AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

DESIGN AND PRODUCTION ENGINEERING DEPARTMENT

Experimental Investigation on The Performance of Vacuum Infused Composites

A thesis submitted in partial fulfillment of the requirement of the M.Sc in Mechanical Engineering

by

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B.Sc. in Design and Production Engineering, 2008

Supervised by

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Cairo-2016

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STATEMENT

This thesis is submitted as partial fulfillment of M.Sc degree in mechanical engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree of qualification at any other scientific entity.

Signature

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ACKNOWLEDGEMENT

I would like to thank Allah for giving me the well to finish this study and I would like to express my sincere appreciation and thankfulness to my supervisors **Prof. Hesham Sonbol** and **Associate Prof. Mostafa Shazly** for their encouragement, support and advice to accomplish this work.

Special thanks to **Prof. Yehia Bahei-El-Din** the principal investigator for Project No. 1493 "Design and Fabrication of Rotor Blades for High Rate Wind Turbines" sponsored by Science and Technology Development Fund STDF through which the experimental study was made possible.

Many thanks to **Eng. Mostafa Bakir**, the head of Bakir Plastics and the consultant for the previous mentioned project for his guidance in learning vacuum infusion technique.

Special thanks to Centre for Advanced Materials (**CAM**) at the British University in Egypt and the Materials Laboratory at the British University in Egypt for the help to perform the experimental work in this thesis.

I am so grateful to my colleagues in **CAM**, Eng. Mohamed Osman, Eng. Ahmed Balah and Eng. Amir Abdelmawla and special thanks to Eng. Mohamed Mobarak.

Deepest gratitude to my father - may Allah have mercy on him- for giving me a good example to follow. Special thanks to my mother and my wife for their encouragement.

ABSTRACT

Composites are known to have superior strength to-weight ratio and excellent fatigue resistance compared to many traditional materials. They are especially preferred for the applications where weight savings are vital. Vacuum Assisted Resin Infusion (VARI) is one of the most commonly used fabrication processes in composite industry due to its ability to manufacture large scale, moderate cost products. However, some fabrication defects arise during VARI that needs to be investigated especially their effect on the mechanical properties structure integrity. Of particular, dry areas that appear at the end of infusion represents a critical defect that must be repaired prior to part deployment.

The present work explores the effect of a repair process using re-infusion approach of previously infused parts with dry areas. It presents results of an experimental investigation on the ultimate tensile strength of repaired (re-infused) and unrepaired (Intact) composite plates manufactured from glass fiber and epoxy.

In order to compare response of the re-infused and intact samples a number of tensile tests were performed for different types of reinforcing fabrics; non-crimp fabrics and woven roving. The results showed that re-infusion has a minor effect on the ultimate tensile strength particularly when the parent and repair laminates have almost the same quality. Based on visual inspection of intact samples, it is noted that each type of fabric has a typical dominant failure mode. For the re-infused samples, the properties of parent and repair laminates determine failure location.

The work also investigated the reasons for dry area formation during VARI and presented a methodology to prevent such defect using finite element analysis program "PAM-RTM". A 25.3 m long wind turbine blade was taken as a case study. Unlike structural finite element analyses where mechanical properties are essential, modeling infusion process requires physical properties such as permeability. Thus experimental tests were carried out to measure the permeability in x, y and z directions using 1D channel flow method. The permeability results were validated using "PAM-RTM". Small deviations were reported between experimental and numerical model.

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Chapter 1

Introduction

1. Introduction

The use of composite materials has increased significantly in the past two decades in many fields such as: aerospace, marine, automotive industries and wind energy sector. This increase is primarily due to their enhanced properties such as high specific strength and stiffness and the flexibility to be tailored to meet specific multi-functionality.

While several techniques such as hand layup, Resin Transfer Mold (RTM) and Vacuum Assisted Resin Infusion (VARI) are among the common methods to fabricate composite panels and sandwich structures, VARI is known to produce good quality products at affordable cost especially in large products [1]. Vacuum assisted resin infusion (VARI) is considered an advanced technique for manufacturing theromset polymer matrix composites. It is based on loading dry fabric into a mold and then the resin is driven by a vacuum system. The resin is then infused into fabric voids and around it and left until cured. The vacuum system minimizes void content and gives higher quality than the conventional technique which is known as hand lay-up or wet-lay-up.

Dry spots or areas are considered as one of the most difficult problems that face vacuum infusion if not properly planned. They are usually repaired after the end of infusion using hand wetting or by a new infusion process referred here re-infusion. To avoid costly repair and material scrape of defected products, numerical simulation of VARI is used to predict the resin flow path and rate in different scenarios [2].

Consequently, re-infusion can be considered as a composite repair technique but without the presence of damaged material that needs to be replaced. A number of experimental and numerical studies on mechanical performance of repaired composites have been presented [3-5]. Atas *et al*. [3] have investigated the fracture toughness of composite plates repaired by either VARI or hand lay-up. It was shown that the reductions in fracture toughness of the repaired samples formed by VARI and hand lay-up are 42% and 67%, respectively. Tzetzis and Hogg [4] applied two scarf designs for the construction of post-repaired laminates using VARI. Both scarf designs have shown high repair efficiencies with dominant failure locations outside the scarf bonded region. The repairs showed a stiffer response than the parent laminates due to the local thickness increase generated from the application of the co-infused overlap.