Faculty of Mechanical Engineering

OPTIMIZATION OF COMPOSITE HINGES FOR AIRCRAFT SPOILER USING FINITE ELEMENT METHOD

Amirul Herman bin Razali

Master of Science in Mechanical Engineering

2019

OPTIMIZATION OF COMPOSITE HINGES FOR AIRCRAFT SPOILER USING FINITE ELEMENT METHOD

AMIRUL HERMAN BIN RAZALI

A thesis submitted
in fulfilment of the requirements for the degree of Master of Science in Mechanical Engineering

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this thesis entitled 'Optimization of Composite Hinges for Aircraft Spoiler Using Finite Element Method' is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :…….....

Name : Amirul Herman bin Razali

Date :…….....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality as a partial fulfilment of Master of Science in Mechanical Engineering.

Signature :…….....

Supervisor Name : Associate Professor Ahmad Rivai

Date :……..

DEDICATION

To my beloved family, lecturers, friends and company (CTRM Aero Composites Sdn Bhd)

ABSTRACT

Current hinge brackets for A320 aircraft are made from metallic materials. The change of material from metallic to composite can reduce the structure weight. The classical method of analysis such as hand calculation and actual testing are not recommended for the new composite hinge design because it leads to high production and testing cost, as well as longer time consumption. This thesis is concerned with the method of modelling and analysing composite hinge bracket for A320 Spoiler using finite element method. The reverse engineering method through MSC PATRAN software is used to benchmark the actual loadings, constraints and allowable stress for the new hinge. Then, the method of optimization using Hypermesh software is used to avoid trial and error method, which requires a lot of efforts and more time. Next, a prototype of composite hinge is developed to validate the weight of the panel. The comparison of results between the old and the new design is done which records a reduction of 32% of the weight. This result proves that the simulation method proposed in this research is indeed feasible to be used for preliminary design stage for the hinge bracket of A320 Spoiler.

ABSTRAK

Kesemua engsel bagi pesawat A320 dibuat daripada bahan logam. Perubahan bahan daripada logam ke bahan komposit boleh mengurangkan berat struktur. Kaedah analisis secara konvensional menggunakan pengiraan manual dan ujian fizikal amat tidak digalakkan bagi reka bentuk engsel baru kerana kaedah ini membawa kepada kos pengeluaran yang tinggi, peningkatan masa dan kos ujian. Tesis ini adalah berkenaan dengan kaedah analisis dan permodelan engsel komposit bagi A320 Spoiler dengan menggunakan kaedah unsur terhingga. Kaedah kejuruteraan membalik dengan menggunakan perisian MSC Patran digunakan sebagai penanda aras beban, kekangan dan tekanan yang dibenarkan untuk engsel yang baru. Kemudian, kaedah pengoptimuman dilakukan dengan mengunakan perisian Hypermesh bagi mengelakkan kaedah cuba jaya yang memerlukan banyak usaha dan masa. Prototaip engsel komposit disediakan untuk diukur berat bagi mengesahkan hasil daripada pengiraan kaedah unsur terhingga. Perbandingan keputusan antara kaedah simulasi rekabentuk asal dengan rekabentuk optimum mendapati terdapat pengurangan sebanyak 32% daripada berat struktur. Dapatan kajian ini membuktikan kaedah simulasi yang dicadangkan dalam kajian ini boleh diaplikasikan pada peringkat reka bentuk engsel spoiler A320.

ACKNOWLEDGEMENTS

First and foremost, I would like to take this opportunity to express my sincere acknowledgment to my supervisor, Associate Professor Ahmad Rivai from the Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for his active supervision, support and encouragement towards the completion of this thesis.

Special thanks to my beloved family members for their moral support to me in completing this degree. Lastly, thank you to everyone who has been the crucial parts in realizing this project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

1D - One dimensional

2D - Two dimensional

3D - Three dimensional

ASME - American Society of Mechanical Engineers

AFP - Automatic Fibre Placement

CAD - Computer Aided Design

CAM - Cylindrical Assemblage Model

CFRP - Carbon Fibre Reinforced Plastic

CLT - Classical Laminate Theory

CS - Constant Stiffness

FAA - Federal Aviation Administration

FACC - Fischer Advanced Composite Components

FE - Finite Element

FEA - Finite Element Analysis

FEM - Finite Element Method

FPF - First Ply Failure

FRP - Fibre Reinforced Polymer

FS - Factor of Safety

g - Gram

Hz - Hertz

IBC - International Building Code

kN - Kilo Newton

mm - millimetres

mm^2 - millimetres square

MPa - Mega Pascal

MS - Margin of Safety

NASA - National Aeronautics and Space Administration

N - Newton

Nm - Newton meter

PPF - Progressive Ply Failure

RBE - Rigid Body Elements

RF - Reserved Factor

RTM - Resin Transfer Moulding

UD - Unidirectional

VSL - Variable Stiffness Laminates

V&V - Verification and validation

VV&A - Verification, validation and accreditation

LIST OF PUBLICATIONS

JOURNAL PAPER

Shamsudin, Z., Razali, A.H., Suzaim, F.H., Mustafa, Z., Rahim, T.A. and Hodzic, A., 2018. Preliminary investigation on the physical properties and morphological of sintered cockle shell/recycled soda lime silicate composite. *Journal of Advanced Manufacturing Technology (JAMT), 12*(1 (3)), pp.125-138.

CONFERENCES ATTENDED

Razali, A.H and Ahmad, R., Reverse engineering method to analyse aircraft spoiler middle hinge using finite element analysis, 2nd Postgraduate Research Symposium on Mechanical Engineering, 05 January 2017.

CHAPTER 1

INTRODUCTION

1.1 Background

The Airbus A320 family consists of short to medium range aircraft with narrow body. The A320 is the pioneer of commercial aircraft that uses Fly by Wire (FBW) flight control system. It is one of the most popular Airbus aircraft that records for high demand from airlines worldwide. In December 2010, Airbus officially launched the new generation of the A320 fleet with new engine options which are CFM International LEAP-X and Pratt & Whitney PW1000G. This new generation aircraft has an improved airframe and additional winglets that are called sharklet. The new A320, namely A320neo delivers fuel saving of up to 20% (Airbus, 2017). During the past 35 years, Airbus has continuously and progressively introduced the composite technology for aircraft part to the world. Figure 1.1 shows the evolution of composite application in aircraft parts.

Wings are the primary structure of an aircraft. Within them, there is a part that functions to increase drag, reduce lift, and assist aileron in rolling, called spoiler. A spoiler is a structure to assist the aircraft during landing and descending from higher to lower altitude. It is also used to generate the rolling motion of an aircraft. The method of control of aircraft movement for spoiler is by 'spoiling' the airflow over the wing (Dawson, 2006).

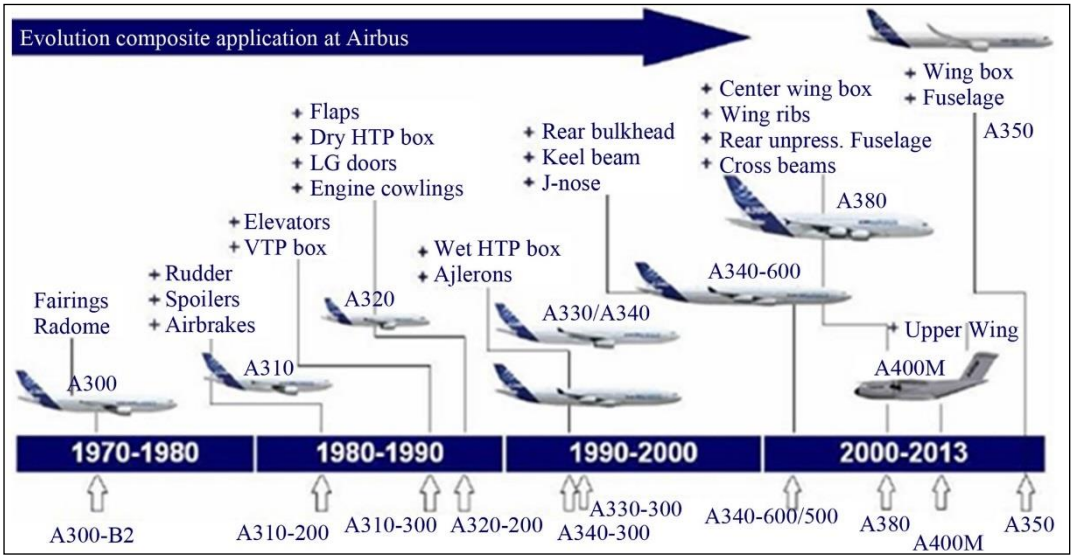

Figure 1.1 : Composite structure development in Airbus (Jane Bold, 2007)

The movement of the aircraft spoilers is controlled by a set of hinges. These hinges function to provide a rotational motion in one axis direction (Leet et. al., 2002). Hinges are usually made from metal and consist of two brackets. The brackets have bearings fitting to reduce frictional force between the brackets and the pin. In the new generation of aircraft constructions, the usage of the metallic material is no more an option in aircraft development. The usage of composite materials has been increasing because its capability in reducing the overall structural weight effectively (Basavaraju, 2005; Mallick, 2007).

Therefore, to meet the new technology demand, the metallic components like metal hinge will be replaced by composite. Hence, the new development of composite hinge is crucial to achieve overall weight reduction in aircraft development. However, the strength of the composite material is difficult to predict especially during flight. Conventional stress calculation is not enough to predict the stress on the composite components. Hence, the use of computer simulation, finite element method (FEM) is very helpful to predict the mechanical behaviour of the composite components under different flight conditions.

Simulation using FEM is a process of modelling a real phenomenon with a set of mathematical formulas. It is an alternative method to provide the best approximation to solve complex engineering problems (Logan, 2007). FEM is an analysis method that uses virtual reality for testing. This method can reduce overall cost and time because it does not require raw material and physical testing (Soutis, 2005).

1.2 Problem statement

Current hinge brackets for A320 aircraft are made from metallic material that is aerospace grade aluminium. In term to improve aircraft efficiency, the major issue with metallic part is the heavy-weight. Material replacement from metallic to composite can reduce the structure weight. However, the development of composite hinges is very different in approach with metal hinges. There are several factors to be considered: design of hinge, type of composite material, number of composite ply, ply direction and manufacturability (Gasbarri et. al., 2009). These five factors need to be properly chosen and optimized to meet the design requirements. Hence, the issue at hand here is the choice of suitable and faster method to achieve an optimized composite hinge design. The current hinges for A320 spoiler are using conventional method during their development phase (Gransden & Alderliesten, 2017). Metallic hinge design parameter is chosen using the design of experiment method. Each set of hinge is fabricated and tested which uses a lot of development time. Therefore, to solve this issue, the FEM and composite optimization method are introduced in this thesis to reduce the development time of composite hinges.