# Predicting Effect Of Flow Of Lubricant, Pressure, Shaft Velocity And Surface Finish On Depth Of Wear Of Lining Thickness Of Engine Bushing By Experimentation

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## Abstract

Hydrodynamic Cu-Pb-Sn material journal bearings are widely used in automobile and industrial application because ofits simplicity, efficiency and low cost. The bearing is often subjected to many stops and starts with unknown loadcycles. During this transient period, friction is high and bushes become progressively worn-out, thus inducting certaindisabilities. The bushes are provided with a lining of Cu-Pb-Sn material which is found in the range of 450 to 600micron. The bearing designers are not provided the attention toward this dimension as in practice the failure of bushesobserved by seizer, scoring, pitting, cavitations, loss of Babbitt due to high fatigue loads etc. The total depth of wear ofhealthy journal bearing is observed 150 to 180 micron up to 40000 kms run. The aim of present experimental work is todetermine the effect of variable load, sliding velocity of shaft and deterministic surface roughness (Ra) of lining materialon sliding wear behaviour and depth of wear of lining thickness(dw) of Cu-Pb-Sn material bush, which is widely usedas bush material in automobile engine. The highest temperature zone was determined and the bush samples are marked circumferentially as a, b, c, d, e, f, g in front side and a’, b’, c’, d’, e’, f’, g’ rear side in that region. Therelationship between depth of wear of lining thickness (dw) versus load, shaft speed, surface roughness is establishedby using the experimental results and regression model. The numerical result indicates that the surface roughness ismost important bearing characteristics and the combined effect of load, shaft speed and surface roughness on depth of wear of lining material particularly in high temperature zone.

**Keywords:** Crank shaft bush, test rig, depth of wear, lining thickness, surface roughness, flow.



## Introduction

Oil lubricated bearings employing sintered Cu-Pb-Snmetal are widely used in many automobile, industrial,marine and machine applications. Particularly inautomobile single cylinder engine, the crankshaftsupported by bushing of Cu-Pb-Sn lining material and these bearing are normally operate in stable hydrostaticcondition wherein a proper oil-film thickness is formedand maintained by using gear pump. The influencingparameters on wear of automobile bearing are studied inrecent works due to fact that manufacturers try to improveperformance of the journal bearing and reduce cost ofbearing induced in manufacturing and maintenance.Duckworth and Forester (1957) have analyzed the wear in lubricated bearing while Dufrane et al. (1983) proposedtheoretical model of worn bearing. Bouyer and Filon(2002) presented influence of wear on steady statecharacteristics of bearings. Behaviours of two lobe wornhydrodynamic journal bearing were proposed by Bouyeret al. (2006). Tamura et al. (2004) focused on effect ofcyclic load and cyclic speed on sliding wearcharacteristics of bearing lined with white metal. Tachi etal. (2005) predicted a relationship between frictionalstress, cut -off life and shaft revolutions. The aim of thepresent work was to analyze the influence of deterministicsurface finish, variable load and speed on depth of wearof lining thickness of Cu-Pb-Sn material bushing of Gl-400 engine of "PIAGGIO" auto rickshaw in realisticcondition, the bushing is dynamically tested onindigenously design test rig for real situations in engineand results are compared with available literature.

Table 1.Chemical composition of specimen.

| Cu% | Pb % | Sn % | Co % | Ni % | Zn % |
|---|---|---|---|---|---|
| 2.22 | >0.130 | >0.285 | <0.0015 | <0.0023 | <0.0010 |

**Test and experimental procedureSpecimen & measuring system**

The chemical composition of lining material Cu-Pb-Snof bushing used in test rig (copper–lead-tin alloy) is shownin Table 1. The test specimen employed was a copperlead-tin bushing of GL-400 engine used in PIAGGIOrickshaw manufactured by Greaves limited. Theschematic representation of bush with the specification isshown in Fig. 1. The detail specification of bush and shaftis presented in Table 2. The surface temperature of bushis measured at 5 location points with 5 RTD (Resistancetemperature detectors) while in test circumferentially tofind highest temperature zone as shown in Fig. 2. Thepressure is measured by using pressure transmitter "MBS3000" and pressure point is selected opposite to load line.The bush is marked circumferentially with the points a, b,c, d, e, f, g from "Front" and a', b', c', d', e', f', g', from"Rear" side as shown in Fig. 1. The surface roughness ismeasured specifically on these points by using Tayler-Hobson Surtronic3+ surface roughness measuringinstrument. The depth of cu-pb-sn lining thickness of bushis measured specifically at above points in front and rearside by using ultrasonic thickness measuring equipmentbefore and after trial run. Load applied while in test doesnot exceeding yield stress of the bush lining material. Allmeasuring instruments are calibrated as per ISstandards. The oil flow rate was varied withPMDC Motor .The Speed variation is ±10 rpm, load variation is ±0.2N,temperature variation is± $0.5^{o}$.

*Fig. 1. Schematic representation of bush.*

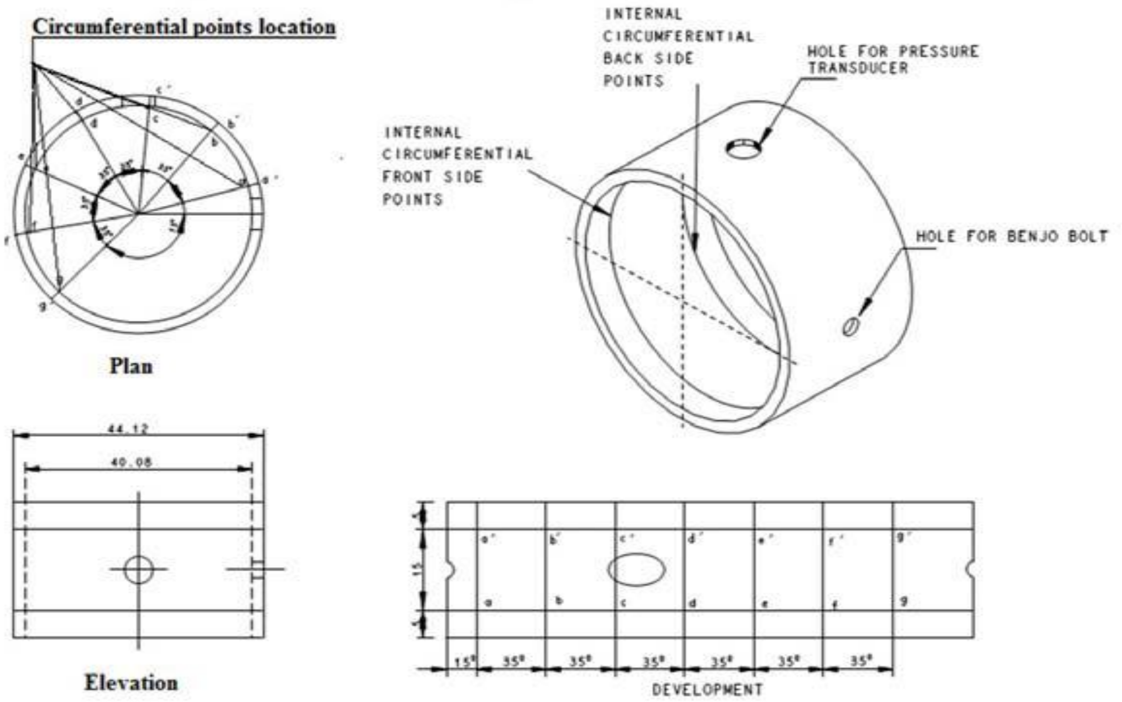
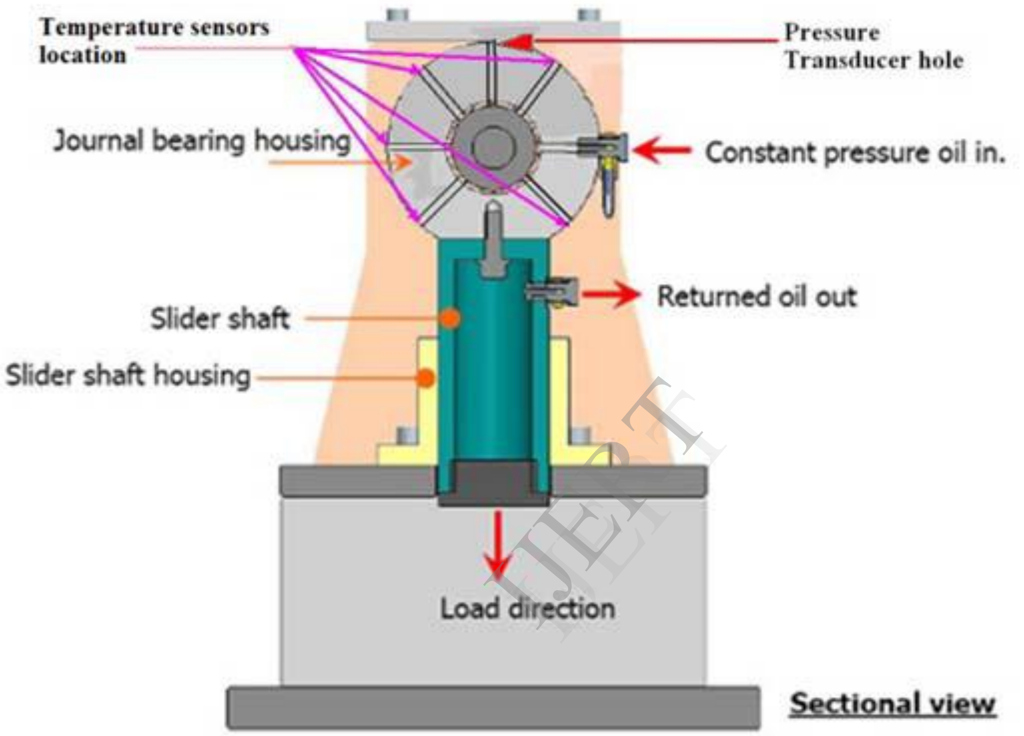


Table 2.Specification of bush & shaft.

| Specification | Outside dia.(mm) | Inside dia.(mm) | Width(mm) | Surfacefinish(Ra) |
|---|---|---|---|---|
| Bush | 44.00±0.1 | 40.00±0.02 | 25.00±0.1 | 50-75 |
| Shaft | NA | 39.900±0.01 | NA | 25-50 |

*Fig. 2 . Schematic diagram of test rig.*






**Test rig & experimental procedure**

The bushing studied has specification as per industrynorms and the shaft material and its specification ismention in Table 2. The detail sectional schematicdiagram of test-rig is shown in Fig. 2. The shaft wasdriven by DCmotor, theexperimentation was conducted to dynamic condition as itexists in engine. The numbers of samples are 3 ofdifferent surface finish. The main variables are 1. Load, 2.Shaft speed 3.Surface finish 4 Flow of oil, which are affecting ondepth of wear of lining material of bush. The numbers oftrials selected for these 3 variables are as per "Taguchimethod";it was observed as L9 orthogonal array.

**Two types of experiments werecarried out in present study:** 1)Experiment under constant static loadwith various shaft speeds is carriedout continuously for 180 min in order to clarify the effect of load, speed,surface roughness on depth of wearon lining thickness of bushing andcircumferential surface temperaturezone of bush. Three bush sampleswere slected with different surfaceroughness. The total depth of wear ismeasured .The supply of lubricant is Varied andthe temperature is measured circumferentially after stablecondition. 2) Experiment under constant shaft speed withvariable loads is carried out continuously to observe sole effect of load on depth of wear on liningthickness of bushing and circumferential surfacetemperature zone of bush.

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**Experimental Results**

Temperature change in circumferential zone

A temperature change in circumferential directionduring sliding process was investigated under variousloads and constant speed. It was observed that thetemperature rises up to 74.6o at 2400 rpm shaft speed.Particularly highest temp is observed at 3rd RTD location

i.e. T3 which is point d and d' on front and rear end ofbush and this rise in temperature is from 3-6°C incircumferential direction. The temperature rise generatedearlier in wear process and its rate of increase is greaterat higher load and higher speed. Fig. 3, 4 & 5 shows atconstant revolution speed of shaft the temperature zoneobserved circumferentially on bush for various load isnearly same.Combined effect of load, speed and surface finish ondepth of wear of lining material. The actual reading & Predicted depth of wear is shown in table no 3.

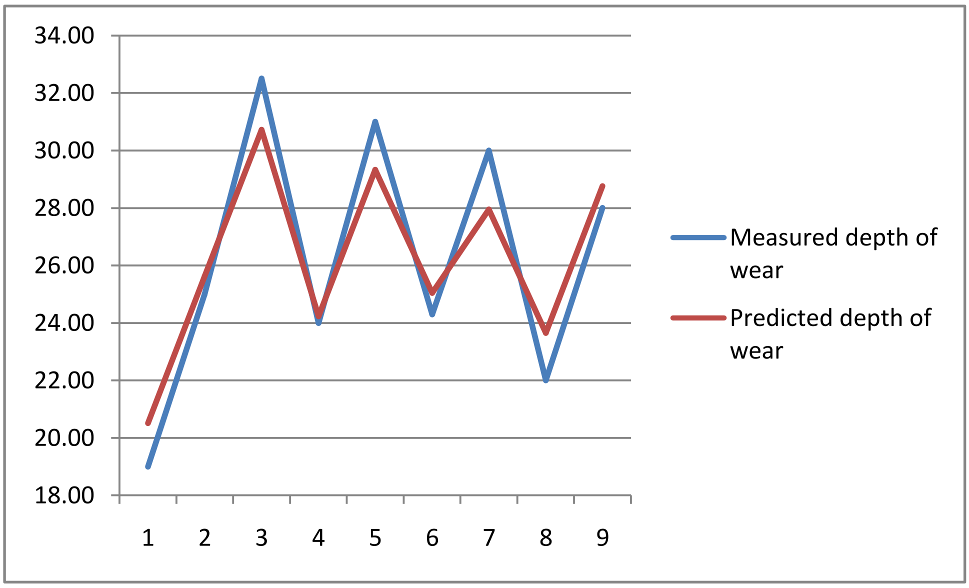
*Table 3. Comparison of measured dw in experimentation & Predicted dwp of lining thickness.*

| Reading | Wear | Load (N) | Speed (m/s) | Flow(Lit/s) | mo | m1p | m2v | m3f | dwp | dwp-dw | %error |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 19 | 98.1 | 1.043 | 0.002 | 6.4081 | 1.1666 | 1.9712 | 9.402 | 18.948 | 0.0519 | -0.2735 |
| 2 | 25 | 98.1 | 2.085 | 0.003 | 6.4081 | 1.1666 | 3.9406 | 14.103 | 25.6184 | 0.6184 | 2.4736 |
| 3 | 32.5 | 98.1 | 3.129 | 0.004 | 6.4081 | 1.1666 | 5.9137 | 18.804 | 32.2925 | -0.2074 | -0.6382 |
| 4 | 24 | 147.15 | 1.043 | 0.003 | 6.4081 | 1.7499 | 1.9712 | 14.103 | 24.2323 | 0.2323 | 0.9681 |
| 5 | 31 | 147.15 | 2.085 | 0.004 | 6.4081 | 1.7499 | 3.9406 | 18.804 | 30.9027 | -0.09726 | -0.3137 |
| 6 | 24.3 | 147.15 | 3.129 | 0.002 | 6.4081 | 1.7499 | 5.9137 | 9.402 | 23.4738 | -0.8261 | -3.3996 |
| 7 | 30 | 196.2 | 1.043 | 0.004 | 6.4081 | 2.3333 | 1.9712 | 18.804 | 29.5166 | -0.4833 | -1.6110 |
| 8 | 22 | 196.2 | 2.085 | 0.002 | 6.4081 | 2.3333 | 3.9406 | 9.402 | 22.0840 | 0.08407 | 0.3821 |
| 9 | 28 | 196.2 | 3.129 | 0.003 | 6.4081 | 2.3333 | 5.9137 | 14.103 | 28.7582 | 0.7582 | 2.7079 |
| %Average Error | | | | | | | | | | | 0.032 |



The fig 3 shows the comparision of measure depth of wear & predicted depth of wear

**Fig.3 Comparision of measured depth of wear & Predicted depth of wear**.

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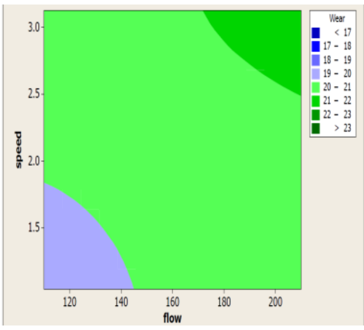
The Counter Plot of Flow & Wear is shown in fig 4.The effect of load & speed on the shaft are more as compaired to flow of lubricant.As in boundary lubrication the film is continously maintained .

***Fig.4Counter Plot Of Flow & Wea*** ***Fig.5Observation of Temp at Constant speed 500rpm***



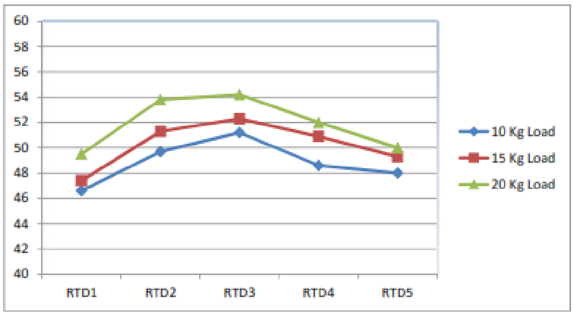
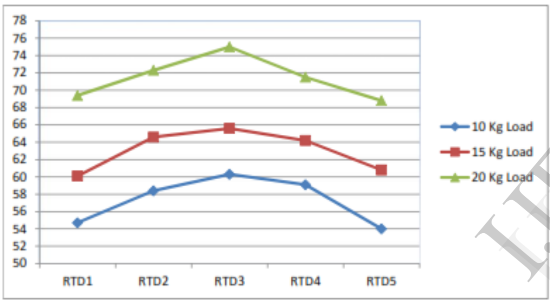




***Fig.6Observation of Temp at Constant speed 1000rpmFig7Observation of Temp at Constant speed1500rpm***



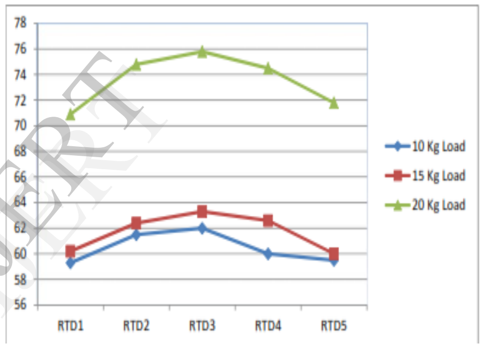
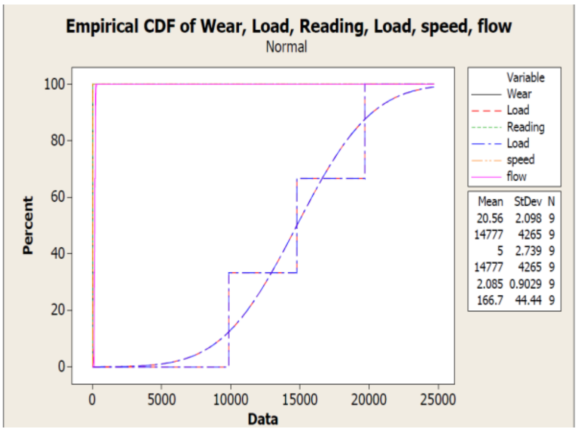
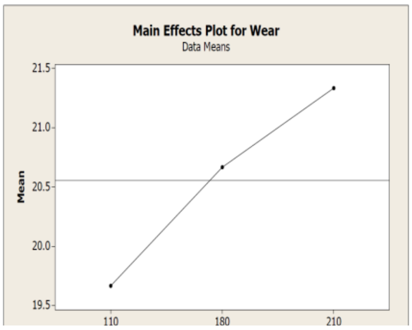




***Fig.8Emperical CDF of Wear,Load,Speed,FlowFig9Main Effects Plot of Wear***



Analysis Of Variance (ANOVA)

| | Factors | DOF | Sums Of Squares | Variance | F-Ratio | Pure Sum | Percent |
|---|---|---|---|---|---|---|---|
| 1 | LOAD | 2 | 1.833 | 0.916 | 9.824 | 1.646 | 16.985 |
| 2 | SPEED | 2 | 3.282 | 1.641 | 17.589 | 3.096 | 31.932 |
| 3 | FLOW | 2 | 4.392 | 2.196 | 23.537 | 4.206 | 43.382 |
| | Other/Error | 2 | 0.186 | 0.093 | | | 7.701 |
| | Total: | 8 | 9.696 | | | | 100.000% |

Optimum Condition and Performance

| | Factors | Level Desc. | Level | Contribution |
|---|---|---|---|---|
| 1 | LOAD | 98.1 | 1 | 0.626 |
| 2 | SPEED | 1.043 | 1 | 0.788 |
| 3 | FLOW | 0.002 | 1 | 0.850 |

Main Effects

| | Factors | Level 1 | Level 2 | Level 3 | L2 - L1 |
|---|---|---|---|---|---|
| 1 | LOAD | -25.936 | -26.769 | -26.982 | -.833 |
| 2 | SPEED | -25.773 | -26.673 | -27.24 | -.9 |
| 3 | FLOW | -25.712 | -26.551 | -27.423 | -.839 |



## RESULT AND DISCUSSION

In this experimentation different variable load, speed and Flow are utilized. Multiple regression analysis was performed to indicate the fitness of experimental measurements. Regression model obtained from depth of wear measurements matched very well with the experimental data ($R^2 > 0.85$). The level of importance of the bearing parameters on depth of wear was determined by ANOVA based on this study, the following conclusions can be drawn-

1. The optimal condition for depth of wear of lining thickness was 196.2 N Load (level 3), 3.128 m/s speed (level 3) and 0.004 lit/sec Flow (level 3).
2. The Flow of lubricating oil had a greater influence on depth of wear as compared to other two factors.
3. By comparing measured depth of wear and predicted depth of wear it is seen that average error is 0.032 %.

## APPENDIX

$d_W$ = Depth of wear of lining material (μm)
$d_{WP}$ = Predicted depth of wear (μm)
V = Sliding velocity of shaft (m/s)
.

## REFERENCES

1. Raymond G. Bayer, Marcel dekker, *"Mechanical Wear Prediction and Prevention"*, New York, pp. 1-2, 7-16,36-56,321-323.
2. J. E. Shigley, C.R. Mischke, R. G. Budynas, K.J. Nisbett, "Mechanical Engineering Design", 8th Edition, Tata McGraw Hill, pp. 599-620.
3. ASM Handbook, "*Friction, Lubrication and Wear Technology*", Vol-18, pp. 1515-1545.
4. Gwidon W. Stachowiak and Andrew W. Batchelor, "Engineering Tribology", pp. 37-48.
5. Andras Z. Szeri, *"Fluid Film Lubrication Theory and Design",* pp. 23-35, 89-102.
6. A Cameron, *"The Principles of lubrication",* pp. 25-40.
7. Bhushan Bharat and Gupta B.K., "*Handbook of Tribology: Wear, Non Ferrous Metals and Alloys*", McGraw Hill Inc., 1991, pp. 2.10- 2.21, 4.25.
8. SAE Handbook, *"Bearing and Bushing Alloys"* SAE J 459 Oct 91, pp. 10.45.
9. SAE Handbook, *"Bearing Bushing Alloys Chemical Composition of SAE bearing and Bushing Alloys",* SAE J 460 Oct 91, pp. 10.43.
10. J. P. Holman, "*Experimental Method for Engineers*", Sixth Edition, McGraw Hill Inc, Singapur, 1994, pp. 60-77.
11. Dr. B. S. Grewal, "*Higher Engineering Mathematics*", pp. 737-750.
12. Ranjit Roy, "*A Primer on Taguchi Methods*", McGraw Hill Pub., pp. 34-50.
13. Bouyer J, fillon M and Pierre-Danos I, *"Behavior of a two-lobe worn hydrodynamic journal bearing",* 5th EDF & LMS poitiers workshop, "Bearing Behavior Under Universal Operating Conditions", 5th October 2006, pp. 1-4.