac{dh}{dt}=\frac{J}{2}\dot{\varepsilon}=V_0-\frac{\eta\pi DL^3 g}{8F}\left(\frac{1}{h_m{}^2}-\frac{1}{h_{m0}^2}\right). \tag{1.2}$$

The relative eccentricity is

$$\varepsilon(t)=1-\frac{2h_m(t)}{J}, \tag{1.3}$$

and the minimum lubricating thickness in the dynamic regime:

$$h_m=\frac{1}{\sqrt{\frac{1}{h_{m0}^2}+\frac{8F\sqrt{2gH}}{\eta\pi DL^3 g}}}, \tag{1.4}$$

where h_{m0} represent the minimum thickness of lubricating in static regime [2].

The instantaneous squeeze force has expression

$$F^*=2\int_0^{\pi/2}\frac{4\eta VDL^3\cos^2\theta\cdot d\theta}{J^3(1-\varepsilon\cos\theta)^3}. \tag{1.5}$$

Thus, we can write:

$$\overline{F}_s=\frac{1}{A}\left[\overline{H}_s{}^3(1+A)-\overline{H}_s^5\right], \tag{1.6}$$

where: $A=4\overline{F}\Pi$, $\overline{H}_s=\frac{h_{m0}}{h_m}=H_{s-ad}$

and the parameters of lubricating film expulsion Π has expression:

$$\Pi = \frac{H}{h_{m0}} \cdot \tag{1.7}$$

2 EXPERIMENTAL ACQUISITION DEVICES

The research was conducted using a HD radial bearing with L/D=0,5, the spindle's diameter d_e =59,86 mm, and the bushing diameter D_e =59,93 mm, spindle's asperity 58-62 HRC, accomplished of 18MoCr10, bronze bushing accomplished of 88% Sn, 8%Sb, 4%Cu.

The dynamic loading it is realizing through the launching of a weight which hits the bearing at different heights. Attempts were made from heights between 5 to 40 cm, using a weight with m=5 kg, so as for H=5 cm we have F_1=1665 N, for H=20 cm F_2=2356 N, and for H=40 cm F_3=3332 N. Static charging is shown for the value H=0 cm.

The tests were accomplished at a 40 °C of the lubricating, being constant, pressure distribution p_{in} having values from 0,5 bar to 10 bar [4].

Using a lubricating oil for bearings LA 32 STR 5152-89 type, with the viscosity of 31,3 cSt at 40 °C, in dynamic loading conditions, we determined the pressure distribution in five places of the bearing's body, with the pressure measuring dose with tensiometric translators. Those 4 tens metric stamps are connected in a tensometric bridge diagram, being related by an amplifier at the acquisition plate ADuC 812 [6].

Figure 2 presents experimental acquisition devices for measuring pressure in dynamic regime.

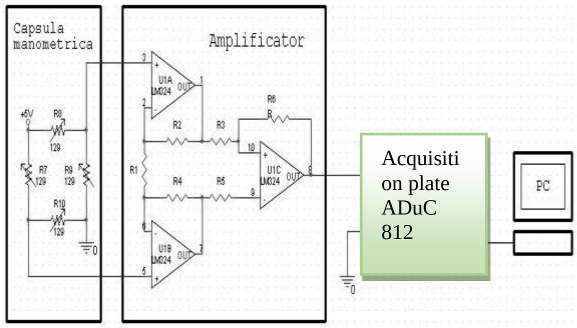

Fig 2. Experimental acquisition devices for measuring pressure in dynamic regime

Using the experimental acquisition devices for measuring pressure in dynamic regime and focusing on the variation exit sign and registering amplifier with acquisition plate ADuC 812, I increased the pressure in pressure measuring dose bar by bar, the dose distortion being linear with the pressure. I set the dependency relation between the tension in the exit point in mV, and the pressure (2,3 mV = 1bar Δp).

3. THEORETICAL RESULTS

Thus, a solution in the Mathcad 2001i program determined the variation of the instantaneous carrying capacity in dimensional form (Ai, Bi, Ci - in N) depending on the minimum thickness of lubricant hi, respectively as a function of the duration of the shock (ci [sec]), for the three weight launching heights H, are presented in figures 3 - 6.

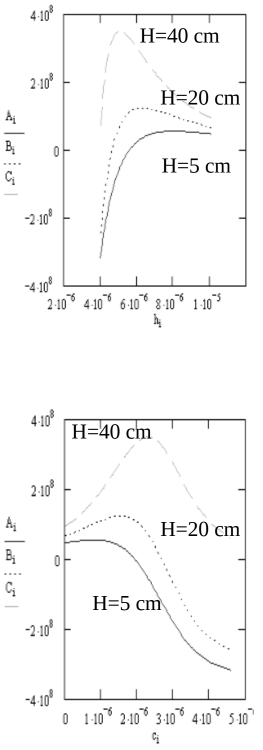

Fig. 3. The instantaneous carrying capacity depending on the minimum thickness of lubricant hi, respectively as a function of the duration of the shock (ci [sec]) (n=370 rot/min, p_{in}=0,5 bar, G=2250 N, h_{m0}=10,175 μm)

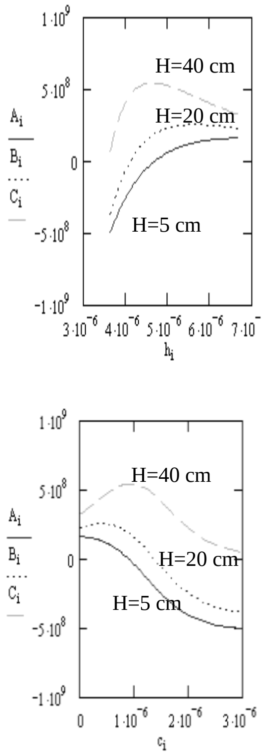

Fig. 4. The instantaneous carrying capacity depending on the minimum thickness of lubricant hi, respectively as a function of the duration of the shock (ci [sec]) (n=370 rot/min, p_{in}=0,5 bar, G=4500 N, h_{m0}=6,723 μm)

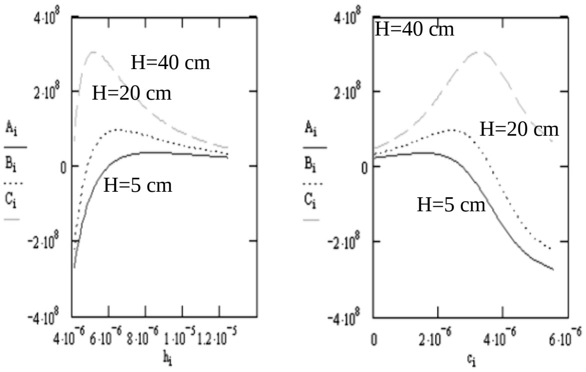

Fig. 5. The instantaneous carrying capacity depending on the minimum thickness of lubricant hi, respectively as a function of the duration of the shock (ci [sec]) (n=600 rot/min, p_{in}=1,5 bar, G=2250 N, h_{m0}=12,554 μm)

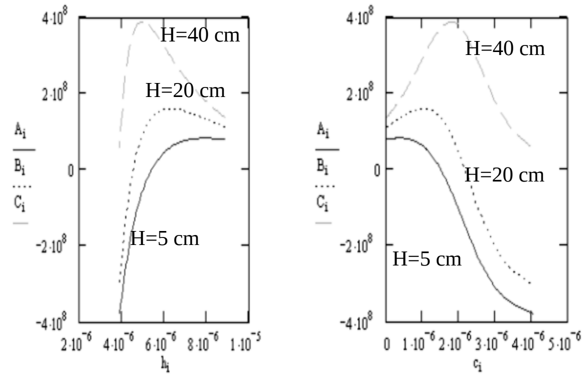

Fig. 6. The instantaneous carrying capacity depending on the minimum thickness of lubricant hi, respectively as a function of the duration of the shock (ci [sec])
(n=600 rot/min, p_{in}=1,5 bar, G=4500 N, h_{m0}=8,493 µm)

4. EXPERIMENTAL RESULTS

The pressure in point P3 of the bearing′s body, depending the supply pressure, the static and dynamic charging conditions at different spindle’s rotations are shows in figure 7 for n=370 rot/min, p_{in} =0,5 bar; figure 8 for n=600 rot/min, p_{in} =1,5 bar and figure 9 for n=960 rot/min, p_{in} =8 bar.

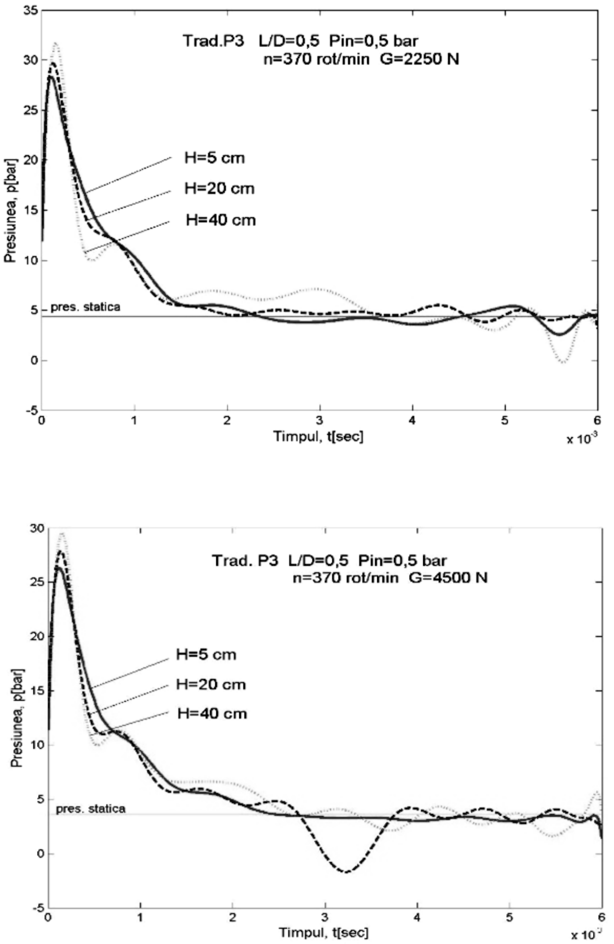

Fig. 7. The dynamic pressure P3
(n=370 rot/min, p_{in} =0,5 bar)

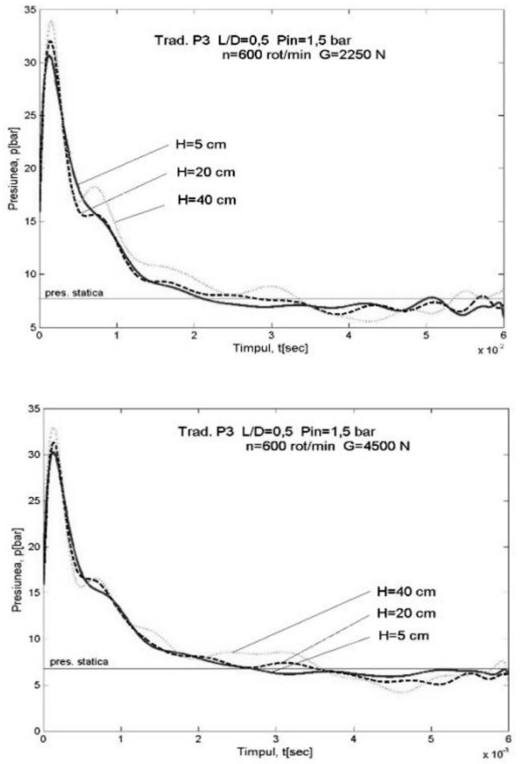

Fig. 8. The dynamic pressure P3
(n=600 rot/min, p_{in} =1,5 bar)

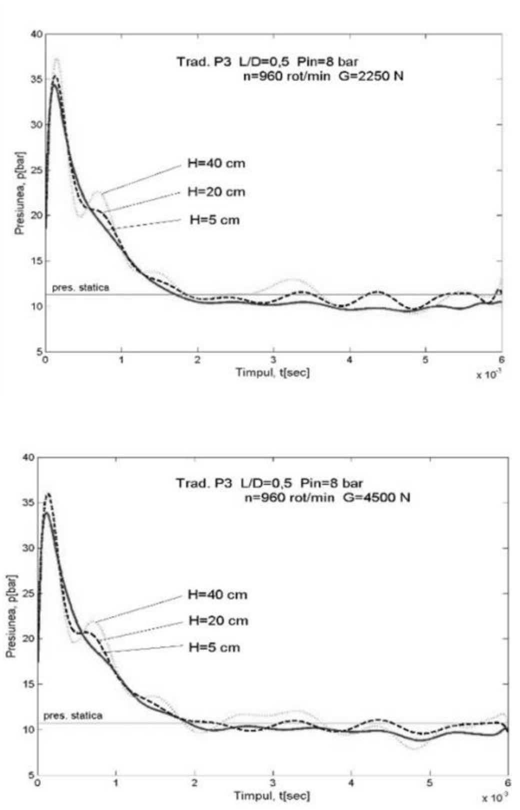

Fig. 9. The dynamic pressure P3
(n=960 rot/min, p_{in} =8 bar)

5. CONCLUSIONS

After analyzing the theoretical and experimental results obtained, the following can be stated:

- the decrease of the lubricating film minimum thickness along with the increase of static loading;
- the decrease, for high dynamic charging (over 2250 N) of the lubricating film thickness under the admissible acceptable value on the basis of rugosity of spindle surfaces, and the bushing respectively ($h_{min,a} \geq 5\ \mu m$);
- the existence of an optimum point from the viewpoint of carrying capacity: any change in the functional parameters of the bearing leads to straying from the optimum value from the viewpoint of carrying capacity;
- the very little influence of the feeding pressure on the minimum thickness of the lubricating for the same rotation of the spindle;
- in all these situations we must take into account the short time for pressure variation in dynamic charging (under 0,5 ms);
- the dynamic pressure in the moment of shock is increased when increasing the dynamic loading conditions; for the studied position, P3, the dynamic pressure rise at the same time with the rise of dynamic charging, the pressure leap being between 5,95 and 7,45 multiplied with static pressure of the bearing;
- the draught's pressure in dynamic loading conditions has a slightly shifting to the entrance zone of the lubrifiant when static loading conditions are increasing;
- the static loading conditions of the bearing does not have an important influence looking the changing in the pressure's values, as the static charging conditions gets bigger, so as the dynamic pressure is bigger;
- for the P3 position, at the same time with the rise of static loading, the static pressure decrease.

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