MODELLING OF THE DEPLOYMENT BEHAVIOUR OF HIGHLY COMPACTED THIN MEMBRANES

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DECLARATION

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ABSTRACT

Modelling of the Deployment Behaviour of Highly Compacted Ultra-thin Membranes

Space structures such as solar sails, solar reflectors, and sun shields have very large surface areas. Hence they require deployable methods to be stored and transported out of the earth's atmosphere in limited cargo capacities available in launch vehicles. A deployable structure changes its shape and geometry to a compact state with the use of folding patterns for convenience in packaging and/or transporting. Ground testing of deployable structures using physical models requires a representative environment, i.e. a zero gravity environment, which can consume a lot of time, effort, and cost, giving rise to the requirement of simulations carried out in a virtual environment. This research develops a modelling technique which can be used to simulate the deployment behaviour of membrane type deployable structures using a commercial finite element analysis software. Commonly used spiral folding pattern was used to demonstrate the modelling technique.

Modification for the fold line arrangement of spiral folding pattern to account for effects caused by membrane thickness; modelling the crease behaviour with the use of rotational springs; and robustness of the analysis indicated by energy histories were three main aspects considered when developing the modelling technique.

Spiral folding pattern was modified by finding the arrangement of nodes in the folded state of the model by providing sufficient offset between planes and checking the ability of the structure to deploy into a plane sheet. This modification was proposed for modules with regular polygonal shaped hubs. Proposed modification was verified with the use of a paperboard model which had a square shaped hub of 10 mm × 10 mm, 15 nodes in a single spiral, and a thickness of 0.28 mm.

Crease stiffness of Kapton Polyimide film was determined comparing data available from an experiment carried out at the Space Structures Laboratory of California Institute of Technology and results of finite element models developed to simulate the experiment.

Finally two finite element models were made from the proposed technique and results of these analysis were discussed on importance of incorporating crease behaviour in finite element models, important aspects of their deployment behaviour, and robustness of analysis.

This research has successfully developed an approach to modify the fold line arrangement of the spiral folding pattern with regular polygonal shaped hubs to account for the geometric effects caused by membrane thickness and a robust technique to model the deployment behaviour of membrane type deployable structures. Crease stiffness of Kapton Polyimide films was modelled as a rotational spring, where the resisting moment is considered to be proportional to the opening angle near the crease. Comparing results of two finite element models, with and without crease stiffness, showed that crease behaviour affects the deployment performance of these structures significantly, and hence it is important to be included in simulations.

Key Words: *deployable structure, finite element analysis, spiral folding pattern, membrane thickness, crease stiffness*

DEDICATION

To anyone who's interested in pursuing research on Origami based deployable structures

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	**Description**
NASA	National Aeronautics and Space Administration
AU	Astronomic Unit
FRP	Fibre-reinforced Polymer
DIC	Digital Image Correlation
FE	Finite Element
IKAROS	Interplanetary Kite-craft Accelerated by Radiation Of the Sun
VLBI	Very Long Baseline Interferometry
HALCA	Highly Advanced Laboratory for Communications and Astronomy
DOF	Degrees of Freedom
CORM	Components of Relative Motion

LIST OF APPENDICES