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ACCURACY ASSESSMENT OF GAS DAMPING RATIO PREDICTION MODELS IN MICROCANTILEVERS

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The frequency response of a microcantilever, due to an external force, depends on the viscosity of the surrounding fluid. The fluid exerts a hydrodynamic force on the beam, which gives rise to a shift in resonant frequency and quality factor from values measured in vacuum. Thus, predicting damping ratio is of key importance in applications such as atomic force microscopy.

J. E. Sader presented in 1998 an analytical model to calculate the hydrodynamic function on rectangular beams with large aspect ratio for the fundamental mode and the next few harmonics [1]. These formulae is part of what has become to know as the calibration method of Sader [2]. Later, in 2007, C. A. Van Eysden and J. E. Sader presented an extended model for arbitrary mode order [3]. The method is based on the one presented in 1998, but there are some key differences about the hydrodynamic function that takes into account the aspect ratio of the beam.

For their part, R. A. Bidkar et al. presented in 2009 an ellipsoidal statistical Bhatnagar-Gross-Krook–model–based fit for gas damping ratio of rectangular microcantilevers. Along with these model, they presented experimental values of gas damping ratio for a set of phosphorus-doped silicon microcantilevers with different aspect ratios and characteristic frequencies, oscillating in rarefied air [4].

In this work, an accuracy assessment of gas damping ratio prediction of the aforementioned models. Codes for the three models were implemented and validated using the results reported by their authors. Then, these codes were run using data from the beams used by Bidkar et al in the experimental part of their work. Figure 1 shows the comparison between this three models and the experimental data for continuum, transition, slip and free–molecular flow regimes.

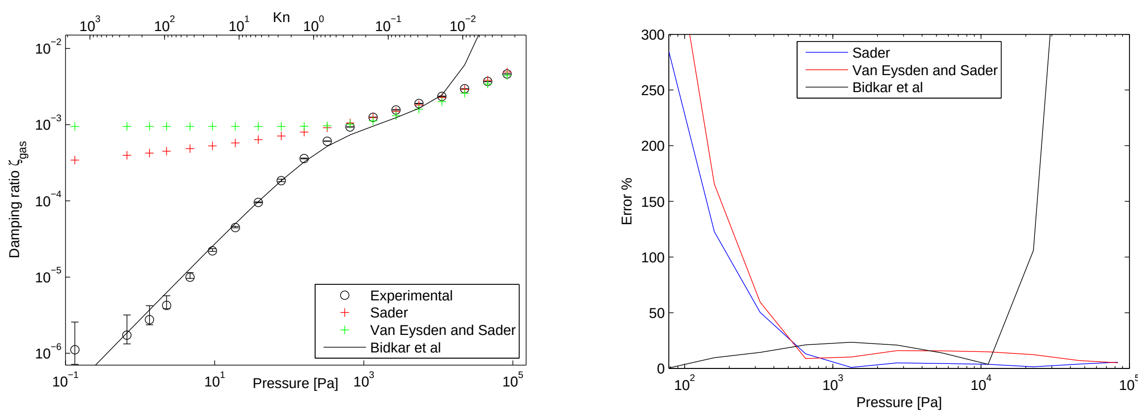

Figure 1: Comparison of the predictions of the Sader's model [1], Van Eysden and Sader's model [3] and the ES-BGK-model-based fit, with the experimental gas damping values for microcantilever A in its first mode [4]. a) Damping ratio values, b) relative percent error.

It was found that Sader's model is more accurate and has lower computational cost than Van Eysden and Sader's model. Also, it is better than Bidkar et al's fit for the continuum flow regime. Because of this, Sader's original model can be chosen as reference method for the continuum and slip regimes. Meanwhile, Bikdar et al's model is more accurate than the others for the transition and free–molecular regimes, and can be chosen as reference method for the corresponding range of Knudsen number.

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