A Study of Lubricating Flows in MEMS Bearings

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Introduction

In the trend towards miniaturization, Microelectromechanical (MEMS) devices have been attracting a great deal of attention. An important issue affecting device performance is the tribological behavior of the various device components during operation. In this work the lubricating behavior of a MEMS bearing has been investigated. The bearing and shaft are part of a safe and arm device and are constructed as an assembly by microelectronic fabrication consisting of multi-layer additive/subtractive plating and planarization processes which can achieve sub micron resolution. The technique is flexible and facilitates creation of assembled multi-component devices.

Figure 1 shows a cross section of a typical bearing device considered. The two .1mm diameter shafts appear on the top and bottom. There is .006mm clearance between the thrust surface and the rotating element. The radial clearance of the shaft is .01 mm. In addition, there is .036 mm clearance between the edges of the rotating element and the bearing cage. When subjected to centrifugal loads, the rotating element moves an explosive charge from the safe to armed position.

Since various candidate bearing designs can be readily produced, it is important to be able to discriminate these in terms of their tribological performance. The goal of the study was to compare various proposed bearing designs in terms of the flow behavior of the lubricating fluid separating the bearing from the shaft. The evaluated designs are a standard journal, four-lobe and six-lobe. For the lobed configurations, the voids are a channel, diffuser or nozzle.

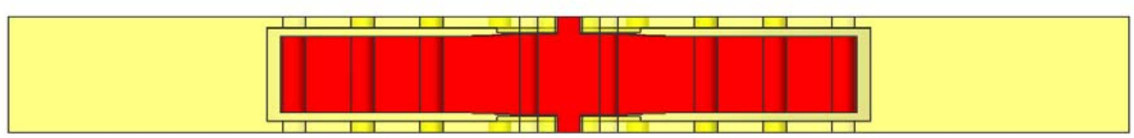

Figure 1: Cross section of MEMS bearing

Use of COMSOL Multiphysics

During regular operation, the relative motion between the rotating shaft and the thrust surface produces flow in the intervening fluid (air). COMSOL Multiphysics was used to create two dimensional models of seven distinct MEMS bearing geometries and to compute the lubricating flow in each case. To simplify the problem, a small bearing offset was imposed to simulate the displacement due to applied load. In each case, the minimum clearance was maintained at .03E-5m, the pressure was set to zero on the shaft and a rotational velocity of 4000 rpm was imposed on the shaft. The effect of shaft offset was evaluated for each of the seven configurations, and the pressure differential was calculated. All calculations produced mesh independent results when using about 4000 elements.

Expected Results

Figures 2 and 3 show computed pressure distributions for two of the designs considered. The pressure field obtained for the standard journal bearing (Fig. 2) was used as reference in comparing the performance of all other bearings. Each bearing design was evaluated in terms of maximum pressure differential. Velocity vectors were overlaid on the pressure contours to visualize the flow field. The results should be of use in the development of high performance MEMS bearings.

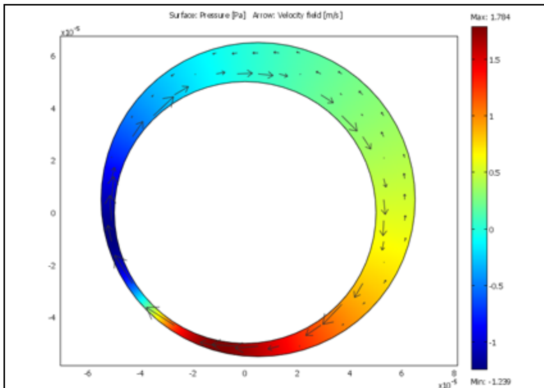

Figure 2. Computed pressure field in Standard Journal Bearing

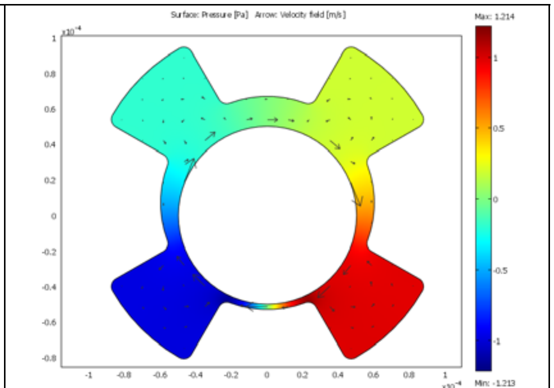

Figure 3. Computed pressure field in four-lobed diffuser-type bearing

Conclusion

The results of this study suggest that, from a lubricity standpoint, the journal bearing is best. The nozzle configuration seemed to be the second best. In the six lobe nozzle design, the pressure differential at standard offset was within 7% of the journal bearing. When the shaft was offset above the channel, diffuser or nozzle void, all of the designs produced less than 60% of the reference pressure differential.

Reference

1. Bhushan, B., 2002, Introduction to Tribology, John Wiley & Sons, New York