Fluid-structure Interaction Modeling of Air Bearing

H.R. Javani[1], P. Kagan[2], F. Huizinga[1]

[1]ASML - MDev – Mechanical analysis, Veldhoven, The Netherlands
[2]ASML - MDev – System Dynamics, Veldhoven, The Netherlands

Abstract

Introduction
Air bearings are special types of bearings which provide nearly zero friction between two surfaces. This is achieved by a compressed layer of gas between the surfaces. This abstract focuses on the modeling of an Air bearing component of in one of our machines. FEM analysis can be used to obtain and optimize the design within the engineering requirements.

Figure 1 shows an Air bearing consisting of a Cylinder and a Piston. As shown in this figure, a vertical load from the top of the piston has to be balanced by an applied pressure from a tank, see Figure 2. There is a thin film of compressed gas (several micrometer thickness) between cylinder and piston which provides the necessary tilt stiffness preventing piston-cylinder contact under an external moment (M_y).

The pressure distribution will locally deform the structure and therefore, influence the gap width (in the same order as the initial gap). Nonetheless, the gap will also change the flow domain and consequently resulting in a different pressure distribution. Consequently, a fully coupled model (Fluid Structure Interaction) is needed to more accurately measure the stiffness.

The gas pressure in the thin film is provided using a number of feeding holes in either Cylinder or Piston (Piston in this study). These feeding holes are similar to orifice in which there is a pressure drop before the gas can flow into the thin film domain, see Figure 3. This pressure drop is included in this model using Bernoulli's principle.

Use of COMSOL Multiphysics®
All these physical phenomena are solved in a fully coupled manner using COMSOL Multiphysics®. Figure 4 shows the deformation of the Cylinder and Piston. As can be seen from this plot, the gap has increased and there is a small rotation in the piston (relative to the Cylinder). This rotation is enough to develop a pressure distribution in the thin film, which compensates the applied moment (provides stiffness).

This abstract presented an efficient modeling technique for the FSI problem in Air bearings. The noble part is simplification of gap domain flow using thin film and specially coupling gas flow from tank to the gap restriction. That would otherwise necessitate the use of real 3D Navier-Stokes simulations in the gap and feeding holes which significantly increases the simulation time

without notably influencing the accuracy. Using a fully coupled approach with justifiable assumptions showed a more robust method compared to segregated techniques commonly utilized in large FSI problems.

Figures used in the abstract

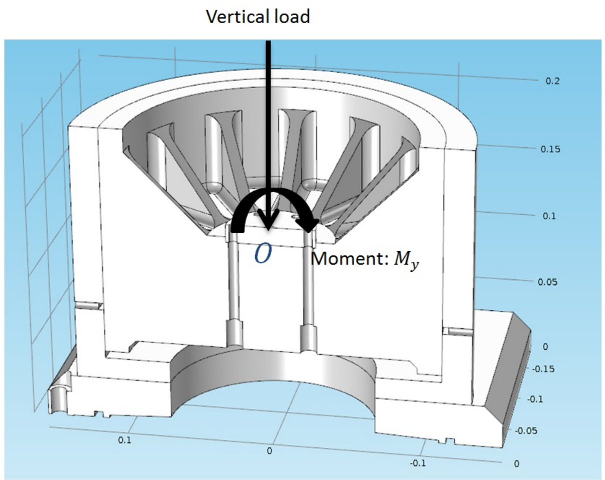

Figure 1: Geometry and boundary conditions of a cylinder and piston

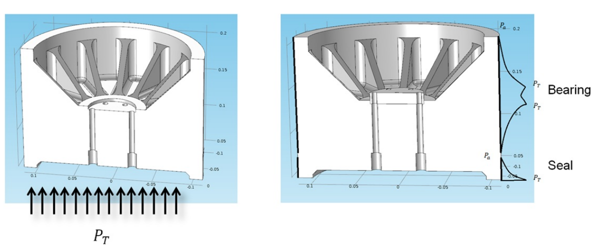

Figure 2: Locations of thin film

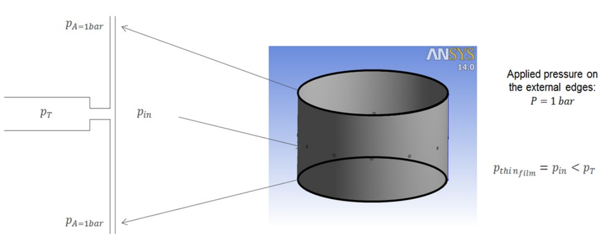

Figure 3: Pressure drops happens before gas flows into the thin film area

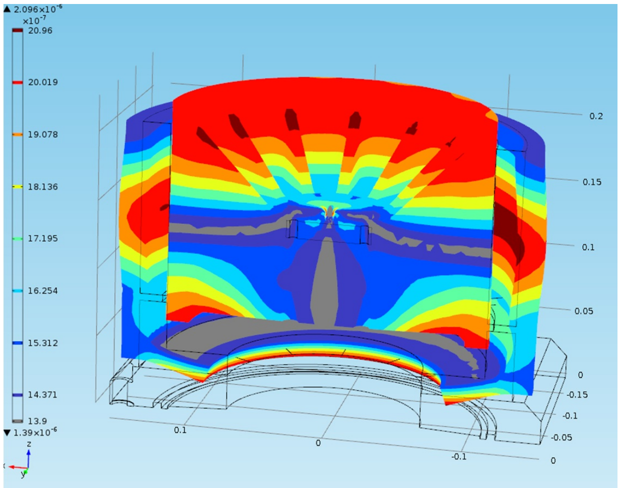

Figure 4: Radial deformation of Cylinder and Piston