# Static and Dynamic Performances of Refrigerant-Lubricated Compliant Bearings

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**Long Abstract**

## Introduction

The reduction of on-board masses and volumes is a central issue regarding transports, particularly in aeronautics. ACM are classified as high-speed turbomachines and nowadays, most of the ECS on civil and military aircrafts and vehicles use Gas Foil Bearings (GFBs) in the ACM [1]. GFBs can be used in an environment different from air, like refrigerants in the ECS. Over the last 20 years, a significant number of studies have shown GFBs were the best options for a consequent range of applications, such as oil-free turbomachinery [2]. However, there are still problems when one tries to implement GFBs into new systems, particularly in refrigerant environments. Studies in this domain already exist but they are either experimental [3] or analytical but without specific lubricant behavior analysis [4]. Refrigerant lubricated GFBs require a specific Thermo-Elasto-HydroDynamic (TEHD) theoretical and numerical model. In this paper, static and dynamic GFBs' behavior are investigated when running in refrigerating gas. A TEHD approach is used in conjunction with gas constitutive equation to describe pressure, density, viscosity and temperature. It involves the use of a GRE (Generalized Reynolds Equation) for turbulent flow, a non-linear cubic EoS (Equation of State) for two-phase flow, a 3D turbulent thin-film energy equation, 3D thermal equations in solids and the foil distortion consideration. Journal bearings' global parameters are calculated for steady state and dynamic conditions.

## 1. Methods

In bearings, for compressible gas, the pressure is related to density, temperature and viscosity. This relation is often described by the ideal gas law. However, when pressure is close enough to the vapor pressure, which is value for which the vapor/liquid transition occurs, this assumption becomes invalid. Two-phase flow has been observed experimentally under specific conditions when refrigerant is introduced into GFBs' lubrication system. Therefore we use a non-linear EoS able to describe the density variation as a function of pressure and temperature, as well as the vapor/liquid transition. Viscosity is also linked to the temperature and to the fraction of liquid in the fluid. We choose a modified Peng-Robinson EoS [5], Some of the lubricant might change from vapor to liquid phase. We choose to use a vapor/liquid transition model which is not directly linked to the enthalpy calculation in order to compute the local fraction of liquid in the lubricant in two-phase flow scenario. The model we choose has shown good efficiency in previous works [7].

The Generalized Reynolds Equation (GRE) [9], is used to determine the pressure field in the lubricant under thin-film assumption and appropriate boundary conditions. The pressure field in GFBs is obtained by solving the steady-state GRE (6) for turbulent, compressible fluids with variable viscosity across the film thickness.

Taking into account the THD effects is related to lubricant thermodynamic behavior. We particularly insist on the radial dimension where strong temperature gradients appear. We solve a steady-state 3D turbulent thin-film energy equation to obtain a local thermal field (and local temperature-dependent molecular viscosity.The temperature generated in the fluid flows through the solids. Fourier's equations are solved with appropried boundary conditions to obtain the temperature fields in the solids.
The variation of the film thickness is due to the eccentricity ratio and the deflection of the foil under the imposed hydrodynamic pressures developed between the bearing clearance. We use the Heshmat's model to consider this deflection.

Results an discussion

As example and using streamlines we present the temperature field. We can note that the bearing edges are a zone of lubricant exchange with the environment (both inlet and outlet flow). This exchange has an important influence on the temperature. Because of the structure distortion and as the load is fixed we observe an increase of maximum temperature zone at the minimum film location which is enlarged.

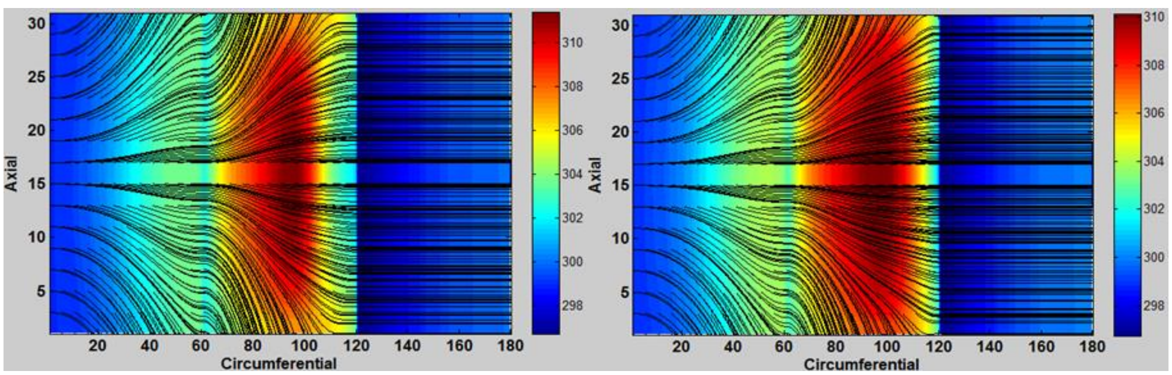


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Fig. 1: Temperature field and streamlines at mid-film thickness, G.F.B (1), Bearing load 15 N, Shaft speed 120000 R.P.M, m=0.2.

In order to extend the field of applications for GFBs as well as their reliability, we studied here their behavior in refrigerating gas in static and linear dynamic conditions. Non-linear phenomena have been coupled and mainly the influence of temperature and foil distortion have been investigated. For the tested cases we have found that temperature can have a noticeable impact while the structure deformation has a weak influence on bearing performances both in static and dynamic configurations.

## References


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