TESTING OF AIRCRAFT COMPOSITE SPOILER HINGES

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TESTING OF AIRCRAFT COMPOSITE SPOILER HINGES

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Testing of Aircraft Composite Spoiler Hinges ” is the result of my own work except as cited in the references.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Structure & Materials).

Signature :. .....

Name of Supervisor : .....

Date : .....

DEDICATION

Special dedicated,

To my beloved family,

Thanks for your morale support and understanding.

To my lovely friends,

Thanks you for all help

May God bless all of your kindness

ABSTRACT

Nowadays, Composite material is a major interest in many industries especially in aviation manufacturing. The transformation of composite over metallic material is due to high strength but light weight which indirectly contributes to save fuel consumption of aircraft. Almost entire structure of aircraft has changed to various types of composite material but only current hinge bracket for A320 aircraft are still made from metallic materials. The structure of hinges bracket are only analyzed by using Finite Element Method (FEM) analysis due to limitation of time and cost. However, this thesis is concerned with the experimental testing method in laboratory to analyze the structure of aircraft composite spoiler hinges. The several custom jigs for tester machine are developed to adapt the real condition in laboratory. The compression testing approach was used to analyze the structure of composite spoiler hinges after the real condition of aircraft testing cannot be replicated due to slipping of custom jig. The analysis of composite hinges by experimental testing is involved the comparing and validating with simulation and theoretical result in term of deflection and failure location. The failure location occurred on composite spoiler hinges by experimental almost similar to the prediction of simulation finite element method. But, the deflection of composite hinge for experiment testing was greater than theoretical and simulation finite element method by 61 and 63 percent, respectively due to imperfection and defect of the composite spoiler hinges prototypes. It is hope that this research will be able to help other researcher on further investigation of laminated composite in aircraft structure.

ABSTRAK

Pada masa kini, komposit merupakan bahan yang menjadi kepentigan utama dipelbagai sektor industri terutamanya didalam pembuatan struktur pesawat. Transformasi bahan komposit daripada bahan logam disebabkan oleh kekuatan yang tinggi malah lebih ringan secara tidak langsung menyumbang kepada penjimatan bahan bakar pesawat. Hampir keseluruhan struktur pesawat telah berubah kepada pelbagai jenis bahan komposit tetapi hanya pendakap engsel bagi pesawat A320 masih dibuat daripada bahan logam. Penganalisaan strutuktur bagi pendakap engsel hanya dibuat melalui Kaedah Unsur Terhingga (FEM) kerana oleh batasan masa dan kos. Walaubagaimanapun, karya ini adalah berkenaan dengan kaedah ujian eksperimen dalam makmal untuk menganalisis struktur pesawat komposit engsel spoiler. Beberapa jig khas untuk mesin penguji telah dibangunkan supaya dapat menyesuaikan keadaan sebenar dengan keadaan didalam makmal. Pendekatan ujian mampatan telah digunakan untuk menganalisa struktur komposit engsel spoiler dimana selepas ujian sebenar tidak dapat dilakukan disebabakan oleh jig ujian tergelincir. Analisis komposit engsel ini melibatkan perbandingan dan pengesahan dengan simulasi dan hasil teori didalam bentuk perubahan pesongan dan lokasi kegagalan. Lokasi kegagalan berlaku oleh eksperimentasi hampir sama dengan ramalan yang dibuat secara simulasi. Akan tetapi, perubahan pesongan engsel bagi ujian eksperimentasi adalah lebih besar daripada hasil teori dan simulasi kaedah unsur terhingga sebanyak 61 dan 63 masing-masing. Hal ini disebabkan oleh ketidaksempurnaan dan kecacatan pada komposit spoiler engsel. Ianya berharap agar kajian ini dapat memberi sedikit pentunjuk bagi siasatan lanjut dalam komposit berlapis bagi struktur pesawat.

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LIST OF ABBREVIATIONS

2D	-	Two dimensional
3D	-	Three dimensional
ASME	-	American Society of Mechanical Engineers
ASTM	-	American Society for Testing and Materials
CAD	-	Computer Aided Design
cm	-	centimeter
cm^3	-	centimeter cubic
CTRM	-	Composite Technology Research Malaysia
Etc.	-	Et cetera
FEA	-	Finite Element Analysis
FEM	-	Finite Element Method
FRP	-	Fiber Reinforced Polymer
FPF	-	First ply failure
g	-	Gram
g/cm^3	-	Gram per centimeter cube
mm	-	millimeters
mm2	-	millimeters square
mm3	-	millimeters cube
MPa	-	MegaPascal

N	-	Newton
Nm	-	Newton meter
NASA	-	The National Aeronautics and Space Administration
UD	-	Unidirectional
UTeM	-	Universiti Teknikal Malaysia Melaka

LIST OF SYMBOLS

%	-	Percent
°	-	Degree
cm3	-	Centimeter cube
g/cm3	-	Gram per centimeter cube
Θ	-	Angle
Vf	-	Fiber volume fraction
Vm	-	Matrix volume fraction
Wf	-	Fiber weight fraction
Wm	-	Matrix weight fraction
ρ	-	Density
ρ_c	-	Lamina density
ρ_f	-	Fiber density
ρ_m	-	Matrix density
E_1	-	Lamina longitudinal modulus
E_f	-	Fiber elastic modulus
E_m	-	Matrix elastic modulus
v_{12}	-	In-plane Poisson's ratio
v_f	-	Fiber Poisson's ratio
v_m	-	Matrix Poisson's ratio
E_2	-	Lamina transverse modulus
ζ	-	Empirical parameter
G_{12}	-	Lamina in-plane shear modulus
G_f	-	Fiber shear modulus Gm - Matrix shear modulus.
G_{23}	-	Lamina out of plane shear modulus
σ_1	-	Maximum local stress along fiber direction
σ_2	-	Maximum local stress transverse to the fiber direction
τ_{12}	-	Maximum shear stress in the principal material direction
F_{1c}	-	Lamina longitudinal compressive strength

F_{mt}	-	Matrix tensile strength
F_{2c}	-	Lamina transverse compressive strength
F_{mc}	-	Matrix compressive strength
F_6	-	Lamina in-plane shear strength
F_{ms}	-	Matrix shear strength
α_σ	-	Standard deviation of fiber misalignment
V_v	-	Void volume fraction
Π	-	A constant with the value of 3.142

CHAPTER 1

INTRODUCTION

1.1 Background

The aircraft spoiler hinges are one of the important components in aircraft wing structure. The function of aircraft spoiler hinges is used as the helping mechanism to control and move the aircraft wing spoiler in order to slow and descend an aircraft. Moreover, the aircraft spoiler hinges also used to hold the panel of aircraft wing spoiler in a position in order to ensure the spoiler can properly function. It is to keep necessary lift and drag force which may receive any disturbances in open air environment at high altitudes such as loading of air and external force by vibration (Nasa, 2010).

Presently, the fast growing implementation composite material in aircraft has been seen include primary and secondary structure. The increasing usages of composite materials in aircraft structure due to high strength, stiffness and light weight. The composite material comprises the combination between reinforcement and matrix material embedded together to allow the material has a strength to change the direction of loading (Cairns, 2009). The polymer matrix composite such as fiberglass, carbon fiber and fiber-reinforced matrix systems are the common composite material used in aircraft structure. The decreasing weight of an aircraft by composite materials will save the fuel consumption of the aircraft. The composite materials in aircraft structure also less maintenance and repair costs compared to the metallic material because it does not easily corrode and crack from metal fatigue. (Houston, 2016).

There are many production methods of the polymer matrix composite in aircraft industries. The processes will depend on several factors such as cost, the shape of the component, the number of components and required performance. Typically, the production method of polymer composite can be related to the combination processes of two constituent such as polymer matrix and reinforcement. The method is involved assembling fiber, impregnating resin, forming product and curing the resin. In addition, the fabrication process of the composite in industries also can be divided into two methods such as open-face moulding and matched-die moulding. Open-face moulding is a method using only one mould, simple equipment and low-cost production while matched-die moulding required specific design moulding, complex tooling and equipment as well as more expensive production cost. Although, matched-die moulding fabrication method better in term of good finishing, closer control over tolerances and high production rate while open-face moulding depending on operator performance (Hoa, 2009).

1.2 Problem statement

Many aircraft spoiler hinges are still made from metallic material. For this research, the laminated composite plates are used as the main material of the spoiler hinge structure. Therefore, the composite spoiler hinges are still not well investigated in term of real condition testing in the laboratory. However, the composite material is heterogeneous and anisotropic in nature which required specific analysis and testing to investigate the hinges structurally. The load cases of existing spoiler hinge in the real condition operation are provided by Spirit Aerosystem. The existing aircraft spoiler hinges are subjected to the resultant force and the

hinge moment due to a combination of air loading and the effect of wing deflections. The previous finite element method (FEM) result has shown that the composite aircraft is suffering some critical point due to the highest maximum stress concentration after subjected load cases (W. C. Mun, 2014). The real condition testing of the composite spoiler hinges in the laboratory is required to validate the finite element method (FEM) result.

1.3 Objectives

The objectives of this research are:

a) To develop jig for real condition testing in order to investigate structural of the composite aircraft spoiler hinge.
b) To compare and validate the finite element method (FEM) results by real condition experimental testing in the laboratory.

1.4 Scope

The scope of this research includes:

a) Literature study on the existing aircraft hinge design is provided by Spirit Aerosystem which includes determination loading applied to the structure of the hinge and working principle of existing metallic hinge spoiler. The study also on the related work of characteristic of the carbon fiber composite, jig design for testing machine and design an experimental test.