Elastic Behavior of Various Flexure Bearing Materials for the Application of Free-Piston Engine Generator

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Flexure springs are known for their long service life and maintenance-free operation. Previous researchers were focusing on flexure design and optimization intended for the application of cryocooler and stirling engine. In this investigation, a concentric spiral flexure bearing with 76mm thickness was designed and fabricated with three different materials. This fabrication will focus on a free-piston engine application by looking at its elastic behaviour through static loading for a range of thicknesses. The fabricated designs were subjected to static loading experiments to validate the FEA model through comparison of axial load displacement which was set at 10% variation validation. It is found that titanium alloy material produced the most elastic design. In terms of thickness, it is possible to have flexure bearing as thick as 2mm for titanium alloy while both AISI4140 and SS316 the measurement should be 1.5mm or lower.

Keywords: *flexure bearing; axial strength constant; energy storage;*

1. INTRODUCTION

Bearings are used to allow the relative motion between the two surfaces. A flexure bearing is a spring which allows relative motion by bending a load element. They are often compact, lightweight, have very low friction, and higher life cycle. Rawlings and Miskimins [1] showed that the use of flexure springs reduced the price and doubled the life of small cryocoolers. Flexure bearing provides a stiff support in radial direction and act as a weak spring in axial direction.

The wide application of the flexure springs in power systems was initiated in the mid-1980s until 1990s which was focused mainly around linear compressors mechanism for cryogenic applications [2]. Oxford University proposed the application of flexure bearing for cryogenic technology [3]. Since that, flexure bearing application mainly has been used for cryocooler system although other applications had been proposed [4, 5] .

To emulate the previous research, a 76mm design flexure bearing with a concentric spiral is produced and fabricated with three different materials mainly; titanium alloy, stainless steel and steel alloy. Perhaps this material selection investigation will open a new frontier to understand free-piston engine application at their elastic behaviour through static loading and for various dimension thicknesses.

2. METHODOLOGY

Figure 1 shows research methodology flowchart. The main scope of this research were design process, mesh sensitivity analysis, parametric load application and experimental validation.

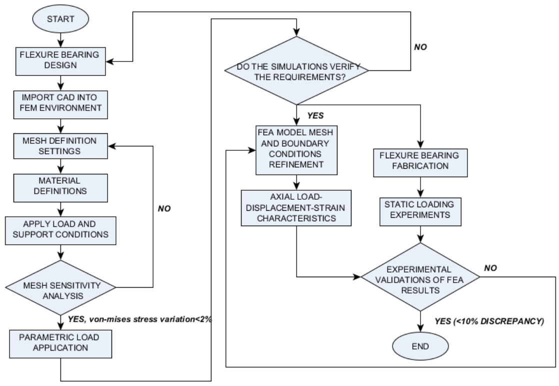

Figure 1 Flowchart of the research methodology.

3. RESULTS AND DISCUSSIONS

Figure 2 shows the result of FEA model indicating the maximum axial displacement against axial force applied on the model for various materials selection. Observation shows titanium alloy is the most elastic material and produced the highest maximum axial displacement of all three materials investigated.

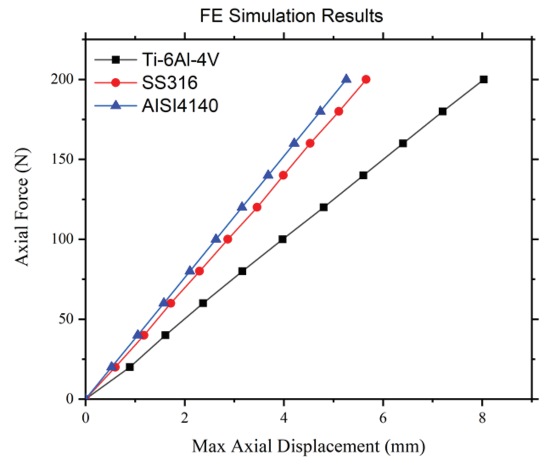

Figure 2 FEA Model results for maximum axial displacement against axial force.

Figure 3 shows comparison of various materials for a similar flexure bearing thickness (1.5mm). It is found that the most elastic material is titanium alloy while the most rigid is stainless steel.

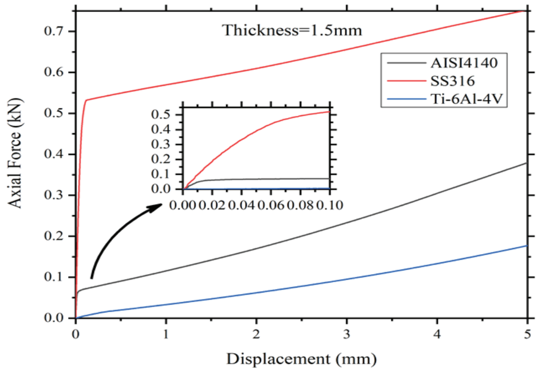

Figure 3 The axial force vs. displacement response for various materials

Next, the value of axial strength constant (equivalent to spring constant) of each flexure bearing thickness of all selected materials was evaluated. The results are presented in Figure 4. The outcomes show titanium alloy has the lowest axial strength constant while in contrast steel alloy produced stiffer flexure bearing characteristic. Although most of the SS316 samples suffered plastic deformation, the results were successfully obtained and plotted.

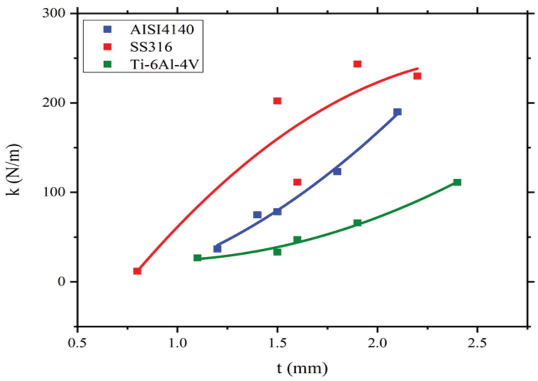

Figure 4 The axial strength of flexure bearing design for various materials.

Titanium alloy required almost halve of the maximum force of both materials. In terms of thickness, there is probability of having thicker flexure bearing for titanium alloy, i.e. as thick as 2mm while both AISI4140 and SS316 must be 1.5mm or lower.

Based on the result and discussion held, titanium alloy is the best material evaluated in this investigation. Comparative results between experiments and simulation are presented in Figure 5. The FEA model has successfully validated against the experimental results for all thicknesses tested

4. CONCLUSION

This paper has presented the results from experiments and simulation method of various flexure bearing materials. Following conclusions are obtained:

- It is found that titanium alloy material produced the most elastic design while stainless steel and steel alloy are rigid comparatively.
- It is observed that, for a similar maximum axial displacement, higher axial force is needed for stainless steel followed by steel alloy. Titanium alloy required almost halve of the maximum force for both of other materials. In terms of thickness, it is possible to have flexure bearing as thick as 2mm for titanium alloy while both AISI4140 and SS316 must be 1.5mm or lower. This is a required dimension to ensure elastic behaviour of the flexure bearing can be obtained.

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