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Original Research Article

The effect of helical groove geometry on journal abrasive wear

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ABSTRACT

The article presents an experimental study of slide bearings operating in lubricant contaminated by Al_2O_3 abrasive particles. The aim of this work was the comparison of wear resistance of slide bearings with different surface geometry on the journal. It was found that helical groove on the journal significantly reduced wear of sliding pairs. The results of experiments showed that groove cross section area and helical groove lead affected abrasive wear. Valuable results concerning the sleeve wear reduction were obtained with respect to bearings with textured journals.

1. Introduction

Idea of helical or herringbone grooves application on the co-operating surfaces of bearings to produce pressure of the lubricating medium appeared in the 1940s. Firstly it was used in gas-lubricated journal bearings [1], then in bearings lubricated by oils [2–4] and solid greases [5].

Journals with grooves found practical application in high-speed low-loaded bearings because of their higher reliability and more stable operation comparing to conventional and because of the possibility to obtain the leakage-free operation of journal bearings [2,3]. Nowadays such techniques find implementations in bearings of the computer spindles in hard discs [6,7] and in small precise engines, for example in DVD players [8]. They are still studied and developed because of their practical applications [9,10].

Abrasive wear decrease in case of hard particles presence in the oil is the important advantage of implementation of the groove on the journal of slide bearing [11,12]. Such effect can be reached by making the helical groove on the journal surface. The amount of abrasive wear depends on the helical groove geometry however there is not enough information explaining these dependences exactly.

The main aim of the study described in this article is presentation of the effect of parameters characterizing the helical line on journal surface on abrasive wear of sliding pairs lubricated by the contaminated oil. Additionally the investigations of the surface topography of the journal are introduced to draw out conclusions about wear mechanism. Ability of moving wear debris and contaminants out from the contact zone by grooves created on journal surfaces could lead to new practical applications of slide journal bearings.

2. Experimental procedure

Abrasive wear of slide bearings consisting of journal with the helical groove on its surface was investigated. The classic

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Nomenclature

b	bearing length
$d(r)$	journal diameter (radius)
dg	groove depth
H	spiral lead of the groove
h_{min}	minimum oil film thickness
I_1	ratio of oil capacities of groove (oil pockets) on journal surface to oil capacity of bearing clearance
I_v	volumetric wear intensity
I_{vj}	volumetric wear intensity of journal
I_{vs}	volumetric wear intensity of sleeve
n	rotational speed of journal
p	nominal pressure
R	sleeve radius
Sa	arithmetical mean deviation of the surface
Sal	fastest decay autocorrelation length
Sf	groove cross section area
Sk	core depth
Sp	maximum height of summits
Spc	arithmetical mean peak curvature
Spk	reduced summit height
Sq	root-mean-square deviation of the surface
Str	texture aspect ratio of the surface
Sv	maximum depth of valleys
Svk	reduced valley depth
s	sliding distance
t	duration of the test
v	sliding speed of journal
W	load carrying capacity
w	groove width
Z_v	volumetric wear
ε	journal eccentricity
Θ	coordinate in circumferential direction as measured from the point where bearing interspace thickness is maximum
φ	attitude angle
Ψ	radial clearance ratio
ω	journal angular velocity

sliding pair with the smooth surfaces of co-operating elements was assumed as the reference point. The scheme of the bearing with the modified journal surface is introduced in Fig. 1.

The investigations of wear in the presence of hard abrasive particles in the lubricant were conducted on the ZAN rig at Gdansk University of Technology. This rig is described in the article [13]. Bearing sleeves were made from alloy MB58 (78% Al, 20% Sn, 1% Cu, 1% Mn) and the journals from steel 42CrMo4 (hardness 52 HRC).

The tested series of sliding pairs differed with the geometry of the helical groove on journal surface. The possibility of wear reduction by oil pockets creation on journal surfaces was also examined. Oil pockets existence on steel surfaces demonstrated beneficial effects on tribological characteristics [14–16].

On the basis of computer simulations and preliminary investigations [17] it was assumed that the following parameters describe the helical groove:

– the groove cross section area $Sf=(w \times dg)/2$,
– the spiral lead of the groove H.

Index I_1 [%] being the ratio of oil capacities of groove (oil pockets) on journal surface to oil capacity of bearing clearance was used to characterize both modified journal surfaces. To obtain I_1 index of journals with helical groove the formula (1) was used.

$$I_1 = \frac{w \times dg \times \sqrt{(2\pi r)^2 + H^2}}{2\pi H \times (R^2 - r^2)} \tag{1}$$

The capacity of oil pockets on textured journal surfaces was the summation of all separate oil pocket capacities. Single oil pocket capacity was calculated on the basis of surface topography of measured samples.

Parameters values describing analyzed journal series in the first stage of examination are presented in Table 1. Tested samples (series 3 and 4) were textured by burnishing technique to obtain isolated oil pockets in two different arrangements. The photos of journals with textured surface are presented in Fig. 2 and journals with helical groove in Fig. 3. In this experiment textured journals were characterized by the same value of index $I_1=1.6\%$ as one of chosen journal variant with helical groove.

The influences of the groove cross section area Sf and the spiral lead of the groove H in wide variable range on journal and sleeve wear intensity were given into examinations.

Evolutionary Operation (EVOP) technique was applied to find the minimum wear intensity of the journal.

There were the following geometry and operating conditions of tested journal bearings:

– journal diameter: $d=52.7$ mm,
– bearing length ratio: $b/d=0.5$,
– radial clearance ratio: $\psi=0.002$,
– minimum oil film thickness: $h_{min}=0.017$ mm,
– rotational speed of journal: $n=600$ rpm (the sliding speed $v=1.65$ m/s),
– nominal pressure: $p=1.57$ MPa,
– duration of the test: $t=20$ h (the sliding distance s = 120,000 m),
– lubricant agent: motor oil SAE 40 with kinematic viscosity 15 mm^2/s,
– contaminant: dust Al_2O_3, the average diameter of grains 21 μm,
– concentration of contaminant in oil 0.05 g/l, cleanliness according to ISO 4406 standard: 22/20/18,
– lubricant temperature: 22 °C.

The wear amount of journal was assessed on the basis of the profiles from the sliding surface in the axial section. Then