

UNIVERSITI TEKNOLOGI MARA

**FINITE ELEMENT ANALYSIS OF
THE TENSILE STRENGTH AND
PUNCTURE RESISTANCE
OF WOVEN FABRICS**

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of the requirements for the degree of
Doctor of Philosophy


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AUTHOR'S DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Teknologi MARA. It is original and is the result of my own work, unless otherwise indicated or acknowledge as referenced work. This thesis has not been submitted to any other academic institution or non-academic institution for any degree or qualification.

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ABSTRACT

The tensile, ballistic and puncture impact behavior of woven fabric have been subject of interests for many researchers. The tensile behavior of woven fabric can be analyzed from the experimental and analytical methodologies. While experiment provides accurate information about woven fabric's mechanical properties than the analytical approach, it also generates sample wastage. Finite element analysis (FEA) method is used to model uniaxial tensile, impact and puncture response of woven fabrics in two and three dimensional geometrical model shapes. Woven fabrics models sizes are based on either unit cell or meso-scale (large scale) approach. Nevertheless, limited publications address woven fabric models in terms of weave repeat sizes. Finite element analysis has the ability to represent fabric geometrical properties and their symmetries, with weave mesh structures able to be made as close as possible, with minimal assumptions. Other than ballistic impact performance, limited work is done to model tensile performance of aramid based woven fabrics. In addition to that, many publications neglect the weaves structures influences such as float and yarn crimp to tensile and puncture impact behavior. Hence, in the study, an alternative simulation procedure was proposed to develop the understanding and prediction of float and yarn crimp relationship in uniaxial tensile and puncture impact behavior of isotropic weave repeat unit. Woven fabric geometrical models were developed with TexGen and Abaqus CAD pre-processor module. The study was divided into three critical stages. Initially, FEA models were established on plain 1/1, 2/2 twill and 8 ends satin. Woven fabrics were configured as a balanced weave thereby allowing systematic investigation of the effect of uniaxial tensile stress on the weave. Woven fabrics were designed to have equivalent densities 8 yarns cm^{-1} for all three weaves. Equivalent woven fabric specifications were manufactured and tested. Stress-strain validation between experimental and simulation results were made. Next, puncture impact models were developed based on the validated uniaxial tensile simulation models framework and its selected assumptions. Woven fabric for puncture simulation was expanded to consider larger model size than the previous uniaxial tensile model. Here, puncture model analysis was developed with 7 ends and picks cm^{-1} with a total of 112 yarns in both directions. Similar in uniaxial tensile approach, validation analysis was made between puncture model and experimental stress-strain result. Parameters studies were executed on the validated puncture models. The effects of yarn frictions and impactor shapes to puncture models stress-strain, post-impact kinetic energy and damage evolution were analyzed. The stress-strain behavior of woven fabrics was found to be related to woven fabric structures. In uniaxial tensile validation, the presence of float in woven fabrics had contributed to stronger square woven fabrics in both warp and weft directions. The apparent gap was more pronounced in puncture model validation than uniaxial tensile model validation. The parameters studies results had shown that flat impactor shape and tightest yarn to yarn frictions contributed to highest stress-strain, post-impact kinetic energy and damage evolution results. Both uniaxial tensile strength and puncture impact present analogous non-linearity behavior in stress-strain result, which indicated the crimp interchange and yarn extension presence in the analysis.

TABLE OF CONTENTS

| | Page |
|------------------------------|-------------|
| AUTHOR'S DECLARATION | ii |
| ABSTRACT | iii |
| ACKNOWLEDGEMENTS | iv |
| TABLE OF CONTENTS | v |
| LIST OF TABLES | ix |
| LIST OF FIGURES | x |
| LIST OF EQUATIONS | xv |
| LIST OF ABBREVIATIONS | xvii |
| LIST OF SYMBOLS | xviii |

CHAPTER ONE : INTRODUCTION

| | | |
|-----|----------------------------|---|
| 1.1 | Background of the Research | 1 |
| 1.2 | Problem statement | 2 |
| 1.3 | Research Objectives | 3 |
| 1.4 | Scope of the study | 4 |
| 1.5 | Thesis Organization | 5 |

CHAPTER TWO : LITERATURES REVIEWS

| | | |
|-------|--|----|
| 2.1 | Introduction to Textile Structures, Properties and Performance | 6 |
| 2.2 | High performance fibers | 6 |
| 2.2.1 | Carbon | 6 |
| 2.2.2 | Glass | 7 |
| 2.2.3 | Aramid | 8 |
| 2.3 | Textiles Structures | 9 |
| 2.3.1 | Two Dimensional (2D) Woven Fabrics | 9 |
| 2.3.2 | Three Dimensional (3D) Woven Fabrics | 10 |
| 2.3.3 | Knitted Fabrics | 15 |
| 2.3.4 | Braided Fabric | 15 |
| 2.4 | Tensile Mechanics of Woven Fabrics | 17 |
| 2.5 | Finite Element Analysis | 18 |
| 2.5.1 | The Finite Element Analysis Concept | 19 |
| 2.6 | Recent work on Finite Element analysis for Woven Fabric | 21 |

| | | |
|-------|--|----|
| 2.6.1 | Geometrical Investigations and Local Phenomena | 21 |
| 2.6.2 | Tensile and Shear strength | 28 |
| 2.6.3 | Ballistic Impact | 34 |
| 2.6.4 | Puncture | 43 |
| 2.7 | Review of Previous Studies | 45 |

CHAPTER THREE : RESEARCH METHODOLOGY

| | | |
|---------|---|----|
| 3.1 | Introduction | 50 |
| 3.2 | Uniaxial Tensile Strength Simulation | 51 |
| 3.2.1 | Yarn Models and Analysis | 51 |
| 3.2.2 | Yarn Cross Sectional Shape | 51 |
| 3.2.3 | Yarn Density | 54 |
| 3.2.4 | Yarn Packing Fraction | 55 |
| 3.2.5 | Yarn Model and Experiment Validation of Uniaxial Tensile Test | 57 |
| 3.2.6 | Woven Fabrics Models and Analysis | 60 |
| 3.2.6.1 | Woven Fabric Model Assumptions | 61 |
| 3.2.7 | Woven Fabric Geometry | 63 |
| 3.2.8 | Contact | 67 |
| 3.2.9 | Loading and Boundary Conditions | 68 |
| 3.2.10 | Mesh | 69 |
| 3.3 | Woven Fabric Manufacture and Experiment | 71 |
| 3.3.1 | Fabric Manufacture | 71 |
| 3.3.2 | Fabric Test | 74 |
| 3.4 | Puncture Simulation | 75 |
| 3.4.1 | Introduction | 75 |
| 3.4.2 | Yarn Geometry | 75 |
| 3.4.3 | Woven Fabric Geometry | 77 |
| 3.4.4 | Impactor Geometry | 79 |
| 3.4.5 | Finite Element Procedures | 80 |
| 3.4.5.1 | Material Property | 80 |
| 3.4.6 | Yarn Interactions | 82 |
| 3.4.7 | Loads and Boundary Conditions | 83 |
| 3.4.8 | Meshing | 85 |
| 3.5 | Puncture Experiment | 86 |