

SIMULATION OF ULTRATHIN MEMBRANES WITH CURVED CREASES

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Origami-inspired structural systems have attracted increasing interest in engineering due to their lightweight, compact, and highly deployable characteristics. While straight-crease origami has been extensively studied, it often leads to geometries with sharp folds and limited adaptability. In contrast, curved crease origami enables smoother surfaces, reduced crease density, and enhanced geometric versatility—features that are advantageous in aerospace, architectural, and robotic applications. However, modelling such systems remains challenging since the panels experience coupled bending and stretching, violating rigid-folding assumptions commonly used in straight-crease analysis. This study investigates the applicability of the Bar and Hinge model for simulating ultrathin membrane structures with curved creases.

The research aims to (i) validate the Bar and Hinge model for single-curved crease configurations by comparison with experimental and finite element (FE) results, and (ii) extend the analysis to multi-curved crease systems, exemplified by a waterbomb-base geometry, to assess overall folding behaviour. In this framework, the sheet is discretised into interconnected Bar and Hinge elements that capture in-plane stretching, out-of-plane bending, and fold rotation. Curved creases are represented by approximating the fold path with multiple short straight segments.

A single-curved crease specimen, modelled using A4 paper properties, was analysed under controlled boundary conditions and prescribed displacements. The predicted folded shape showed good agreement with both experimental observations and FE simulations performed using ABAQUS commercial FE package. Minor discrepancies in curvature distribution were mitigated by mesh refinement, which improved correspondence with reference results. Energy decomposition indicated that increasing crease curvature reduces global bending energy while increasing local folding energy, illustrating the mechanical trade-off intrinsic to curved crease mechanisms.

The waterbomb base, featuring six alternating curved folds, was subsequently simulated to evaluate model performance in multi-crease configurations. The model successfully reproduced the characteristic saddle-like folded form and exhibited bistability. Coarse discretisation introduced minor asymmetry, which was corrected through mesh refinement, demonstrating the sensitivity of the method to mesh quality.

Overall, the findings confirm that the Bar and Hinge model provides a viable and computationally efficient approach for analysing single- and multi-curved crease origami. Nevertheless, its current limitations include difficulty in capturing double curvature within a single panel and dependence on discretisation density. Future work will involve experimental validation of multi-crease geometries and model enhancement to improve predictive fidelity for complex curved crease origami systems.

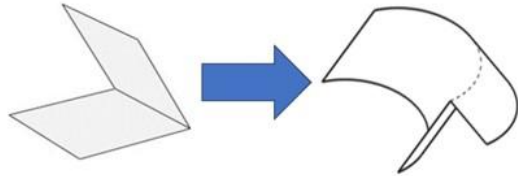
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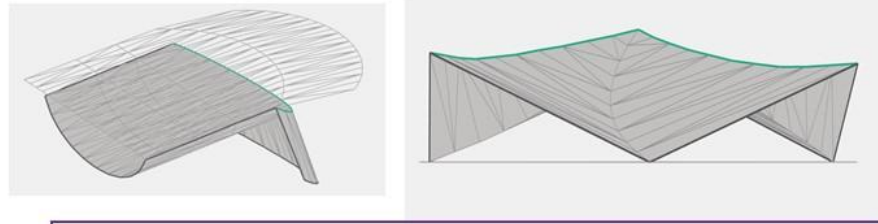
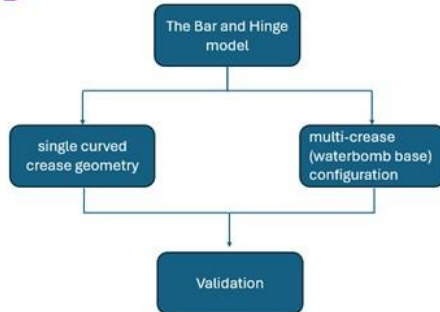
BACKGROUND



Straight crease origami to curved crease origami ?

- Improved Surface Quality
- Fewer Creases
- Increased Design Flexibility

METHOD



CONCLUSION

- ✓ Accurately simulates curved crease origami in ultrathin membranes
- ✓ Validated with experiments and detailed FEM for single-crease structures
- ✓ Qualitative comparison shows accurate shape capture in multi-crease systems
- ✓ Future: full experimental validation for multi-crease structures

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