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Folding and deployment of stored-energy composite structures

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Abstract

This lecture will present novel simulation techniques for lightweight deployable structures consisting of very thin sheets of fibre-reinforced composite materials. These structures are folded elastically and are able to self-deploy (dynamically) when they are released. Novel structural concepts of this kind were recently introduced on missions requiring parabolic reflector dishes for telecommunications and tubular deployable booms supporting sensors. A variety of related concepts are currently under consideration for future missions.

Designing these structures requires detailed predictions that capture both the overall, large displacement deformation of the structure, including the effects of contact and friction at the interfaces between parts of the structure that come into contact, and also the localised deformation of the most heavily deformed regions of the structure, in order to verify that no damage will occur in these regions.

Achieving this poses a number of novel challenges. First, the constitutive behaviour of thin composite materials differs fundamentally from that of standard composites and hence needs to be approached with suitable homogenization theories. Second, contact between heavily deformed (but still elastic) surfaces plays a key role in the tight packaging of these structures and the interaction between local and global instabilities that are encountered, even for the simplest configurations of current interest, is such that implicit solution schemes that attempt to capture the complexity of the physical situation become overwhelmed. Third, folding aids, such as jigs, straps, etc. are often used to facilitate the actual folding of a real structure without causing any damage and, although modelling this process in full detail is not necessary, any simulation needs to be steered through a maze of instabilities. The engineer must have confidence in the final predictions, because a fully detailed model of the folded configuration is required, to provide the initial conditions for any study of deployment.