COILING AND DEPLOYMENT MECHANICS OF TAPE-SPRINGS

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DECLARATION

I hereby witness that this thesis represents my original research work conducted after registration for the degree of MSc at Department of Civil Engineering, University of Moratuwa. It has not been submitted elsewhere or for any degree or diploma and the collaborative contributions and previous work related to current study have been stated and properly acknowledged.

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The above candidate has carried out research for the Masters under my supervision

Name of the supervisor: Dr. H.M.Y.C. Mallikarachchi

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ABSTRACT

Recent advances in space exploration call for smaller space structures that can be reconfigured to achieve large surfaces when in operation. Compact, lightweight structures that can be folded or coiled up for launch have been made possible thanks to self-deployable booms. These can then be self-deployed in orbit to support a variety of small spacecraft systems. However, prior understanding of deployment behaviour is important before launch. This study focuses on model reduction techniques in predicting the deployment behaviour of coiled long-narrow thin shells known as tape springs. Coiling, stowage, and deployment stages that demonstrate considerable cross-section deformation of the tape-spring are discussed. The developed numerical benchmarking model well agrees with the theoretical framework that has previously been established in terms of deployment time and stored strain energy. This numerical model has further been used in a stage-wise development of a beam-shell hybrid model. The effect of varying hub radius is introduced to the existing theoretical framework to predict the coiling and deployment behaviour more accurately.

DEDICATION

“When twilight drops her curtain down - And pins it with a star

Remember that you have a friend - Though she may wander far.”

— L.M. Montgomery

(1874-1942)

To my dearest friends,

Asitha, Kasun, Isuri, and Gayan,

Thank you.

I wouldn’t have made it this far without you.

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LIST OF ABBREVIATIONS

STEM - Storable Tubular Extendible Member booms

CTM - Collapsible Tubular Masts

TRAC - Tubular Rollable, and Coilable booms

STACER - Spiral Tube and Actuator for Controlled Extension and Retraction

SIMPLE - Self-contained Linear Meter-class deployable

1D – One dimensional

2D – Two dimensional

MATLAB - MATrix LABoratory

MPC – Model Predictive Control

CAE – Complete Abaqus Environment

FE – Finite Element

FEM – Finite Element Method

BeCu - Beryllium Copper

S4R – 4 node general-purpose shell, reduced integration with hourglass control, finite membrane strains

B31 - 2 node linear generalized beam