

Bistable behaviour of a deployable cylinder with Miura origami

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Abstract

Bistable behaviour attracts much attention because it allows reprogrammable reconfiguration of shape and bulk properties in the design of metamaterials or motion path. These properties of different non-rigid origami patterns have been investigated using constantly improved mathematic approach. Schenk and Guest proposed a bar-hinge model by triangulating an origami sheet to a truss framework with constrained rotational hinges. The structural analysis formulation of the model was developed with an assumption of infinitesimal deformation and displacement. Based on the bar-hinge model as shown in Figure1, Liu K and Paulino GH stepped further to propose a fully nonlinear and displacement-based formulation for quasi-static finite element analyse of origami structures.

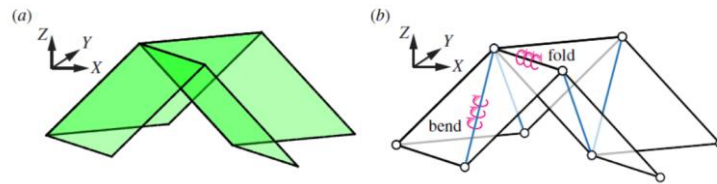


Figure 1 (a) The Miura-ori unit cell. (b) The bar-and-hinge model for a unit cell of Miura-ori

But there are many defects in the former analysis method, the position of the hinge bar need to determine before the analysis and it have a huge influence on the analysis result and cause extra uncertainty. Besides, the out-of-plane bending is allowed in only one direction, which was not a reflect of the actual deformation behaviour.

This manuscript discusses two topics. One is a more accurate nonlinear analysis method of non-rigid origami structures. The other is to investigate the bistable behaviour analysis of deployable cylinder with Miura origami based on the proposed method.

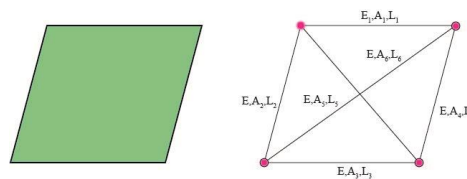


Figure 2 Equivalent truss system schematic

For the first topic, assuming bending stiffness of the fold line to be negligible, the facet can be regarded as a truss system, as shown in Figure 2. The quadrangle facet is

replaced by six trusses with different cross-section areas and lengths. Then the bending, stretching and shearing of the facet can be described by the elongation and shortening of the trusses based on the energy principle.

For the second topic, the deployable cylinder with Miura origami is analyzed. The geometric parameters and the corresponding truss system of the pattern are shown in Figure 3.

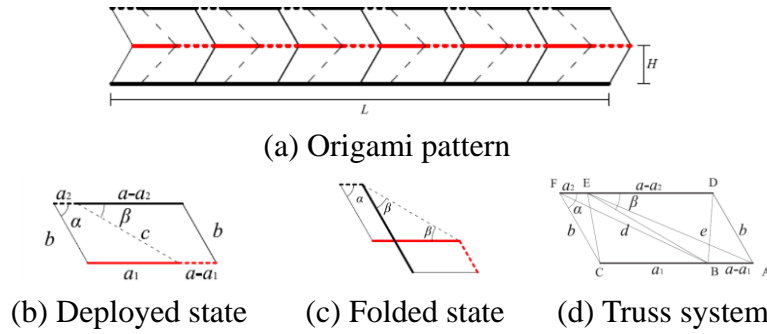


Figure 3 Miura origami for deployable cylinder

Assuming the trusses in the system have the same cross-section area firstly, the deploying process of the one-storey truss system (one storey cylinder) can be achieved through ABAQUS simulation as shown in Figure 4. The total strain energy changes during the process, the energy curves with two different sets of geometric parameters are shown in Figure 5. It could be found that bistable behaviour occurs when the second set is employed.

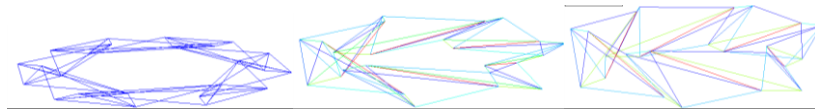


Figure 4 Folding process of a one-storey cylinder

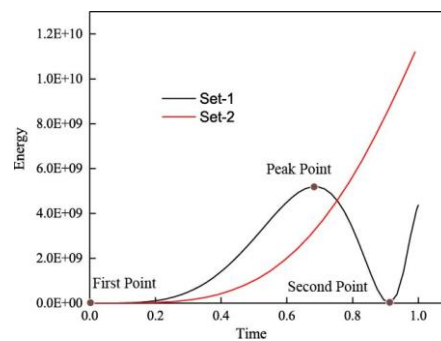


Figure 5 Total energy curves during the folding process

In this manuscript, the proposed analysis method with different cross-section truss system is used to investigate the energy during the folding as a contrast to same cross-section truss system. Then, the critical excitation geometric conditions for the bistable behaviour of the two truss systems are analysed. And the other object is to design the position of the peak point and the second point.