ANALYSIS OF CURVED CREASE ORIGAMI STRUCTURES

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Research on origami-based folding patterns has led to major technical developments from nanoscale metamaterial to large-scale deployable space structures. Deployable space structures such as solar sails and reflectors require them to be stored in a small volume while being able to deploy into a large configuration when in operation. The developability of origami facilitates the employment of deployability and self-actuation qualities in making these lightweight structures. In general, these structures are constructed with ultrathin materials and the quality of deployed surface increases the efficiency of the functionality of the structure.

The curved crease origami structures consist of fewer creases than their equivalent straight crease counterparts. Lower number of creases leads to increase in efficiency as well as faster manufacturing rate. At present origami related research is mainly focused on predicting straight crease behaviour and the possible use of curved crease origami folding patterns requires more attention. This research is focused on studying the effect of membrane thickness on the folding behaviour of the curved-crease Miura Ori structures.

Analytical equations for predicting the edge curve motion were first considered after a thorough literature review and an elliptical curved-crease Miura structure with a radii 40 mm and 69 mm made of 80 gsm copier paper was selected as a case study. The proposed numerical scheme for predicting folding and deployment behaviour discretises the curved crease into a series of straight line segments which are then replaced with a series of rotational springs. The equivalent rotational stiffness of a perforated straight crease was measured using a simple experimental setup which measures the force required to open a crease with crease angle opening. Same procedure was repeated for three different specimens and the mean rotational stiffness was used as an input to the rotational spring employed in the numerical model. The selected curved crease pattern was then simulated using the proposed numerical technique to obtain the deformed configuration under predefined loading conditions. The predicted shape was then validated against surface mesh obtained using a LiDAR scan of a physically constructed model under similar loading conditions. The experimentally validated numerical technique was then used to assess the changes in folding behaviour with changing membrane thicknesses. It is shown that the membrane thickness has a clear impact on the folding of the curved crease Miura Ori structure.

Change in edge curve location leads to an overall change in displacement of the folded structure and hence the overall deployability of the structure changes with varying membrane thickness. This change of the edge curve coordinates gets accumulated when the base structure is tessellated to form the final deployable structure.

Keywords: Curved crease, Origami, Miura Ori, Crease stiffness

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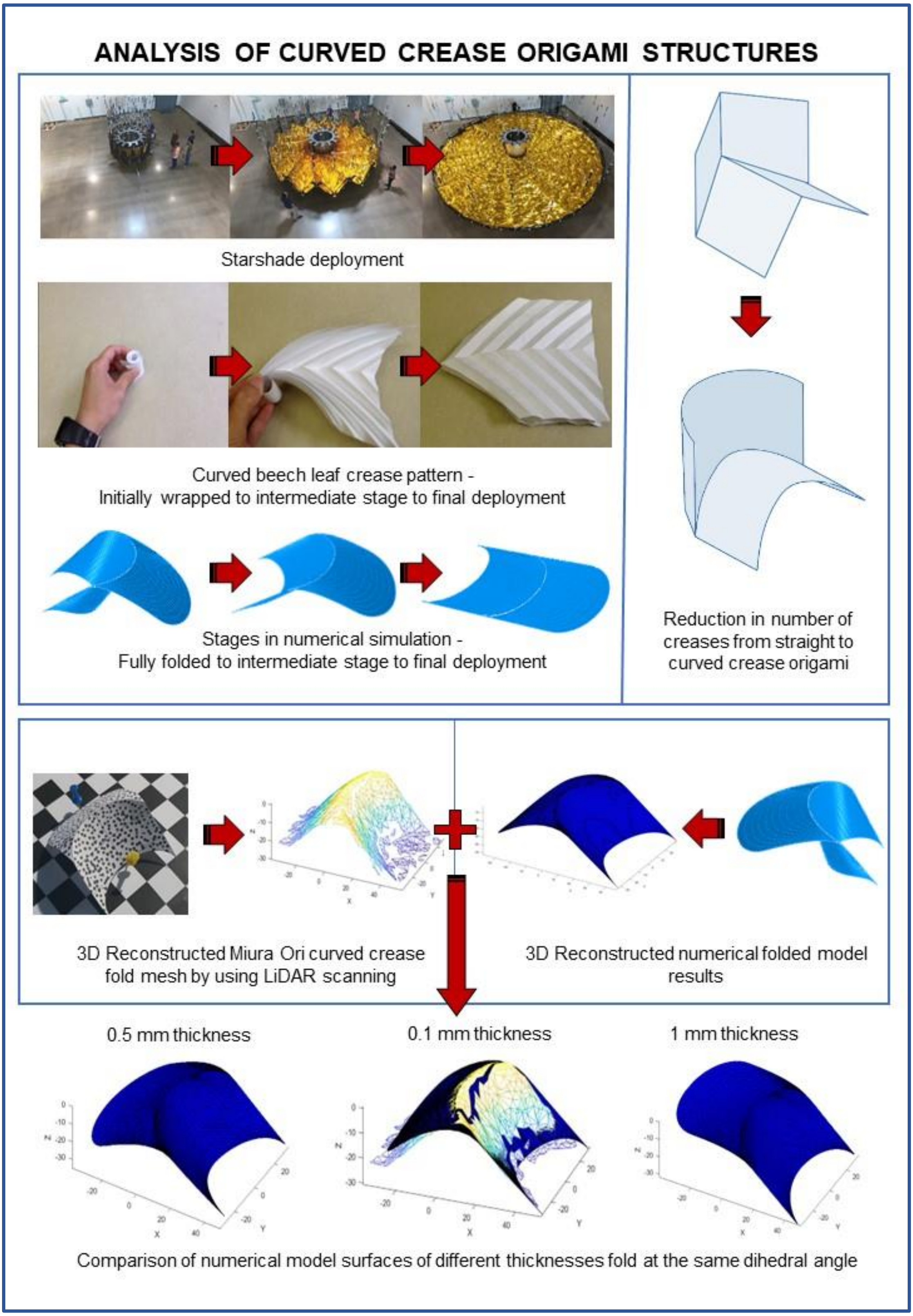

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Starshade deployment

Curved beech leaf crease pattern -
Initially wrapped to intermediate stage to final deployment

Stages in numerical simulation -
Fully folded to intermediate stage to final deployment

Reduction in number of creases from straight to curved crease origami

3D Reconstructed Miura Ori curved crease fold mesh by using LiDAR scanning

3D Reconstructed numerical folded model results

0.5 mm thickness

0.1 mm thickness

1 mm thickness

Comparison of numerical model surfaces of different thicknesses fold at the same dihedral angle