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Hydrostatic and hydrodynamic bulge testing of pre-stressed thick elastic plates for microfluidic applications[1] VISHAL ANAND, IVAN C. CHRISTOV, School of Mechanical Engineering, Purdue University, West Lafayette, Indiana 47907, USA — Bulge tests are used to characterize material properties of elastic sheets. We present a theory of hydrodynamic bulge tests based on the fluid–structure interaction between a deformable top wall of a rectangular microchannel and a viscous Newtonian fluid flow within. Taking into account uniform isotropic pre-stress within the wall, we derive a model for the deformation using first-order shear-deformation theory for thick plates. It is shown that pre-stress reduces the transverse deformation. Then, the mechanics problem is coupled to flow under the lubrication approximation, in a perturbative manner, to capture both the effect of (non-constant) hydrodynamic pressure on the deformation and the effect of wall deformation on the channel's hydrodynamic resistance. We obtain an analytical expression for the flow rate–pressure drop relation and show how it can be used to characterize the material properties (e.g., Young's modulus or pre-tension) of an elastic sheet without measuring its deformation, which is difficult to do accurately at the microscale. Direct numerical simulations are performed using the commercial software ANSYS to explore the range of validity of the proposed bulge testing theory.

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