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SPRINGBACK DEFORMATION MEASUREMENT OF COMPOSITE USING 3D SCANNER AFTER CURING PROCESS

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SUPERVISOR DECLARATION

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of degree in Bachelor of Mechanical Engineering (Structure and Material) (Hons.)"

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fulfillment for the award of
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DECLARATION

"I hereby declare that the work in this thesis is my own except for summaries and quotations which have been duly acknowledged."

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Special thanks to my family members, supervisor, panels and friends for helping me throughout the project towards achieving my goals

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ABSTRACT

Springback deformation is a natural occurring phenomenon which exists during the cure of laminate composite. Eliminating springback deformation is impossible but controlling the amount of springback helps decrease scarp rates in the industries. Past researches have done experiments to gain knowledge regarding springback deformation. The aim of this project is to measure springback deformation on certain specimens and study how it is affected by thickness, size, and angle of the specimen. 3D scanner is the device used in this project to measure springback deformation. The advantage of using 3D scanner over other devices like coordinate measuring machine (CMM), and laser tracker is that it uses a noncontact method. Specimens to be measured are scanned first before the image file is converted into computer aided drawing (CAD) file where the measurement process takes place. For this project, flat specimens of dimensions 300×300 mm^2, 400×400 mm^2, and 500×500 mm^2 were measured. Each specimen contains different plies of 4, 8 and 16 respectively. Other than that, L-shaped specimens were also measured to gain a better knowledge of springback deformation on the shape. The L-shaped specimens came at three different angles which are 30°, 45°, and 90°. The results obtained were then compared with the previous research. Fortunately, an agreement is met when the results obtained are similar to the previous research. Therefore, it is concluded that thicker specimen leads to less springback deformation while bigger specimen tends to experience higher springback deformation. Lastly, as the angle of the L-shaped specimen increases, the specimen tends to experience greater spring-in deformation which is usually negative in value.

ABSTRAK

Perubahan bentuk kerana “springback” merupakan satu fenomena yang berlaku secara semulajadi sewaktu proses pembuatan komposit lamina. Perubahan bentuk ini adalah mustahil untuk dielakkan secara keseluruhan tetapi kawalan terhadap perubahan tersebut mampu mungurangkan kadar pembaziran dalam industri. Pelbagai kajian telah dilakukan dalam usaha untuk mengetahui dan mempelajari ciri-ciri “springback”. Tujuan projek ini dilaksanakan adalah untuk mengukur jumlah perubahan bentuk yang dialami oleh specimen tertentu dan juga mengetahui bagaimana ketebalan, saiz dan sudut mempengaruhi perubahan tersebut. Pengimbas 3D merupakan alat yang digunakan dalam projek ini untuk mengukur perubahan bentuk yang dialami. Kelebihan menggunakan pengimbas 3D daripada peranti lain, seperti “coordinate measuring machine”, dan “laser tracker” adalah kebolehannya untuk mengukur tanpa menyentuh spesimen. Proses pengimbasan dilakukan terlebih dahulu sebelum fail imej ditukarkan kepada imej lukisan berbantu computer di mana proses pengukuran dilakukan. Spesimen yang digunakan untuk projek ini merangkumi spesimen rata berdimensi 300×300 mm^2, 400×400 mm^2, and 500×500 mm^2. Setiap spesimen tersebut mengandungi jumlah lapisan yang berbeza iaitu 4, 8 dan 16 lapisan. Selain itu, spesimen berbentuk L juga diukur untuk projek ini. Spesimen berbentuk L ini mempunyai sudut yang berbeza iaitu 30°, 45°, dan 90°. Hasil kajian ini dibandingkan dengan kajian lepas. Hasil bandingan tersebut membuktikan keserasian eksperimen dengan kajian lepas. Oleh itu, kesimpulan boleh dibuat bahawa spesimen yang tebal akan mengalami perubahan bentuk yang kurang manakala specimen besar akan mengalami perubahan bentuk yang lebih besar. Akhir sekali, sekiranya sudut bagi eksperimen berbentuk L adalah besar, maka perubahan bentuk yang dialami juga besar.

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LIST OF ABBREVIATIONS

CAD	Computer Aided Drawing
CFRP	Carbon Fiber Reinforced Plastic
CMM	Coordinate Measuring Machine
CTE	Coefficient of Thermal Expansion
FEP	Fluorinated Ethylene Propylene
MCU	Master Control Unit
PTFE	Polytetrafluoroethylene
UD	Unidirectional
UTeM	Universiti Teknikal Malaysia Melaka

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Carbon fiber reinforced plastic (CFRP) is a complex profile of a polymer bonded to carbon fiber. This composite exhibits a very high strength to weight ratio and coped with high rigidity makes an ideal application in many industries such as aerospace, automotive, motor racing and sports. The wings of an Airbus and the body frame of a competition bike are examples where CFRP is useful to give great strength and yet remain light weight. The fusion of carbon fiber and resin is done through curing process. Curing process refers to the hardening of a polymer material achieved through cross linkage of polymer chains. Curing process is done with the aid of heat, electron beams, chemical additives, or even ultraviolet radiation. In the rubber industry, curing of rubber is known as vulcanization. There are several ways to induct a curing process of CFRP.

Pre-impregnated laminate composite or known as prepreg is a composite fiber with existence of matrix material within it. Conventional method would require liquid resin to be applied onto the fiber in a closed mold. For that purpose, the epoxy resin, the fabric and resin hardener are prepared according to the right proportion before molding takes place. On the other hand, prepreg comes in a complete set with sufficient amount of both resin and hardener already impregnated in the fabric matrix. That is the huge difference between using conventional composite preparation and prepreg. Prepregs have been the most common choice nowadays in the industries worldwide due to its simplicity.

After undergoing curing process, the CFRP induces a permanent deformation known as the springback. Such deformation from the desired shape causes impediments during the assembly process and higher scraps rate. Even if the deformed parts were joined by force, the level of the internal stress will further increase and thus shorten the life expectancy of the component. Deep understanding of springback phenomena is required to produce quality components to accommodate high manufacturing rate for the production of modern aircraft such as the Airbus A320. Springback deformation occurs due to the stress build up during the crystallization of the resin within the composite. Therefore, warpage acts onto the composite after curing process. Based on previous research, three different mechanisms were identified as the source of the stress generated by the curing process. Those mechanisms are chemical reaction, thermal condition and finally the interaction between the tool and the laminate.

Experimental parameters which play an important role on the springback are divided into two categories which are intrinsic parameters and extrinsic parameters. Intrinsic constraints refer to the physical parameters of the laminate composite such as the length, thickness, number of plies and shape. Extrinsic constrains on the other hand denotes manufacturing process parameters such as surface condition, tool material, cure cycle and pressure of the autoclave.

1.2 PROBLEM STATEMENT

Autoclave chamber is used for the curing process of carbon fiber reinforced plastic. The ply closest to the tool in autoclave will experience the most expansion and the expansion gradually decreases as it reaches the middle ply. As a result, permanent deformation is induced. Such deviations from the actual desired shape lead to complications during the assembly process and higher scarp rates. High manufacturing rate of composite parts for an aircraft requires high quality components with low marginal errors. Therefore, springback behavior must be well understood to achieve accuracy in producing quality components as well as to reduce scarp rates.

1.3 OBJECTIVE

The investigation on the springback deformation of composite material after curing process is done with several objectives in this project. Those objectives are:

1) To measure the springback deformation of the composite material after undergoing curing process using 3D scanner.
2) To determine the effect of the thickness, dimension and angle of the composite material on the springback deformation after undergoing curing process.

1.4 SCOPE

The following statements are the scopes of this project:

1) CFRP specimens are L shaped and flat plate.
2) 3D scanner is used to scan the specimen to convert into computer aided design file.
3) Computer aided software is used to define planes and measure deformation.
4) Analysis of the measure deformation (springback).

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, reviews of pass studies from journals were made. Literature review is essentially examined according to the sources and described to justify the statements with proof of research or study in related subject. For this research, the phenomena of springback deformation, method used for measuring, and ways to control springback deformation are discussed.

2.2 PHENOMENON OF SPRINGBACK DEFORMATION

Springback deformation is an inevitable occurrence during the process of producing carbon fiber reinforced plastic for modern day usage. Understanding of this phenomenon took place as early as before World War II in the year 1940‟s during which fiber reinforced plastic were made into actual production (Times, n.d). Knowing the causes and effects of springback deformation on carbon fiber reinforced plastic is part of understanding the phenomena. Other than that, a clear understanding of the factors affecting the springback also serves as knowledge in the process of understanding springback deformation.

2.2.1 Causes of Springback Deformation

The main cause of springback phenomena is due to the stress build up during the curing process. In return, the stress induces warpage onto the composite material during the cooling stage after coming out of the autoclave chamber (Safarabadi & Shokrieh, n.d.). According to the past investigations, three main mechanisms were identified as the cause of the stress generated during curing process. Those mechanisms are chemical reactions (Oliver, 2006), thermal reactions (Parlevliet, Bersee, & Beukers, 2007) and interaction between tool and the laminate (Twigg, Poursartip, & Fernlund, 2003).

Chemical reactions between the molecules of the resin which causes phase change during curing process is what contributes to stress build up and eventually roots springback deformation. The phase change of resin into solid substance is known as crystallization. The crystallization process contains three steps which are viscous, rubbery and finally glassy. Each step is productively more crystallized than the previous state. Thermoset resins such as epoxy, vinyl ester, and polyester exhibits similar behavior when undergoing cure. Upon the introduction of heat, the viscosity of the resin drops and experiences maximum flow. At the same time, the increasing of the degree of cross linking between oligomers pushes the resin into the gelation or rubbery boundary. Oligomers are referred to complex molecules which have few monomer units attached to it. The mobility of the resin in the rubbery state is very limited. This is when the micro structure of the resin and the composite material fuses together and experience diffusion limitation for further cure. Therefore, it is common to increase the process temperature after the gelation stage to achieve better vitrification of the resin. The vitrification of the resin is achieved through cooling process or even through compression process. Morphing of the resin from viscous state to rubbery state and finally glassy state causes a significant change in volume. Figure 2.1 shows the morphing of the resin undergoing viscous, gelation and finally glassy state against temperature.