ME – MTech(Res) Thesis Colloquium

Compression-Induced Pattern Formation in Fiber-Reinforced Elastomer Substrates

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ABSTRACT

Wrinkling or surface instabilities are ubiquitous in nature and in several engineering applications that involve bilayered materials. In biology, these patterns appear in a variety of forms, ranging from skin wrinkling and surface patterns in raisins and date due to dehydration, to the intricate folds of the brain. Previous investigations have primarily used experiments and models based on a homogeneous and isotropic framework to study surface instabilities. However, biological tissues and organs such as the skin and brain exhibit significant anisotropy due to the directional organization of collagen fibres within their microstructure. The primary objective of this study is to investigate the role of fibre reinforcement in wrinkle formation in bilayered substrates.

We fabricated anisotropic Fiber Reinforced Elastomers (FREs) using a compliant elastomeric matrix reinforced with embedded Nylon fibres in orthotropic architectures at angles of ±30°, ±45°, and ±60°, with fibre pitches of 5 and 7.5 mm. We characterized the material properties of the FREs using uniaxial compression tests and fit the experimental data to an anisotropic constitutive model. FRE specimens were next pre-stretched, and an isotropic elastomeric sheet was bonded to create a bilayered substrate. Compression-induced surface instabilities were experimentally generated using a custom setup, and the resulting patterns and their evolution into higher-order modes were analysed and compared with a control specimen without fibre reinforcement. Results demonstrate that the 30° FRE substrate developed significantly complex patterns and a greater number of modes compared to the 45° and 60° FRE substrates. We used a linear perturbation analysis to predict the onset of wrinkling instability in such anisotropic materials. By parametrically increasing the anisotropy contribution, we demonstrate that the governing equations admit only a narrow range of real solutions. These analytical predictions are consistent with experimental observations, suggesting that substrate anisotropy plays a relatively minor role compared with boundary conditions and substrate pre-stretch in producing the rich diversity of observed surface morphological patterns. These findings provide new insights into the role of anisotropy in surface instability phenomena and may be useful to researchers in soft matter, biomechanics, flexible electronics, and help in the design of bio-inspired materials and structures where controlled surface pattern formation is desired.

ABOUT THE SPEAKER

Yogesh Thapliyal is an M.Tech (Research) student in the Department of Mechanical Engineering, IISc Bangalore under the supervision of Prof. Namrata Gundiah. He earned his B.Tech degree in Mechanical Engineering from the College of Technology, Pantnagar University in 2024. His research focuses on the mechanics of soft materials, including fibre-reinforced elastomers, constitutive modelling of anisotropic materials, mechanical instabilities, and corneal biomechanics.