AIN SHAMS UNIVERSITY
FACULTY OF ENGINNERING
DESIGN AND PRODUCTION ENGINEERING DEPARTMENT

Draping Behavior of Woven Fabrics for Polymer Composites Applications

A Thesis Submitted in Partial Fulfillment for the Requirements of the Degree of Master of Science in Mechanical Engineering

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Statement

This Thesis is submitted in partial fulfillment for the degree of Master of Science in Design and Production Engineering Department, to Faculty of Engineering / Ain Shams University. The work included in this thesis is carried out by the author, at laboratories of Design and Production Engineering Department / Faculty of Engineering, Ain Shams University. No Part of this thesis has been submitted for degree or qualification at any other university.

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Abstract

The present work presents a scientific contribution towards better understanding and prediction of the draping behavior of woven fabrics for their potential use in polymer composite systems. The draping behavior describes the deformation behavior implying the ease of which the reinforcing fibers will conform to the required geometry. This allows the prediction of deformation defects in woven composites manufactured with hand lay-up or liquid molding processes. The thesis focuses on the study of natural Egyptian Jute fabrics, for which the current use is limited to packaging applications. The aim of the study is to investigate the potential use of these fabrics as continuous reinforcement systems by comparison of their characteristics with the well established synthetic glass fibers. Therefore, several types of plain weave jute and glass fibers with variations of densities and woven structure were considered. Experiments for the characterization of the physical and mechanical properties of the studied fibers were performed. In a further step, experiments were conducted for the characterization of the deformation behavior of fabrics over single and double curvature molds. The correlation between woven fabric properties and their deformation behavior was analyzed. Finally, numerical analysis based on Finite Element modeling was implemented for the prediction of draping behavior of fibers. For this purpose, the operation of the draping simulation software PamForm2G was investigated. Moreover, by comparison to experimental results, important model variables which have significant effects on simulation accuracy were identified. The achieved understanding of the model parameters provides more accurate predictions which allow optimization of the composite forming process.

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Abbreviations

NF	**N**atural **F**ibers
GF	**G**lass **F**ibers
PMC	**P**olymer **M**atrix **C**omposites
VARTM	**V**acumm **A**ssisted **R**esin **T**ransfer **M**olding
VARI	**V**acumm **A**ssisted **R**esin **I**nfusion
DC	**D**rape **C**oefficient
KESF	**K**awabata **E**valuation **S**ystem for **F**abrics
DSFM	**D**irect **S**hear **F**orce for **M**easurement
BE	**B**ias **E**xtension
PF	**P**icture **F**rame
PJN	**P**in **J**ointed **N**et
FEM	**F**inite **E**lement **M**odeling
FEA	**F**inite **E**lement **A**nalysis
CCD	**C**harge **C**oupled **D**evice
PMMA	**P**oly**M**ethyl **M**eth**A**crylate
CF	**C**over **F**actor
DIC	**D**igital **I**mage **C**orrelation
RGB	**R**ed **G**reen **B**lack
SE	**S**quare **E**lements
DDR	**D**rape **D**istance **R**atio
ARR	**A**mplitude to **R**adius **R**atio

Chapter 1

Introduction

The mechanical properties of polymers reinforced with continuous fibers have made such composites attractive for structural applications where high strength-to-weight and stiffness-to-weight ratios are required. For example, percentage by weight of composites has been increasing steadily in commercial aircraft, from 4% in Airbus A300 to over 25% in A380; Boeing's 787 and Airbus A350 are expected to use over 50% of composites, thus giving a much needed boost to the composites industry [1].

Woven fabric reinforced composites have especially attracted a significant amount of attention from both industry and academia because of their continuous fiber reinforcement advantages, and supreme formability characteristics. Woven fabrics are created by weaving of yarns into a repeating pattern. A yarn is made of continuous or stretchable fibers with diameters typically in the order of micron meters (μm). Woven reinforcement textiles are tailor-designed to meet the requirements for their end use. The woven strength, thickness, extensibility, porosity and durability can be varied depending on the weave used, the number of threads per centimeter (thread spacing), the raw materials structure (filament or staple) and twist factors of the warp and weft yarns. Woven fabrics provide higher strengths and greater stability compared to any other fabric structure weaved using interlaced yarns. Structures can be varied to produce fabrics with widely different properties in the warp and weft directions [2]. Apart from aircraft applications, other commercial applications for textile composites