Chapter 2

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2.0 INTRODUCTION
As put forth in the previous chapter, various factors characterising the wear of journal bearing application need to be considered during its design and development. In the concluding remarks, the existing gaps in relation to the following have been brought out:

(i) Manufacturing capability related data for wear performance evaluation.
(ii) Comprehensive test practices for the understanding of wear characteristics of journal bearings.
(iii) Causes of wear failure of precision journal bearings.
(iv) Integration of various design inputs with test practices and arriving at application specific design recommendations.

The significance of these studies arises due to the need for life improvement of precision small size journal bearings specific to the application in order to realise the market requirement of 'fit and forget' designs. A composite approach by analytical and experimental studies is employed in the current investigation on journal bearings in association with one of the large-scale manufacturer of two wheeler oil pumps. This chapter outlines the overall direction of the developmental task to achieve the above-mentioned goals. The configuration details of one such oil pump assembly indicating the bearing assembly consisting of journal and bush is shown in figure 2.1 (a) and (b). The oil pump is basically of the gerotor positive displacement type, number of teeth in the inner and outer rotor being 6 and 7 respectively with a displacement capacity typically in the range of 2.8 lpm at 0.15 N/mm² pressure and 4000 rpm onwards with variable gerotor thickness. Figure 2.1 shows oil flow ports together with the necessary mounting details.
2.1 AIMS AND SCOPE OF WORK

The aim of the present work is to provide more insight into the design factors of the precision journal bearing and to establish a lab-to-field correlation of wear characteristics. Accordingly, main objectives of the work are:

- **Bearing geometry analysis including clearance under mass manufacturing condition.**
- Proposal for development of improved test practices incorporating the realistic application data of bearings viz.
  1. Speed spectrum for various operating conditions
  2. Vibration spectra of the engine assembly
  3. Pressure variation of the lubrication system
  4. Oil condition of 'used' samples.
- Design and development of accelerated wear test procedure using "controlled dust" particles.
- Wear experimentation based Taguchi's methodology considering the following factors for establishing optimum bearing parameters:
  1. Sintered part density
  2. Surface roughness of bush
  3. Sintered material mix
  4. Bearing clearance
- Field data collection to evaluate the performance of present journal bearing design over a reasonably long use and correlation with experimental studies.

For achieving a totality of design improvements, associated parts like filters, rotors, used-up oil etc., too need a closer investigation. Volume and weight loss measurements, study of wear patterns of journal, bush etc., are considered essential for categorising the design.

2.2 INVESTIGATION PLAN

Based on the aim and scope described above, a summary of investigation plan as shown in figure 2.2 was prepared.
Studies on Design and Manufacturing Aspects of Precision Journal Bearings - an investigation

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(*) Equipment Used

Figure 2.2 Investigation plan
(*) Equipment Used
2.2.1 Study of Manufacturing Practices of Oil Pump Bearings
Process sequence for the manufacture of bush and journal were analysed. Sub-assembly operations for the shrink fitting of bush into the housing were studied in depth and requisite analytical models using ANSYS version 5.5 was developed. Geometry variation caused by the shrink fitting is reduced by bore burnishing operation. Parameters influencing burnishing were studied from the burnishing torpedo and bush surface finish point of view. Dynamic torque measurement and estimation of coefficient of friction helped to draw Stribeck curve applicable to the journal bearing under investigation.

2.2.2 Bearing Clearance Studies
Dimensional measurement and statistical analysis of journal and bush dimensions were done at different levels along the axial direction for the parts drawn at random from the manufacturing line. Process capability analysis was undertaken with the above data. Estimation of the resulting bearing clearance based on the following approaches was carried out:

- Numerical convolution
- Surefit law and
- Statistical analysis of piece part errors

Based on the above study, process improvement suggestions related to the mean shift were given to the collaborating industry.

2.2.3 Existing Test Practices of Oil Pumps and Bearings
The tests currently under practice by the industry were studied and they could be classified into two categories:

(i) Manufacturing line tests and
(ii) Product validation tests.

In the course of undertaking various product specific tests like leakage, oil flow, free rotation of journal, wear endurance tests, areas needing improvement like,

(i) Vibration of engine
(ii) Noise level change in the bearing assembly
(iii) Change in oil flow rate
(iv) Factors influencing the viscosity of oil flowing through the bearing
(v) Weight/volume change of the journal and bush due to usage
(vi) Change in surface finish and other geometric parameters etc.,
were ascertained. Scope for improvement in the range of tests were identified and analysed.

2.2.4 Development of Improved Test Practices

A proposal for a comprehensive wear test rig based on the following field data collected was finalised viz.,

(i) Speed spectrum
(ii) Vibration spectrum
(iii) Lubricant oil pressure variation with reference to speed and operating temperature.

Design and development of an Accelerated Wear Test (AWT) procedure with the intention to significantly reduce the bearing and oil pump testing time was undertaken. The data collected were useful in drawing a correlation between the existing test practices, wear observed from Field Run (FR) bearings and the proposed accelerated wear test.

2.2.5 Wear Experimentation Based on AWT

Wear experiments (employing Taguchi's Orthogonal Arrays) were carried out the AWT procedure based on the following factors:

(i) P/M part density of bush
(ii) Surface roughness of bush
(iii) Material mix variation for the sintered bush and
(iv) Bearing clearance.

Analysis of MEANS was done to predict optimum combination of design parameters to minimise wear. ANOVA analysis helped to predict the relative contribution of the parameters in respect of wear of bearing bushes. Recommendations for selective assembly were arrived at based on test results. Estimation of improvement in wear behaviour of bearings for the predicted optimum combination of test factors was drawn.

2.2.6 Seizure Study of Typical FR Bearings

Microscopic study of the wear debris was done based on wear debris collected from seized oil pump assemblies. The worn out bearing parts were also subjected to a surface topography study. Investigations into the surface damages and used oil were done using ferrography technique.
2.3 CONCLUDING REMARKS

Outline of work discussed in the above sections is grouped under different headings in the following chapters. These chapters are:

(i) Bearing Manufacture & Geometric Measurements
(ii) Analysis of Measured Clearance in Manufacturing Line
(iii) Existing Product Test Practices
(iv) Development of Improved Test Practices
(v) Design Recommendations Based on Wear Tests and
(vi) Analysis of Wear Data of Selected Bearings.

The chapters listed above embody appropriate methodology relevant to the topic dealt with and the results along with relevant discussions are provided. The major conclusions drawn are listed as a separate chapter towards the end of the work.