FE Analysis Of Flexural Bearing For Linear Compressor

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Abstract : Flexure bearing is a new concept and used for precision applications such as Programmable focusing mechanism (PFM), linear compressor etc. These bearings are compact and inexpensive.

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

This paper deals with the study of flexure bearings in linear compressor and makes theoretical analysis on it to calculate axial stiffness, radial stiffness and parasitic motion. Using software's like CATIA and PROE ,modeling of flexure bearing done. Also make FEM analysis on it by using Ansys software. Then compare result of theoretical and FEM analysis. And lastly, this project considers the fatigue life criteria for flexure bearing and tries to optimize it. Gaurenkar have made design calculation and FE Analysis for flexure bearing to make appropriate model. This bearing contains three slots having 120° apart and 12 peripheral holes are used to clamp the disc rigidly onto a support structure. One central hole made for movement of shaft.

Keywords-Flexure bearing, CATIA model for flexure bearing, Axial stiffness, Radial stiffness, FEA analysis.

Introduction

Advanced engineering applications such as µ-manufacturing and precision metrology requires bearings with low friction, high accuracy, repeatability, smooth motion almost no mechanical wear with no lubrication requirements.

In addition they are require to be compact, light weight and in expensive. Flexure bearing offers these advantages.

A Simplest **flexure bearing** is a hinge made by attaching a long strip of a flexible element to a door and to the door frame. Another example is typical

turbines are often supported on flexible shafts so an imperfectly-balanced turbine can find its own center and run with reduced vibration.

Basic ideas of the finite element method originated from advances in aircraft structural analysis. "In 1941,Hrenikoff presented a solution of elasticity problems using the frame work method". Courant's paper, which used piecewise polynomial interpolation over triangular sub regions to model torsion problems, appeared in 1943. Turner derived stiffness matrices for truss, beam and other elements and presented their findings in 1956. The term finite element was first coined and used by Clough in 1960.In early 1960 engineers used the method for approximate solution of problems in stress analysis, fluid flow, heat transfer and other areas. In late 1960s and early 1970s FEM was applied to nonlinear problems and large deformations [8][9]

Peculiar Applications Of Flexural Bearing

The Flexural bearing is new concept and there are very precision applications to understand concept of flexural bearing.Few of them are explain as follows:

1Novel Rotary Flexural Bearing
2.Linear Bearing For Linear Compressor
3.Programmable Focussing Mechanism (PFM)

Proposed Work

Simple analytical methods are inadequate in predicting the operating characteristics of the flexure bearing due to the mutual coupling effect between the three flexural arms making up the bearing. Use of finite element analysis (FEA) method in tackling such a geometrically non-linear problem thus becomes indispensable. FEA has been conducted with a view to examine, apart from the stress distribution, characteristics such as axial stiffness, radial stiffness and extent of parasitic rotation as a function of axial displacement.

First Phase

- Design of flexural bearings by traditional method
- Determination of parameters of flexural bearings such as axial stiffness, radial

stiffness, parasitic motion (linear or rotational)

Second Phase

- Dynamic Modeling and simulation of Flexural Bearing considering linear compressor application
- Finite Element Analysis of Flexural Bearing
  - Static Analysis
  - Dynamic Analysis

Third Phase

- Optimization of Flexural bearing considering criteria of long fatigue life

Literature Survey

Ajit S. Gaunekar, Gary P. Widdowson, Narasimalu Srikanth, Wang Guangneng paper states that Programmable Focusing Mechanism (PFM) is one of the application of flexure bearing in which one is moving lens and one is fixed lens and the position of moving lens is detected by LVDT.The moving lens is affixed in a cylindrical tube 'which is suspended by two flexure assemblies. The space between two flexures is taken by small voice coil motor which actuates the moving lens. Flexures offer incomparably high repeatability of motion since motion is enabled through elastic deformation of the material [1]

Zhao S-B ,**H.P. Luo, B. Zhang, Z.X. Zhou** paper states that because of the bearing subjected to cyclic stress condition, the fatigue problem must be taken into consideration at the design stage in order to have bearing a long lifetime. Generally titanium is used as material of bearing[10][4].

H.P. Luo, B. Zhang, Z.X. Zhou, paper states an important and challenging research topic has been to design m-machines or m-devices that are capable of micromanipulation, precision motion devices and 3-D m-manufacturing at the nanometric accuracy level. Hence, this study proposes a new concept of bearings i.e. flexural bearings or suspension systems[4].

Ajit S. Gaunekar[1] paper states that for linear compressor in which a typical unit of a flexure suspension system is shown in Figure 1. Each unit is in the form of a thin flat metal disc having three spiral slots, yielding three spiral arms which bear the

1. Fatigue strength

Each arm of the flexure disc due to reciprocating movement is subjected to alternate stresses at operating frequency of the linear motor. For a given axial displacement, the location and the magnitude of the maximum stress in a disc are dependent upon the spiral profile, diameter and thickness of the disc.

2. Radial stiffness

radial and the axial loads. Each spiral sweeps an angle of 480^o. In the present work, twelve peripheral holes are used to clamp the disc rigidly onto a support structure. These are slightly oversized with respect to the bolt size to ensure free radial positioning, in order to account for any misalignment between the concerned mating parts. The central hole in the flexure allows for fitting of the shaft snugly. Small holes have been provided at the end of the spiral slots to relieve stress concentration.Sufficient numbers of flexure discs are stacked, together with spacers between consecutive flexures, to obtain the desired axial and radial stiffness. Two such stacks are used for dynamic stability. Unlike the helical spring (low radial stiffness) which has a buckling tendency, the flexure spring has very high radial stiffness compared to the axial stiffness. Generally, Beryllium Copper or Stainless steel is used for manufacturing the flexure bearing.[1]

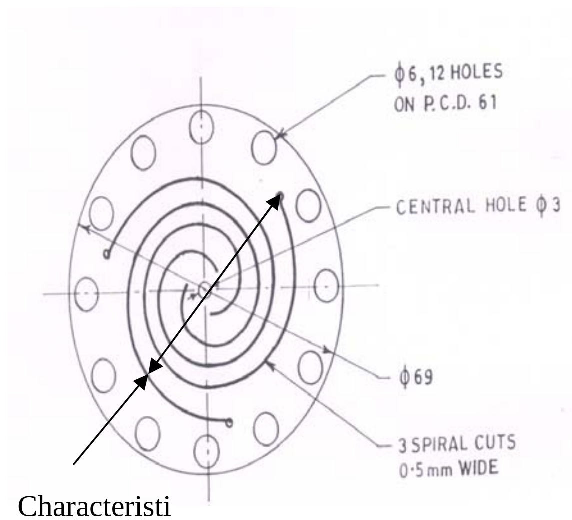


Fig 1 Typical flexure unit of the suspension system

Design requirements

In general the flexure bearings have a threefold design requirement viz. fatigue strength, radial stiffness and axial stiffness.

Design requirements of compressor flexure bearing

The radial stiffness of the flexure bearing assembly (Figure 2 (a)) should be high enough to support the clearance seal under the effect of the suspended mass which comprises mainly of the piston-shaft sub assembly, coil and coil former. In order to evaluate the radial stiffness requirement for each of the flexure discs that constitute the two stacks of the whole bearing assembly, a simplified model proposed andpiston deflection is formulated.shown in Figure 2 (b) has been used.[1]

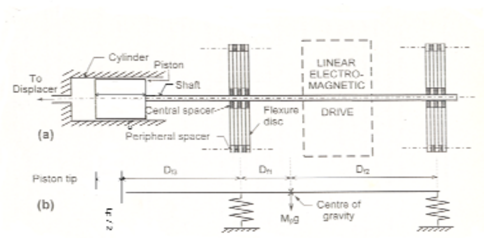


Fig.2 Assembly of the flexure bearing a. Schematic diagram b. Simplified model

T.R.Chandrupatla,A.D.Belagundu, Nitin Gokhale, Sanjay Deshpande books states basic ideas of the finite element method originated from advances in aircraft structural analysis. In 1941,Hrenikoff presented a solution of elasticity problems using the "frame work method". Courant's paper, which used piecewise polynomial interpolation over triangular sub regions to model torsion problems, appeared in 1943. Turner derived stiffness matrices for truss, beam and other elements and presented their findings in 1956. The term finite element was first coined and used by Clough in 1960.In early 1960 engineers used the method for approximate solution of problems in stress analysis, fluid flow, heat transfer and other areas. In late 1960s and early 1970s FEM was applied to nonlinear problems and large deformations [8][9]

Discussion

Design a flexure bearings are a specialized area and requires applications specific approach. Geometrical intricacies, special components, materials and non linearity in behavior of components demand the use of advanced analysis tequnique.

Previous design method shows analytical expressions to determine bearing performance and determination of stiffness of bearings in axial and radial direction. But in actual practice it is difficult to apply these conventional analytical expressions and has limitations due to assumptions made is derivation of these. Hence it is necessary to analyze the system using commercialize Finite element modeling softwares such as Abaqus, Ansys etc. Dimensions derived from above analytical expressions are to be utilized to develop 3D model of flexural bearing and compressor system. After development of geometric model finite element mesh is to be created and appropriate boundary conditions are to be imposed. Present work can be summarized in analyzing the linear compressor and flexural bearing system in following tasks

- Static analysis of flexural bearing set-up to determine axial and radial stiffness, pay load carrying capacity, stress distribution etc.
- Modal analysis of developed FE model to determine its natural frequencies
- Transient analysis of FE model
- Harmonic response or Frequency response of flexural bearing system

Knowing modal frequencies, harmonic response is necessary to deveop second order mathematical model of proposed system. This mathematical model will help in further development of control system and improving performance of compressor to suit varying load conditions.

FEA analysis of the flexure bearing for specific application shall give an opportunity to model analyzes and validate this special type of bearing.

Catia Model Of Flexure Bearing And Ansys Assembly Of Linear Compressor:-

In Catia software , a proper model of flexure bearing with proper dimentions as mentioned above made.Now to calculate axial stiffness and radial stiffness, used analysis software Ansys.

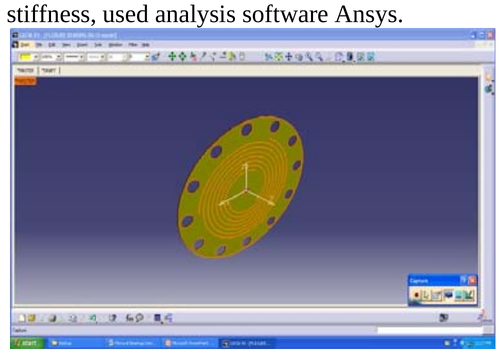
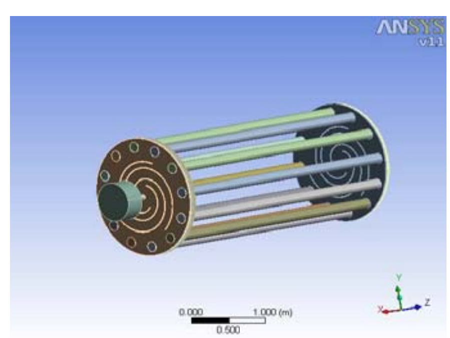


Fig. 3 Catia Model For Flexure Bearing

a flexure bearings In Ansys we have made assembly of linear compressor with flexure bearing in front and back stack.



Ansys Assembly Of Linear Compressor

Analysis Of Flexure Bearing in ANSYS-

In Ansys v 11 we calculate maximum principal stress, maximum shear stress, equivalent stress for axial loading for force 100 N . Following are the results taken from Ansys which are generated by solver for axial loading. Similarly,we are calculating results for radial loading.

1)AXIAL LOADING FOR 100N :-

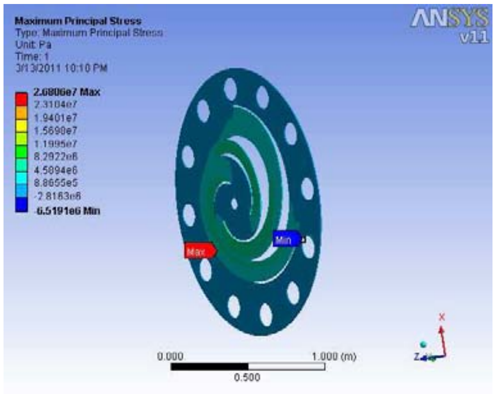


Fig. 6Maximum Principal Stress

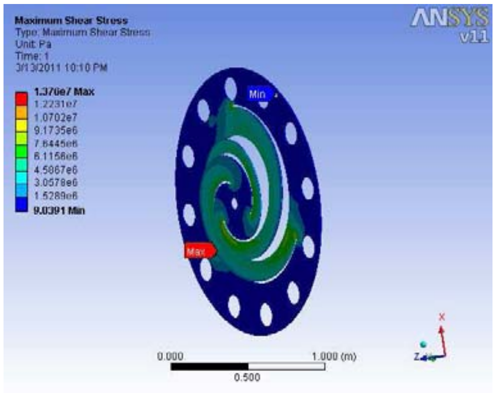


Fig.7Maximum shear Stress

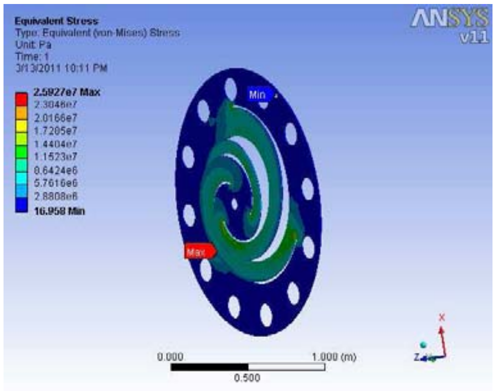


Fig.8 Equivalent Stress

2)RADIAL LOADING FOR 100N-

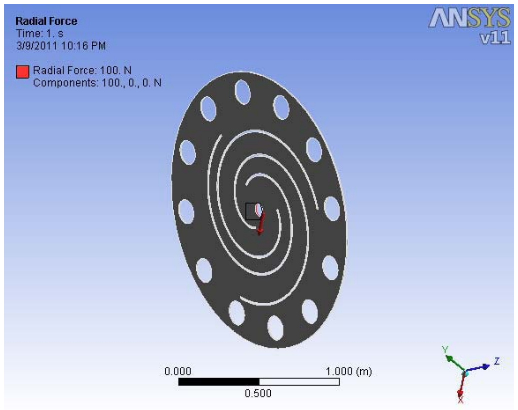


Fig. 9 Radial Force

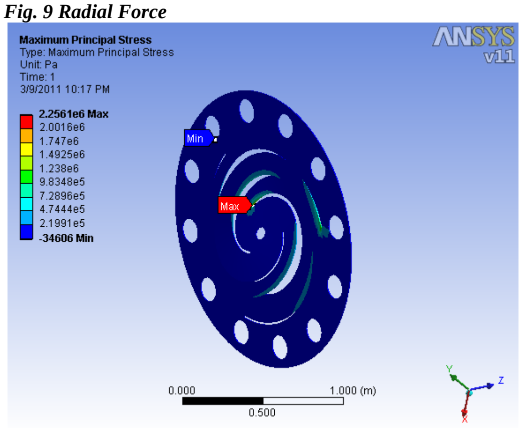


Fig. 10 Maximum Principal Stress

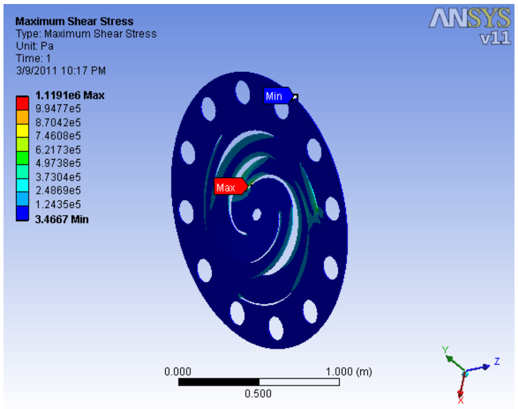


Fig.11 Maximum Shear Stress

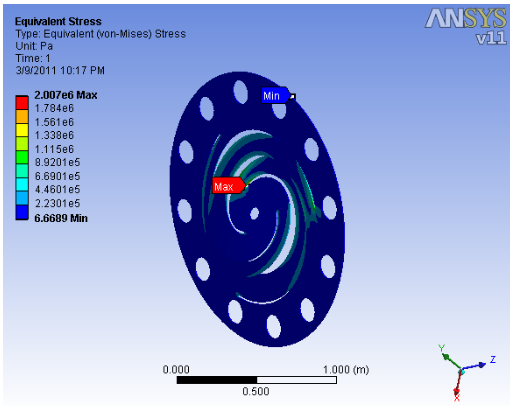


Fig.12 Equivalent Stress

Material Data

1)Copper Alloy

Structural

Young's Modulus 1.1e+011 Pa
Poisson's Ratio 0.34
Density 8300. kg/m³
Thermal Expansion 1.8e-005 1/°C
Tensile Yield Strength 2.8e+008 Pa
Compressive Yield Strength 2.8e+008 Pa
Tensile Ultimate Strength 4.3e+008 Pa
Compressive Ultimate Strength 0. Pa

Thermal

Thermal Conductivity 401. W/m·°C
Specific Heat 385. J/kg·°C

Electromagnetics

Relative Permeability 1.
Resistivity 1.724e-008 Ohm·m

2)Aluminum Alloy

Structural

Young's Modulus 7.1e+010 Pa
Poisson's Ratio 0.33
Density 2770. kg/m³
Thermal Expansion 2.3e-005 1/°C
Tensile Yield Strength 2.8e+008 Pa
Compressive Yield Strength 2.8e+008 Pa
Tensile Ultimate Strength 3.1e+008 Pa
Compressive Ultimate Strength 0. Pa

Thermal

Specific Heat 875. J/kg·°C

Electromagnetics

Relative Permeability 1.
Resistivity 5.7e-008 Ohm·m

By using above material data we are getting some graphs for axial and radial force.

Fig.13 Ansys Model For Flexure Bearing

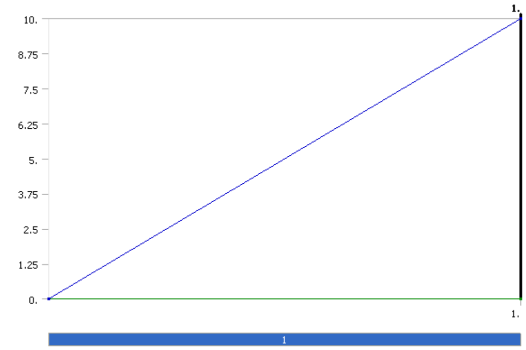


Fig.14 Model > Static Structural > Axial Force

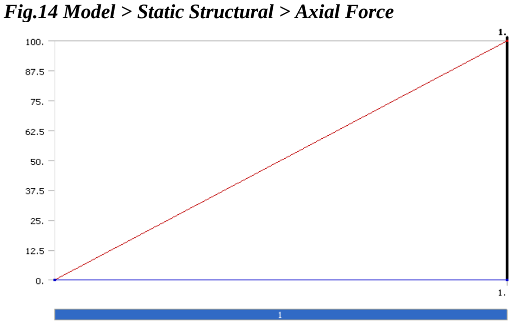


Fig.15 Model > Static Structural > Radial Force

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