ABSTRACT

The trend in the development of product design demands products with enhanced reliability and extended MTBF characteristics. The above constraints are exclusively imposed on the product designer by the expectations of the customers. The designers are compelled to arrive at innovative solutions without restoring to costly materials and processes to improve product life. Such a scenario drives the designer to improve the performance of the critical components like bearings, joints, transmissions, etc., by appropriate optimisation techniques, Precision journal bearings are used in various engineering applications like speedometers, tachometers, oil pumps, electrical instruments, micrometers, sensors, etc. The wear life of journal bearings is influenced by several parameters like fluctuation in speed, temperature, lubrication, clearance, surface roughness of mating parts, hardness & material combination characteristics of journal and bush materials.

Quality of journal bearings used in automotive accessories like oil pumps, are critical for the trouble free functioning of the whole engine. Cylindricity error introduced in the manufacture of bushes, non-conformity of the bearing dimensions in mass produced parts with design specifications and inadvertent process mean shift in the manufacturing line will result in significant bearing clearance variations; the latter in turn affects the wear characteristics of journal bearings. Testing practices for oil pumps and hence, the bearing performance validation in manufacturing line, lack of design inputs like, variations in engine speed, engine vibration, oil condition, line pressure etc. and moreover the testing process are tedious.

The wear characteristics of the bearing under study depends upon various design parameters like the clearance, speed of operation, the surface roughness of mating parts, form errors of mating parts etc. To improve the wear characteristics of the bearing under investigation, the following objectives have been attempted in this work.

- To predict the clearance of the bearing under investigation from the measured dimensions of the bush and journal using statistical tools,

- ❖ To establish the influence of following parameters on the wear of journal bearing using Taguchi's experimental technique using accelerated wear test,

    - Bearing clearance
    - Surface roughness of the bush
    - Hardness of the journal
    - Cylindricity error of the bush

- ❖ To establish the wear life of the bearings from the collected field run vehicle pump bearings, based on the following performance characteristics

    - Noise level
    - Specific wear rate
    - Lubrication film parameter
    - Surface topography

- ❖ To compare the life of the pump under investigation with that of another pump used for similar application in another variant of the vehicle.

- ❖ To develop a questionnaire for the evaluation of pump failure and wear characteristics of the bearing and obtain, analyse feedback from the service mechanics using statistical tools.

An industry which is manufacturing such oil pumps has been chosen for the study of manufacturing data. The journal is made from aluminium alloy, die cast, machined, bored and ground. The bush is made of stainless steel, machined and ground. Both the bush and journal are processed to meet the required surface finish, dimension and geometric tolerances.

It was observed that the mean diameter of the bush was shifted to the right by 0.7 μm and that of the bush was shifted to the left by 1.38 μm. The mean clearance was shifted to the right by 1.42 μm. The clearance obtained by Monte Carlo simulation

method is ranging from 2.6 μm to 49.1 μm. It may be inferred that the clearance obtained by Monte Carlo simulation method is in close agreement with that of the numerical convolution method.

The designers, while designing may not include the variations in clearances, surface finish, speed, hardness of the journal and bush combination, error in cylindricity, etc. In this work, an attempt has been made to establish optimum combination of the four bearing parameters viz. bearing clearance, surface roughness of the bush, hardness of journal and cylindricity error of the bush. This would minimise the wear rate. An accelerated wear test (AWT) with artificially induced wear particles was selected with all other operational parameters like speed, load, temperature and lubrication maintained as per actual conditions. The selected test factors are considered to be under direct influence of the designer. Average value of signal to noise ratio was computed to perform the "analysis of means" of the bearing parameters. Variance analysis was done to understand the relative effect of various test factors on the wear of the bush and journal. From the optimum parameters which minimises the weight loss, an empherical equation was developed using MATLAB.

Optimum values of the factors were arrived at as under:

Surface roughness at bearing bore	: 0.4 μm
Material hardness of the journal	: 280BHN
Bearing clearance	: 10 μm
Cylindricity error of the bush	: 1 μm

Among the test factors considered, the influence of bearing clearance factor on the weight loss of the bush is relatively significant.

In order to check the performance of the pumps which mainly depend on the wear of bearings during actual usage, a sample of pumps fitted in the vehicles which were run for a kilometer range of 25000 to 55000 were collected. The following tests were conducted to evaluate their performance characteristics.

- Noise level measurement
- Weight loss estimation
- Wear particle extraction
- Oil viscosity measurement
- Percentage flow rate

An attempt was made to compare the wear life of a similar pump fitted with a journal bearing made of sintered steel bush and steel journal. The parameters like percentage flow rate, noise level, vibration pattern, geometry, average surface roughness value, lubrication film parameter, specific wear rate, journal and bush weight and volume loss of journal and bush of the pump indicate the wear pattern of the journal bearing. Weight and volume losses and the specific wear rate of typical field run samples were analysed. Based on comparative study of the pumps, wear life was estimated.

The wear life was estimated to be around 30000 km for the steel journal on aluminium alloy bush pump and 60000 km for the steel journal on steel bush pump.

Used lubricating oil samples specific to service kilometers and samples from wear experiments were subjected to ferrography analysis. As wear particles caused by specific wear modes have distinctive characteristics, predominant wear mode identification and associated wear contribution are feasible from the ferrography results.

The bearing assemblies received from the field were tested for their performance conformity. Subsequent disassembly testing helped to derive additional correlation based on surface finish and wear pattern. Dimensional, geometric and surface roughness measurements were resorted to for the analysis and the wear pattern change was analysed.

Running-in phase starting from initial run of the vehicle seems progressing through 25,357 km (an equivalent of 18.26 million revolutions). It was observed that the journal bearing at the end of "running-in" phase shows an improvement in surface finish when

compared to the finish in the unworn portion. The surface topographic view of the journal shows the start of severe abrasive wear phase.

In order to gain an insight in to the maintenance aspects of the bearings and the pump assembly leading to wear of such pumps, a survey was conducted from one of the important customer segment namely the service mechanic of the two wheelers. A questionnaire was developed focusing on the impact of oil pump failure on engine performance and the influence of pump bearing wear characteristics on pump failure. The questionnaire included eleven questions covering the various aspects of the bearing assembly viz. maintenance by customers, noise, vibration and temperature rise in due course of usage of the vehicle. Responses received from the customers were analyzed.

From the above survey, it could be inferred that the customers are not aware that the absence of periodic pump maintenance could be a major contributor in engine seizure, which calls for serious efforts to educate them. However, the link between the premature failure of the engine and pump failure is well understood by the customers. The results of the survey agree with the predicted life of these pumps.