Lubricated motion of a rigid sphere in an elastic tube

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【Introduction】

The motion of large objects through narrow tubes is a common problem in physiology and more generally in the biological world. We address this problem with a model experiment where a rigid sphere is displaced at constant velocity inside a narrower elastic tube. We investigate both the dry sphere/tube contact and the lubrication by a fluid layer.

【Results and Discussion】

The friction force in the dry case is well described by the Coulomb law with the pressure generated by the stretched tube. In the lubricated case, the force is generally lower than that in the dry situation. Interestingly, the force increases with ηV to the power 1/3, where η is the viscosity of the lubricant and V is the pulling velocity. The force also depends on the geometry and the mechanical properties of the tube. All our experimental data are well described by a scaling law combining lubrication and elasticity equations. We furthermore measured the thickness of the lubricant film and found that measured values well suit with our prediction.

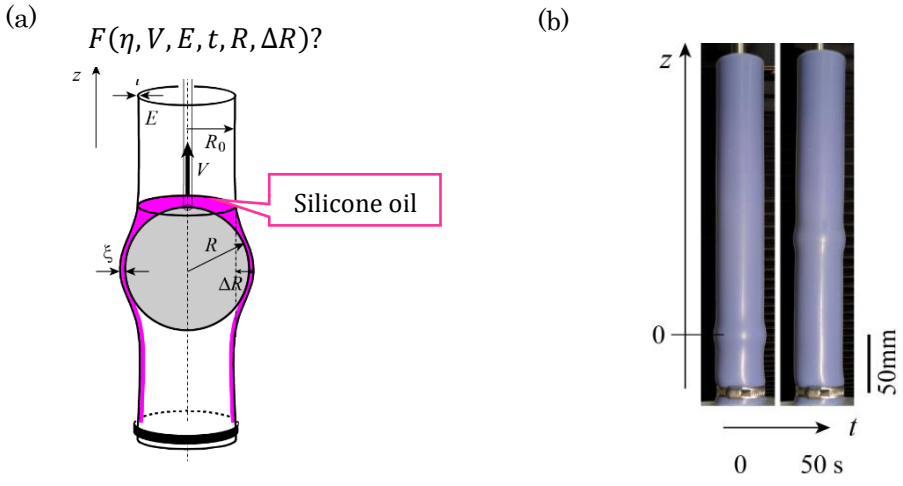

Figure: (a) Large sphere pulled in a narrow lubricated elastomer tube: the pulling force is found proportional to the velocity to the power 1/3, and also depends on the viscosity of the lubricant, the geometry and the mechanical properties of the tube. **(b)** A series of pictures during a typical experiment (the radius of the sphere $R = 19.8$ mm and the inner radius of the tube $R_0 = 17.6$ mm).