CHARACTERISING THE SELF-OPENING BEHAVIOUR OF SINGLE CREASED KAPTON POLYIMIDE FILMS

Navaratnarajah S.* and Mallikarachchi H.M.Y.C.

Department of Civil Engineering, University of Moratuwa, Moratuwa

Use of thin folded membranes for deployable structures is becoming increasingly popular especially in aerospace applications such as a deployable solar arrays, sun shields, and solar sails. The folding and compaction process of thin membranes, which introduces permanent, non-recoverable, localized plastic deformation, changes the geometric shape and material properties. Therefore, precise prediction of folding and deployment behaviour is essential for the mission's success as incorrect folding, storage, and deployment could result in damaging the membrane or not achieving the expected deployed configuration. Virtual simulation is a feasible solution in comparison with physical testing which requires reduced gravity, friction, and air-drag-free environment in design optimization of these structures. However, accurate idealisation schemes will significantly reduce number of elements meaning lower the degrees of freedom and hence reduce the computational cost. Therefore, a proper understanding of the mechanics of creased membrane structures is the key, in formulating such idealisations. The underlying mechanics in the deployment of creased membrane structures from the folded state to the deployed state involves two phases. First, the structure self-opens from the fully folded state to the stress-free stable state. It then requires an external force to deploy from stress-free state to fully deployed state. This can be referred to as forced opening. The focus of the previous studies was limited to the characterisation of crease behaviour during forced opening but not the self-opening which is also crucial in the design of gossamer structures.

In this research, an attempt has been made to characterise the crease mechanics of single creased thin Kapton polyimide membranes during their self-opening behaviour using two different experimental approaches. One experimental study investigates the rotational motion of a panel in a single creased membrane immediately after creasing where angle, angular velocity, and angular acceleration variation were obtained to develop the moment-rotation response. The second experimental study evaluates the moment-rotation response of crease during quasi-static folding of the single creased membrane once it achieved the stress-free stable state. It has been found that the moment-rotation response during the self-opening behaviour shows a linear trend for all thicknesses considered. The effect of membrane thickness and width on the crease rotational stiffness was also investigated in the experimental study. Accordingly, crease stiffness increases with increasing thickness and is independent of the width of the specimen. A simple analytical study was performed to predict the rotational stiffness of the crease which shows a good qualitative agreement with physical experiment results. Finally, the results from the self-opening study were combined with the forced opening study which was done by previous researchers. Based on the results it is reasonable to assume the fold-line stiffness to be linear during the whole deployment with a constant crease stiffness. This value can be easily incorporated as spring stiffness in the finite element model by idealising the crease region as a rotational spring to reduce the computational cost.

Keywords: ultrathin membranes; crease stiffness; self-opening; forced opening

* Correspondence: sutharshanan1996@gmail.com