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EXPERIMENTAL METHOD FOR FORCASTING THE WEAR RATE OF A JOURNAL BEARING AND ITS VARIATION WITH CLEARANCE SPACE

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ABSTRACT

The paper presents the experimental method adopted to find out a relation between the shaft & bearing clearance to the rate of wear on either of the tribological element. For simplicity of the setup establishment, the shaft has been rigidly fixed on the 3-jaw chuck of a lathe and the other end supported on the revolving center. The bearing has been positioned at the designated location with help of a positioning clamp. To generate the effect of the radial load on the shaft acting downward, the bearing-positioning clamp has been loaded through pullies, so as to generate a force on the bearing acting upwards. The experiment has been made free from statistical errors typical to such experiments by using two sets of ring - the outer ring acting as bearing and the inner ring acting as the journal. By selection of softer material for the inner ring as compared to the outer ring, the wear has been obtained on the inner ring only. Wear rate of the inner rings has been determined experimentally in the range of clearances varying from 0.01mm to 0.3mm using virgin pair of outer and inner ring, for all the experiments. Based on the data acquired from the experiment the relationship of the wear rate with clearance space and the corresponding Sommerfeld number has been established which gives a clear idea of the lower optimum clearance, for the specific bearing set.

Key words: Wear rate, Sommerfeld no, optimum clearance.

1. INTRODUCTION

The primary objective behind inserting/creating lube oil film between the shaft and the bearing is to minimize the metal-to-metal contact. This is done in industrial bearings by hydrodynamic action of the lube oil and the extent to which this separation will exist depends on the maximum film pressure developed. But, the film sufficiently pressurized, available or not, there is always a certain amount of wear on the tribological elements. All the operating characteristics of the shaft and bearing is controlled by the operating parameters of the machine on which the bearing is to be mounted, baring the operating clearance. The performance enhancement solution for the bearing technologist hence, depends purely on the extent to which he/she can change and adjust the bearing clearance. The contemporary research in the field is very indicative but clear quantification of the performance parameters of the bearing and its relationship with clearance space is generally not available. The thumb rule has been established as:

“Too narrow a clearance causes excessive oil temperature rise and hence wear, where as too high a clearance causes problems of misalignment and vibration, again leading to wear. Also, at high clearance the maximum film pressure developed is considerably low as compared to the operation with lower clearance” [1].

From the discussion, it is evident that a bearing must have a range of clearances, within which its operation will generate the minimum wear. Also, it can be assumed without diversion from the principles of lubrication that the wear apparent on any of the element of the pair will depend mostly on the geometry and the operating parameters of the bearing and not only on the material selected for the bearing and the shaft. However, while comparing the wear rates of two sets of the tribological pairs, it will follow the same trends and have separate values for wear rates. This prediction follows from the fact that the two elements of the tribological pair are always assumed (and in fact they are) separated by a film of lubricant. This film may be only a few molecular dimensions thick (or thin to say) in adverse conditions and a few μ-meters thick in normal operation.

The wear in case of slow sliding under comparatively low nominal surface pressures is characterised by moderate rise of temperatures on the surface. But, if the condition are made severe i.e. increasing sliding speed or surface pressure the change in coefficient of friction are not great, but the rate of wear enhances significantly (Archard and Heist, 1956)[2]. Our problem in hand falls in the second category. To avoid the excessive wears that may arise due to selection of stringent operating condition, the present problem has been analysed under first set of conditions to keep a proper monitor of the wear and to increase the observation period. This is also necessary for casting away the effect of statistical errors in such experiments.

After the development of first linear bearing in 1945[3], Lundberg-Palmgren published their work on life theory of rolling bearings in 1947 leading to a formula [4] based on Weibull distribution proposed by Weibull in 1932 [5], which uses a basic unit running life of 10^6 revolutions, corresponding to linear distance of 50 km. However ISO uses a URL of 100 km in dealing with such bearings. The first theoretical base specially aimed at linear bearings was initiated for the development of a life theory with experimental support by Shimizu and Izawa [6,7]. Study of all such papers on linear bearings prompted authors of this paper to think of life estimation parameter for hydrodynamic journal bearings, where the correspondence of the wear resistance is to be made with the Sommerfeld number, as opposed to the basic dynamic capacity for the linear bearings.

2. METHODOLOGY

The schematic diagram of the experimental setup is presented in fig.1. The rotation of the shaft is obtained by holding one end of it in the three jaw chuck mounted on the lathe spindle and the other end of the shaft supported on the revolving center, mo unted on the tailstock. To generate the effect of self-weight acting on the shaft, a load acting upward has been applied on the bearing with help of separate rope and pulley arrangement, this load designated as W. A container filled with lubricant of known properties is provided below the bearing for bath type lubrication. The level of the lubricating oil in the container is kept high enough to submerge a part of the inner ring.

The parameters selected for the experiment are:

r = 50 mm (for all the sets)

μ= 0.24 N.s/m^2 (from standard data of the lubricant)

N= 54 rpm

W= 78.48N

c = 0.01 to 0.3 mm (variable for individual bearing sets in increments of 0.1 mm)

To obtain this increment in bearing clearances, the statistical nature of error occurrence has been exploited. The inner diameter and outer diameter of the outer rings and inner rings were individually measured and pairs created to generate clearance variation ranging from 0.01mm to 0.3mm, with 0.01mm increment .The Sommerfeld number of all the bearing sets thus created where determined for all the clearances.

For the ease of erosion determination, the inner rings (acting as shaft) were made from mild steel (commercial grade) without heat treatment and the outer rings (acting as bearing) were made from 20 MrCr5 steel, hardened and super finished. The erosion on the inner rings (shaft) for one hour run was obtained by measuring the change in outer diameter of the ring. As outer rings have nearly three times the Rockwell hardness the experiment showed negligible erosion on them.

Based on the experimental results, the following graphs were plotted

i) Clearance space v/s rate of wear

ii) Sommerfeld number v/s rate of wear

3. PROCEDURE

The shaft S with a keyway at the designated location was mounted on the 3-jaw chuck. The inner ring (acting as journal in the experiment) was keyed on the shaft at the designated location. The outer ring O enveloped in the circular clamp CC attached with rope passing through pulley and loaded at the other end. (Not shown in fig.1) was put over the inner ring. The circular clamp CC ensures the prevention of rotation of the outer ring. Another U shaped clamp CA was positioned on the outer ring to negate its chances of movement in axial direction. The oil bath B (movable) was placed under the arrangement, such that the bearing surface of the inner ring and outer ring was submerged in the lube oil. The revolving center was brought to rest the other end of the shaft S on it.

With the preplanned operating parameters of W=78.48 N and *N*=54 rpm, the setup was allowed to run for 1 hour. The arrangement was dismantled after 1 hour run and the outer diameter of the inner ring examined for the appearance of erosion on it.

The experiment was repeated with new pair of inner and outer rings with clearance increased by 0.01mm as compared to the ring set of the previous experiment. For every bearing clearance, two ring sets were tested to avoid consideration of erosions, which may arise due to material defects and experimental errors.

4. DATA COLLECTION

The data obtained from the experiment is presented in table –1.

Table 1 : Observation table

Sl.No.	c#	S##	Reduction in Dia.*	Wear Rate**
1	0.01	123.85	0.13	2.79
2	0.02	30.96	0.12	2.58
3	0.03	13.76	0.08	1.72
4	0.04	7.74	0.07	1.50
5	0.05	4.95	0.06	1.29
6	0.06	3.44	0.06	1.29
7	0.07	2.53	0.04	0.86
8	0.08	1.94	0.02	0.43
9	0.09	1.53	0.02	0.43
10	0.10	1.24	0.00	0.00
11	0.11	1.02	0.00	0.00
12	0.12	0.86	0.00	0.00
13	0.15	0.55	0.00	0.00
14	0.20	0.31	0.00	0.00
15	0.30	0.14	0.00	0.00

#: Clearance space, in mm

:Sommerfeld number

*: Reduction in outer diameter of the inner rings **: Based on density of the commercial mild steel, gm/hr

5. SUMMARY OF RESULTS

From the data acquired out of the experiment, the following relationships has been analysed graphically:

i) Operating clearance v/s wear rate, fig (2)

ii) Sommenfeld no.v/s wear rate, fig (3)

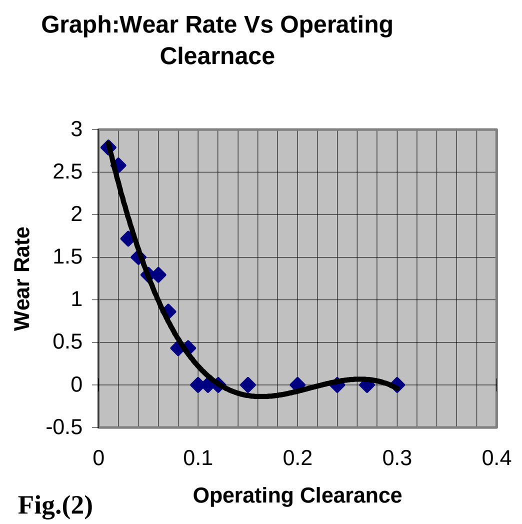

Fig.(2)

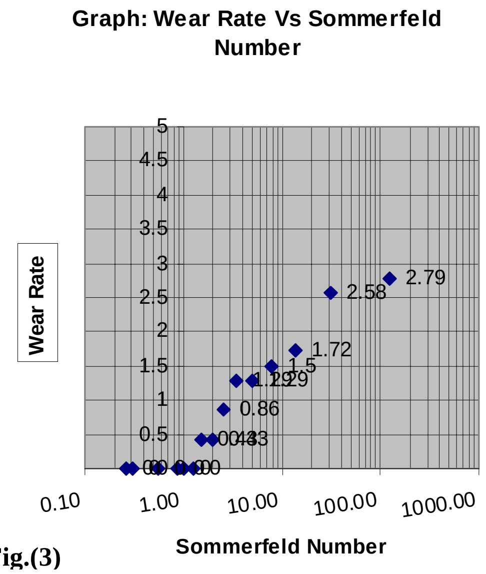

Fig.(3)

Fig.2 shows a clear knee of the curve with respect to the clearance space after the clearance of 0.1mm, after which there has been negligible wear on the inner ring. Fig.3 shows the knee of the curve with respect to the wear rate in the Sommerfeld number zone of 10 to 2 and a knee with respect to Sommerfeld number in the Sommerfeld number zone of 0 to 2.

The above two facts as observed from the graph clearly indicates the existence of a "optimum clearance" on the lower side and also the "optimum Sommerfeld no." on the upper side, which typical to the existing experiment is 0.1mm of clearance and 1.24 of the Sommerfeld number, The optimum Sommerfeld number obtained from the experiment is in good agreement with the established practice in industries for selection of bearing clearance under low load conditions.

6. CONCLUSIONS

For any particular bearing there must exist at least one set of parameters at which the bearing will have the minimum wear rate. As, all other parameters baring the operating clearance are governed by the operating conditions of the machine; the determination of the optimum clearance will complete the information regarding the set of parameters at which the bearing has the lowest wear rate. Operation of the bearing at this clearance is bound to enhance its durability as long as wear is the failure criteria. Further, if the bearing characteristic number (Sommerfeld number.) is considered an indicator of the performance characteristics, a bearing characteristic number of 1.2 assures of a condition where the bearing will undergo minimum wear.

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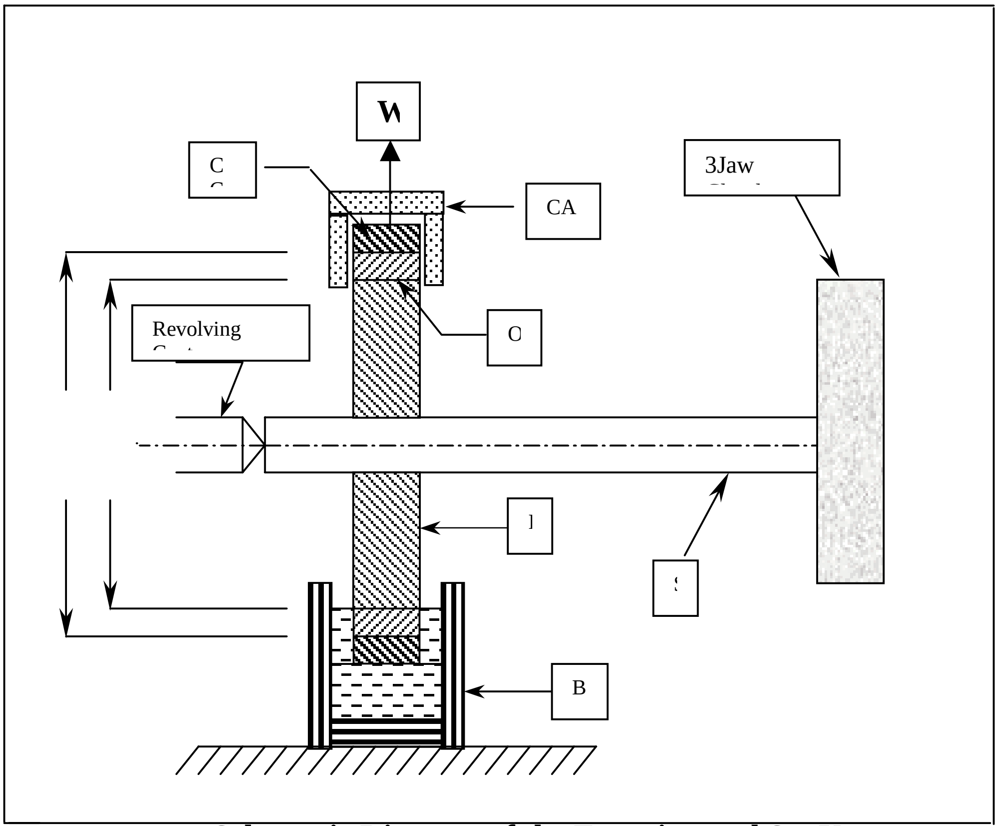
9. NOMENCLATURE

Symbol	Meaning	Unit
r	bearing radius	(mm)
μ	absolute viscosity	(Pa.S)
N	shaft rotating Speed	(min^{-1})
W	applied load	(N)
C	bearing clearance	(mm)



Schematic Diagram of the Experimental Set Up