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Sliding of cylindrical shell into a rigid hole

Yukiho Matsumoto[1], Keisuke Yoshida[2], Tomohiko Sano[3]

[1] School of Integrated Design Engineering, Keio University, 3-14-1 Hiyoshi, Yokohama 223-8522, Japan., Japan. matsumoto.yukiho@keio.jp
[2] Research Organization of Science and Technology, Ritsumeikan University, Kusatsu, Shiga 525-8577, Japan., Japan. kyosh424@gmail.com
[3] School of Integrated Design Engineering, Keio University, 3-14-1 Hiyoshi, Yokohama 223-8522, Japan., Japan. tomohiko.sano@keio.jp

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Abstract

The assembly of materials offers a versatile route for creating complex, multi-component structures. Among various approaches, snap-fit assembly is a classical mechanism in which flexible elements are forced to interlock with rigid counterparts, inducing elastic deformation. This highlights the essential interplay among elasticity, geometric configuration, and contact friction. Although fundamental aspects of snap-fit mechanics have been examined in previous model studies, practical design procedures still rely heavily on physical prototyping and empirical adjustments. We focus on a representative configuration: the insertion of a naturally curved elastic beam into a rigid aperture. An analytical framework based on elastica theory is developed, incorporating the effects of contact friction. The predictions show excellent quantitative agreement with both numerical simulations and physical experiments. Furthermore, three distinct sliding states—Folding, Pinning, and Unfolding—are identified and systematically organized into a phase diagram defined by the key geometric parameters of the curved structure and the aperture. The results provide a predictive basis for designing frictional, elastic, and geometrically constrained contact-based assemblies and contribute to a unified understanding of their complex interaction dynamics.

Keywords:

Snap-fit Thin shell Experiment Elastica Theory Simulation