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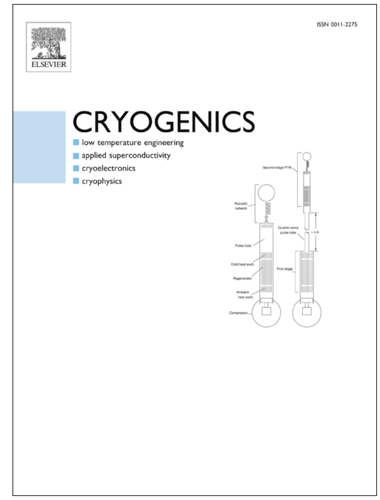

Research paper

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An Optimization Method for Flexural Bearing Design for High-stroke High-Frequency Applications

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Abstract

A method for optimization of a high-stroke, high-frequency flexural bearing was completed. The main goal was to design a flexural bearing system as the energy restoration component of a one kW free piston linear engine alternator (LEA) operating at 90 Hz and maximum targeted displacement of 22 mm. Defined electricity output of 1 kW, with more than 30% efficiency, required engine operation under high speed and high stroke conditions. Under such challenging stroke and frequency requirements, a method of design was required to select between a wide range of parameters in flexural bearing design. A parametric CAD model was prepared and used in the optimization package of a finite element analysis (FEA) software. Four main parameters of flexural bearing geometry were identified and included the outer diameter, thickness, number of arms, and sweep angle of spiral cuts. Other design parameters including spiral gap width, shape factor and spiral start points angle were shown to be less important compared to these four main parameters in primary design and were examined separately. A neural network algorithm was used to investigate the interactions and effects of design parameters. The sensitivity of each parameter on output criteria such as maximum stress and natural frequency was examined and design charts developed. Methods for further modification of the spiral curve at end points were introduced to reduce the maximum stress level by up to 20%. Several steel alloys and a titanium-based alloy were identified as proper material candidates for high cycle applications and the final designed spring was manufactured and tested to validate the FEA results of axial stiffness and strain level throughout the flexure arms. The percent of the flexure's moving mass was estimated to be 29% with FEA analysis and compared well with the experimental value of 31%. The stress/strain results of the FEA analysis matched with the experimental results - within ±5%.

Keywords: flexural bearing, free piston linear engine alternator, high cycle fatigue, design optimization, finite element

1. Introduction

Energy utilization and emissions from fossil-fueled combustion have been at the forefront of engine design since the 1960's due to the Clean Air Act, subsequent amendments, and regulations [1]. Electrical power generation from fossil-based fuels in the United States (US), and elsewhere, are characterized as boiler-based Rankine cycle, gas turbine-based Brayton cycle,