New measurement strategies in data-driven mechanics provide fresh physical insights

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Abstract

There has been explosive growth in numerical data-driven mechanics approaches for various problems in the mechanics of materials. These data-driven methods are data-hungry, but traditional measurement protocols are inherently data-poor. Consequently, most studies using these data-driven methods have relied on synthetic data. This dearth of measurement techniques presents opportunities to transform laboratory-based methods, making them more suitable for emerging methodologies in data-driven mechanics. We first present a brief overview of some emerging laboratory techniques to provide observations that were hitherto considered nearly impossible, at least in a laboratory setting. These methods include (i) dynamic tomography to enable 3D visualisation of high-speed deformations and (ii) democratising synchrotron technologies to allow the measurements of local stresses within statically indeterminate specimens to provide fully labelled stress-strain pairs for supervised constitutive model discovery approaches.
These and other new laboratory measurement methods provide new observations and large datasets, but are they giving new insights into the mechanics of solids? To address this question, the bulk of the presentation will focus on one of the oldest problems in the mechanics of solids: rubber elasticity. Using innovative X-ray measurements capturing the three-dimensional (3D) spatial volumetric strain fields, we demonstrate the established idea that, under isothermal conditions, stress is (non)linearly related to strain, and no other state variable might need to be revisited. We show that rubbers and many common engineering polymers undergo significant local volume changes, but remarkably, the overall specimen volume remains constant regardless of the imposed loading. This strange behaviour, which also leads to apparent negative local bulk moduli, is due to a mobile phase within these materials. Using a combination of X-ray tomographic observations and high-speed radiography to track the motion of the mobile phase, we propose a revision of the classical thermodynamic frameworks of rubber elasticity.

References

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