PLANE POISEUILLE FLOW IN A RAREFIED GAS WITH GENERAL BOUNDARY CONDITIONS

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Abstract

Rarefied gas flows in ultra-thin film slider bearings are studied in a wide range of Knudsen numbers. Since in ultra-thin films (when gas rarefaction effects dominate) the molecular interactions with the surfaces affect strongly the velocity profile and the gas flow rate, we solve the generalized Reynolds equation in the most general case of two surfaces with different accommodation coefficients.

EXTENDED ABSTRACT

Rarefied gas flows occur in many micro-electro-mechanical systems (MEMS) [1], [2], therefore a correct prediction of these flows is important to design and develop MEMS. Nanoscale design occurs for computer components as well.

In most computers today, magnetic disk storage devices use a flying head slider suspended nanometers above the rotating recording surface to support the read/write head. A thin gas-lubricated film formed between the slider and the rotating disk is used to maintain the spacing between them. The air between the read/write head and the surface of the spinning platter forms a so-called slider air bearing. The basic geometry of the two-dimensional gas film is outlined in Fig. 1. In order to achieve higher storage densities, the head is required to levitate progressively closer to the spinning platter. For ultra-high density recording systems, a 5-10 nm clearance between the head and the floating media is required. Considering that the mean free path for air is about 65 nm at standard conditions, the current hard drives already operate in the transition flow regime, while the next generation drives will push this limit towards the free-molecular flow regime. Therefore, development of lubrication models valid in a wide range of Knudsen regimes is necessary.

Traditionally, the classical Reynolds lubrication equation has been used to model slider bearings. The Reynolds equation is an approximation of the full Navier-Stokes equation with the continuum no-slip boundary conditions. However, rarefaction effects are significant for gas flows in close spacings and appropriate corrections to this equation were first introduced by Fukui and Kaneko [3], [4]. We have extended the generalized Reynolds equation derived by Fukui and Kaneko, by allowing for bounding surfaces with different physical structures, as an issue of relevance for applications. The Maxwell scattering kernel has been used to describe the gas-wall interactions in the most general case of two surfaces with different accommodation coefficients. The generalized Reynolds equation is a flow rate based model, therefore its solution requires that the fundamental flows in

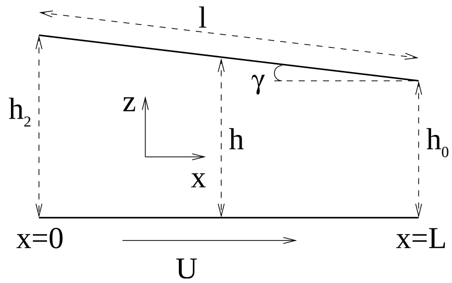

Figure 1: Geometry of a slider bearing.

the lubrication film, Poiseuille and Couette flow rates, have to be accurately calculated in advance. The Poiseuille and Couette flow rate coefficients have been evaluated by means of a numerical integration of the Boltzmann equation [5] using a finite difference technique first introduced by Cercignani and Daneri [6]. Moreover, the Poiseuille flow rate has been evaluated by means of a variational technique which applies to the integrodifferential form of the Boltzmann equation [7] based on the BGK model [8].

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