FATIGUE ANALYSIS OF FLEXURE BEARING FOR LINEAR COMPRESSOR

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Abstract

In new technology, the flexure bearing is used in linear compressor to improve the efficiency by eliminating the wear, friction and vibration losses with the maintenance free operation. Also used where the precision movement is required.

In the present work, the design methodology of a flexure bearing has been studied firstly by studying parameters of flexure bearing, then the finite element program is used to analyze the fatigue life performance of flexure bearing. Furthermore, the experimentation is carried out and validity of final element program has been provided by experimentation data

Keywords: **Flexure bearing, Finite element method, linear compressor, vibration exciter, CATIA, fatigue life, equivalent stress, stiffness.**

Introduction

A bearing is rotating component witch is placed between two parts to allow them to move easily a flexure bearing a just that it allows to part to move with each other with no trouble. In traditional reciprocating type of compressor uses a conventional type of bearing which having disadvantages of backlash, higher friction and more wear. In order to over come this limitations, the linear bearing also called as flexure bearings are used campers to conventional bearing , flexure bearing are very simple to manufacturing and also easy and cheap to replace with less maintenance cost.

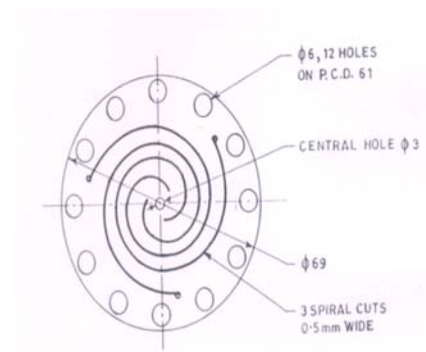


Fig.1 Spiral arm Flexural Bearing

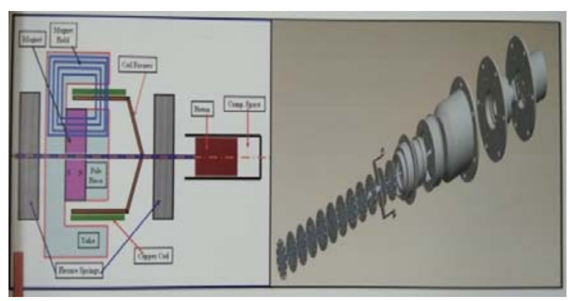


Fig. 2 : Schematic assembly of the flexure bearing

A flexure bearing is designed for specific applications. This design can usually be done with the advanced design tools like FEA. With advent of computer FEA has been most suitable tool for engineering analysis where conventional approach is not suitable, geometric complexity are involved.

A flexure bearing play important role in applications such as micro-manufacturing and precision methodology requires bearings with low friction, high accuracy, repeatability, smooth motion with almost no wear also with no lubrication requirement . a flexure bearing have many advantages including they do not jitter or wobble as they are fixed into the place

Literature survey

1. Maruti khote, et al had Studied the design and geometrical optimization of flexure bearing using FEA and developed the design chart for spiral flexure bearing as well as linear flexure bearing .

2. Lei peny et al had used strain energy principle to represent a universal analysis model of axial stiffness and radial stiffness of flexure spring for the design and optimization of any geometry of flexure spring and then they had obtained FEM results for validation.

3. Simon Amoedo et al had developed graphical designed method, by comparison was made between axial and radial stiffness, the natural frequency, and the maximum induced stresses with the finite element analysis results. And its validation to theoretical results, for the selection of the flexure bearing geometrical parameters based on pre – determined geometric and material constraints.

4. A.S. Gaunekar et al had conducted non linear static finite element analysis of flexure discs for a specific spiral profile. They had developed design graphs for three parameters viz. maximum stress, radial stiffness and axial stiffness and normalized axial displacement. They had done experimentation using a fibre – optic interferometer technique and a simple dead weight method and then validate the FEA results.

5. Prasad R. Bhokare et al had designed developed and tested the electromagnetic vibration exciter with flexure bearing to generate the friction less vibration such vibrations can be used to determine the structural, dynamic and fatigue characteristics of materials. Electrodynamics vibration provide a testing platform for transportation simulation, mechanical shock, mission profile and environmental stress screening they had optimized design of flexure bearing by considering the design parameters as spiral angle starting radius of spiral, ending radius of spiral and thickness of flexure.

6. A.S. Gaunekar et al had designed and developed a high Precision Programmable Focusing Mechanism (PFM), to achieve high position repeatability and overall reliability by combining the voice coil motor and flexure bearing , which is used to move a lens relative to another fixed lens for the altering the focus of the optical system . they had done FEA analysis to examine the characteristics such as axial stiffness and radial stiffness and extent of a parasitic rotation under the axial displacement they had used electromagnetic FEA to optimize voice coil motor.

7. Amit Jomde et al had analyzed the parameters of flexure bearing which made up of beryllium copper UNSC 17200 used in linear compressor . They had utilized FEM tool to fined equivalent stress and stiffness and they had optimized parameters on the basis of performance and service life at lower operating stresses and higher stiffness as per requirement

8. Rajesh V.R. et al had designed flexure bearing for the cryocooler. They had focused different parameters of flexure bearing viz spiral sweep angle, spiral slot width, number of spirals and disc thickness. To find the stresses and fatigue damage for three different materials viz beryllium copper, spring steel and stainless steel. They had concluded maximum stress is developed at both the ends of spiral arms and curling is introduced at ends to minimize the stress concentration.

Experimental setup

A elector magnetic device called as vibration exciter is used to produce mechanical vibrations, which are used to find the fatigue life performance of flexure bearing. In vibration exciter , the electrical a.c signals are transformed into mechanical vibrations with required cycles of excitations at the required frequency . To find the fatigue life performance of flexure bearing a different cyclic excitation forces (1N, 2N, 3N, 4N and 5N) are produced by exciter.

In order to measure the output characteristics of flexure bearing a taste setup is developed. A schematic drawing of experimental setup for the testing of flexural bearing is shown in figure3. It consist of power amplifier, an oscilloscope , a signal generator and a charge amplifier , electromagnetic device along with the actuator . The vibration signals are generated from signal generator, amplified it via the power amplifier and finally utilized to control the vibration amplitude and frequency of the shaker. Accordingly, the electromagnetic device will under goes excitations and generate output voltage signal which is recorded to dSPACE software. Displacement signal will be measured by LVDT (Linear Variable Differential Transformation Transducer) and then shown on the monitor of the computer. he photo of experimental system for testing of flexural bearing is shown in figure4.

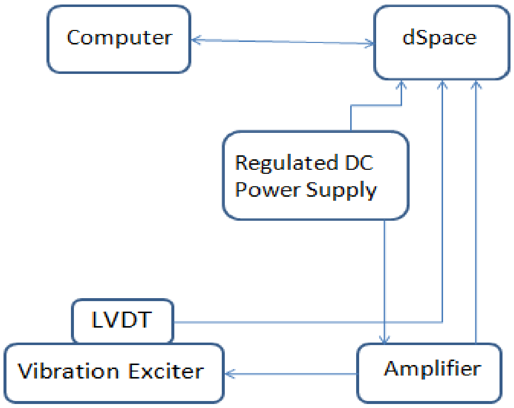
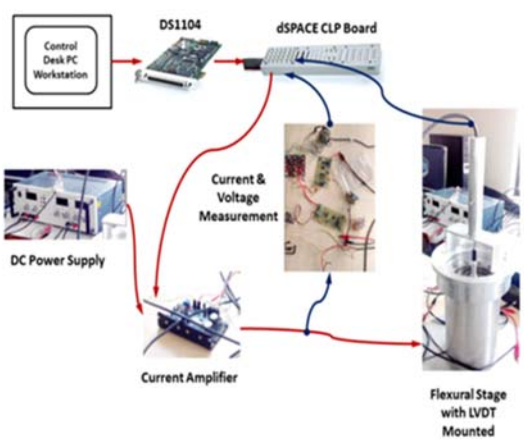


Fig 3 Schematic diagram for experimental setup

Components of flexural bearing test setup
1 Linear Actuator
2. Base Plate
3. Top Plate
4. Magnet Support
5. Coil Holder
6. Inner Spacer
7. Outer Spacer
8. Flexural Spring



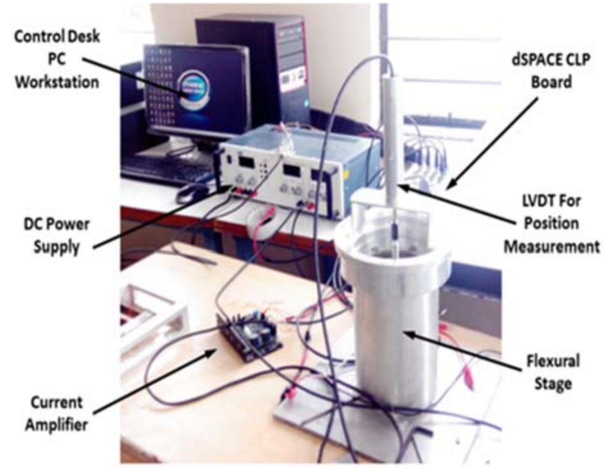


Fig. 4 Experimental setup with dSPACE DS1104 Microcontroller

Flexural bearing specifications
1 Frequency F = 50Hz
2. Loads = 1N. 2N, 3N, 4N and 5N
3. Inner Diameter of Spiral (ID) =130mm
4. Outer Diameter of Spiral (OD) =119mm
5. Thickness of Disc =1 mm
6. Width of Disc =130mm
7. Spiral Angle =360^0

Material properties of spiral arm flexural bearing: –
Beryllium copper alloy Becu 17200
Density = 8100 Kg/m^3
Young's Modulus = 130 GPa
UTS = 678 MPa
Poisson's Ratio = 0.3
The methodology developed for the experimental tasting is in adequate in the predicting fatigue life characteristics of the flexural bearing under the different load condition with constant of frequency of the motion i.e. 50 Hz. So that the arm flexure bearing are subjected to alternating stresses at a frequency 50 Hz that is operating frequency of linear compressor. The Fatigue life of flexure bearing depend upon spiral profile , diameter and thickness of flexure bearing and also upon the working load . The flexure bearing act as a stiff support in radial direction and spring support in axial direction . A spiral flexural bearing system used in linear compressor is shown figure4.

Fig 4 flexure bearing

The significant parameters of flexure bearings are diameter, spiral angle, spiral width , ID, OD etc

Finite element analysis of flexure bearing:

CAD model of flexural beam were built using CATIA software. The each unit is in the form of a thin flat metal disc having three spiral slots, yielding three spiral arms which bear the radial and the axial loads. Each spiral sweeps an angle of 360º.The outer diameter of disc is 130 mm and P.C.D. of outer clamped holes is 119 mm. The central hole is having 10 mm diameter while outer clamped 12 holes having diameter 5 mm and thickness of disc is 1 mm with depth of cut of the spiral slot as 1.5mm. The starting radius of spirals is 4 mm and ending radius is 26.5 mm. All these three spiral slots are placed at an angle of 120^0.

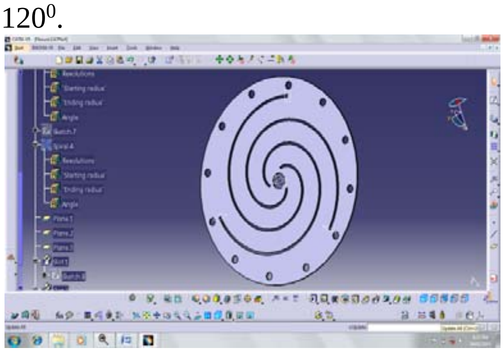


Fig 6 CAD Model of Flexural Bearing

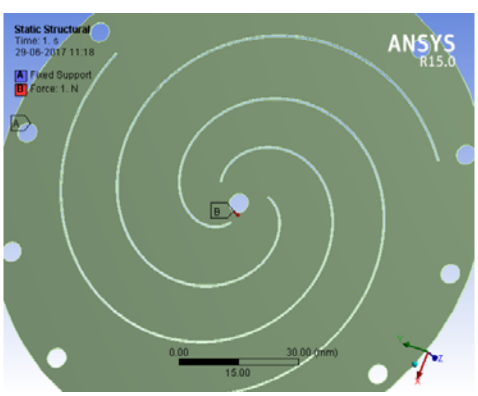


Fig 7. ANSYS Model

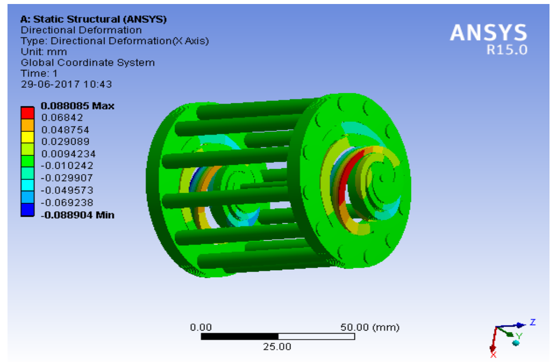


Fig 8. Directional Deformation(X-axis)

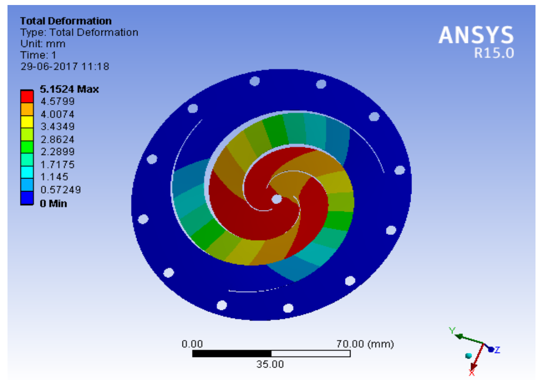


Fig 9. Total Deformation

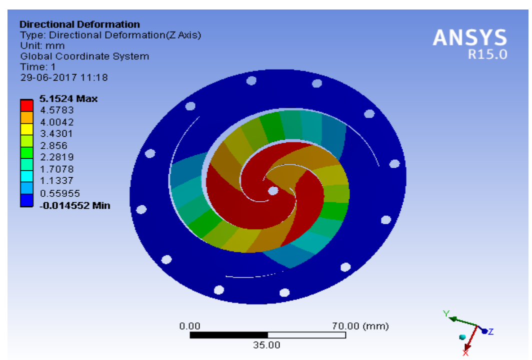


Fig 10. Directional Deformation (Z-axis)

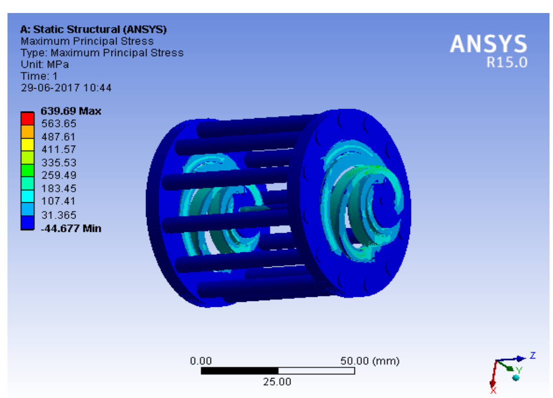


Fig 11. Maximum Principal Stress

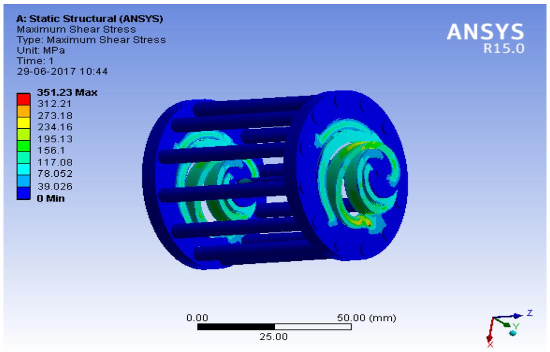


Fig 12. Maximum Shear Stress

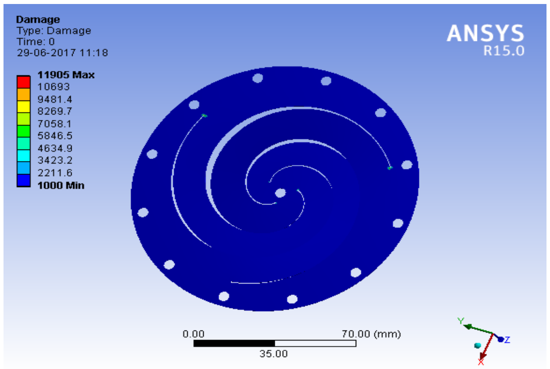


Fig 13. Damage.

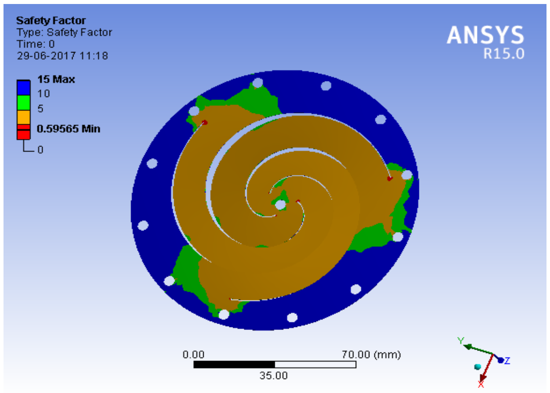


Fig 14. Factor of safety

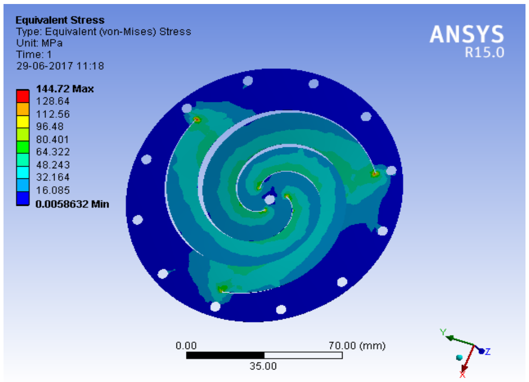


Fig. 15. Equivalent Stress

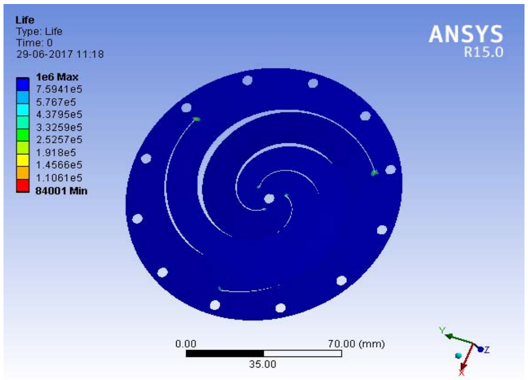


Fig 16. Life at 1N Force

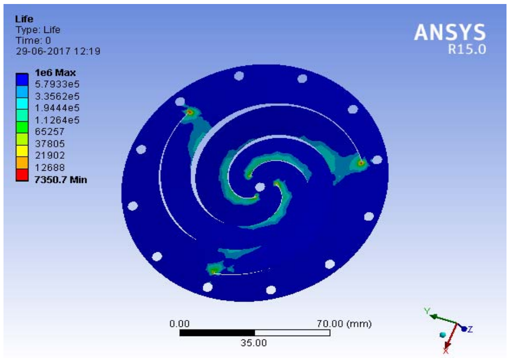


Fig 17. Life at 2N Force.

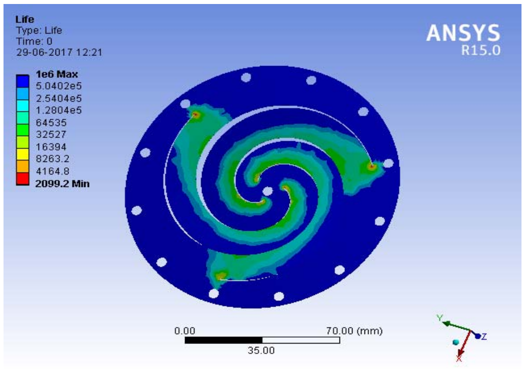


Fig 18. Life at 3N Force.

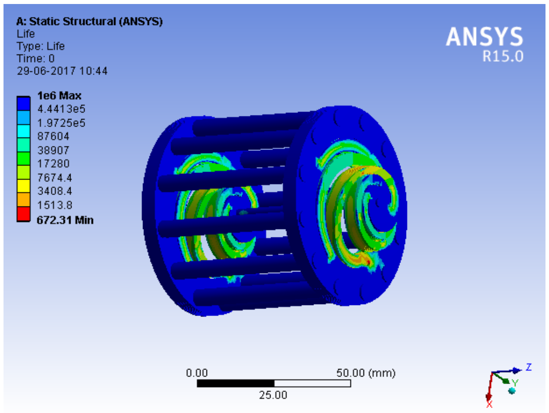


Fig. 19. Life at 4N Force

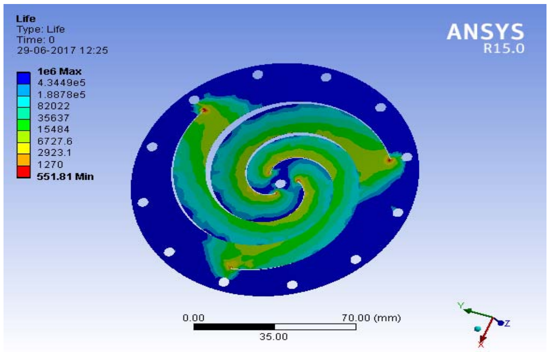


Fig 20. Life at 5N Force.

Experimental validation of FEA results

a. Force and displacement curve

The experimental readings are obtained by keeping input voltage 0.5V, 1V and 2 V respectively with varying the frequencies from 1Hz to 80 Hz at an interval of 1 Hz and plotted by using MATLAB program and dSPACE .

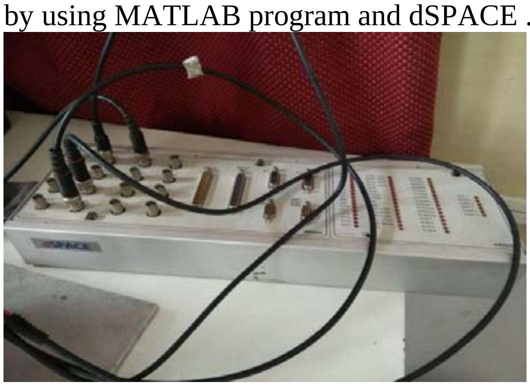


Fig 21. dSPACE

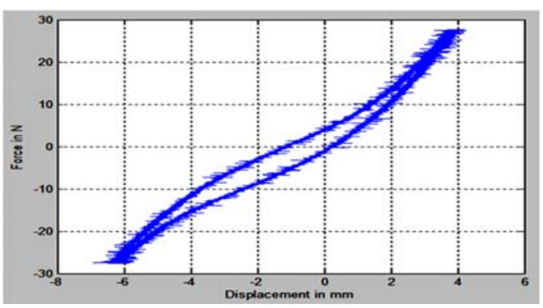


Fig22. Force vs displacement for 1Hz

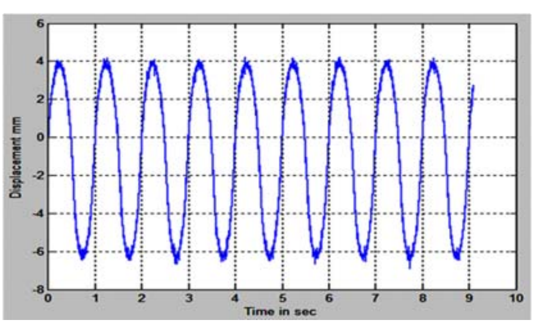


Fig23. Displacement vs time for 1Hz.

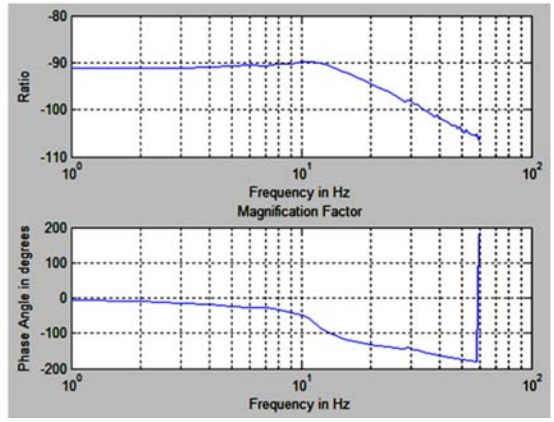


Fig24. Graph of Ratio V/s frequency and phase angle V/s frequency at input 2 volt and frequency range 1 Hz to 60Hz.

From the graph (figure 24) at ratio (output voltage or force to the input displacement) -90 the frequency is $10^{1.081}$ Hz = 12.05 Hz and at ratio -106.4 the frequency is $10^{1.77815}$ Hz = 59.99Hz

From the graph, the phase angle is 0 at frequency 1 Hz and reaches at 180^0 at frequency 60 Hz. The variation in phase angle is because of damping. As if there is no damping (damping, ζ=0) the phase angle is either 0^0 or 180^0 and at resonance the phase angle suddenly changes from 0^0 or 180^0. Here the resonance frequency is 60 Hz.

b. Fatigue life Estimation.

The experimental readings are obtained by keeping input voltage of 1V and frequency of 50Hz with different load viz 1N , 2N, 3N, 4N and 5N , to determine the fatigue life of flexure bearing mentioned previously . Experiments are conducted and failure of the bearing may be in terms of small crack, complete breakage is observed. Table below explains the comparison of experimental and FEA results and shows a close matching between each other.

Table 1RESULT TABLE

Sr. No.	Force	Frequency	Experimental Life (no of cycles)	FEA Life	
				Maximum	Minimum
1	1	50	7.5×10^5	7.5941×10^5	84001
2	2	50	5.9×10^5	5.7933×10^5	7350.7
3	3	50	4.8×10^5	5.0402×10^5	2099.2
4	4	50	4.5×10^5	4.4413×10^5	672.31
5	5	50	4.1×10^5	4.345×10^5	551.81

Conclusion

A design methodology is developed to analyze the fatigue performance of flexure bearing under five different load conditions .

In this study , a typical shape of flexure bearing is designed , modeled and take experimentation result to compared the FEA results for validation . The fatigue failure is observed at the starting of spiral arm and the end of spiral arm in the form of crack and also the complete breakage of arm at the end and starting . From the above table we are concluded that as a force increases the fatigue life performance of flexure bearing reduces.

Future Work

Using this experimental setup , one can find frequency , stiffness and fatigue life of coated flexure bearing , and also find the behavior of flexure bearing for various design parameters of flexure bearing and compare the result of ANSYS . Create the design data of flexure bearing.

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