STRUCTURAL ANALYSIS OF CORELESS SPOILER

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To my beloved mother and father

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ABSTRACT

The A320 spoiler has a sandwich structure with honeycomb component as its core. However, honeycomb core is vulnerable to water ingression, causing damage to the control surface due to its weak moisture resistance behaviour. The objective of this project was to conduct the design and analysis of an improved composite structure for a coreless spoiler. Weaknesses of a coreless spoiler were identified through Finite Element analysis done by using Abaqus software. In addition, topological and parametric optimizations were applied to produce an improved configuration as an alternative to the honeycomb core. Multi-spar and multi-rib designs were studied and compared for topological optimization. The variables used for evaluation were Tsai-Hill failure index and critical buckling load. The most potential design was considered for parametric optimization. Looping of parametric optimization was carried out to obtain the most satisfactory configuration. The results showed that the upper skin of the spoiler without honeycomb core failed the Tsai-Hill criteria. Furthermore, the multi-spar configuration outperformed the multi-rib configuration. The final multi-spar configuration achieved a weight reduction of 24% from original spoiler without violating the Tsai-Hill criteria and buckling constraint. As a conclusion, the weaknesses of the spoiler without honeycomb core have been identified and an improved composite structure for coreless spoiler has been proposed.

ABSTRAK

A320 spoiler adalah terdiri daripada struktur berlapis dengan teras buatan struktur bersel. Walau bagaimanapun, air yang masuk ke dalam teras akan membawa kerosakan kepada spoiler disebabkan sifat ketahanan kelembapannya yang lemah. Tujuan projek ini adalah untuk mereka bentuk dan menjalankan kajian ke atas struktur komposit bagi spoiler tanpa teras. Kelemahan spoiler tanpa teras telah dikenal pasti melalui kaedah unsur terhingga dengan menggunakan Abaqus. Tambahan pula, pengoptimuman topologi dan parametrik telah dilaksanakan untuk menghasilkan konfigurasi yang lebih baik demi menjadi penggantian kepada teras. Penggunaan multi-spar dan multi-rib dalam reka bentuk telah dikaji dan dibanding semasa pengoptimuman topologi. Faktor-faktor penilaian adalah Tsai-Hill index dan beban lengkokan kritikal. Reka bentuk yang paling berpotensi telah diteruskan ke pengoptimuman parametrik. Pengoptimuman parametrik telah diulangi demi mendapatkan reka bentuk yang mencapai tahap memuaskan. Hasil kajian menunjukkan bahawa kulit di bahagian atas spoiler tanpa teras gagal memuaskan kriteria Tsai -Hill. Tambahan pula, konfigurasi multi-spar mempunyai prestasi yang lebih baik daripada multi-rib. Produk akhir telah mencapai pengurangan berat sebanyak 24% daripada spoiler asal tanpa melanggar hukum Tsai-Hill dan kekangan lengkokan. Secara kesimpulannya, kelemahan untuk spoiler tanpa teras telah dikenal pasti dan struktur komposit yang berprestasi baik telah dicadangkan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

E	-	Modulus of elasticity
G	-	Modulus of rigidity
ρ	-	Density
σ	-	Axial stress
τ	-	Shear stress
γ	-	Shear strain
N_o	-	Composite buckling
[D]	-	Bending stiffness matrix
u	-	Displacement in x-axis
v	-	Displacement in y-axis
U	-	Displacement
ε	-	Strain
[A]	-	extensional stiffness matrix
%	-	Percentage
A	-	Area
P	-	Pressure
X	-	Load per unit length
θ	-	Degree
Q	-	Modulus
h	-	Thickness of plies
k	-	Constant
HM_{ext}	-	Hinge moment
$(Sc)_{sp}$	-	Reference area and chord of spoiler
[B]	-	Coupling stiffness matrix
λ_i	-	Eigenvalues

i	-	Buckling mode
N	-	Load
M	-	Moment
υ	-	Poisson's ratio
F	-	Force

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

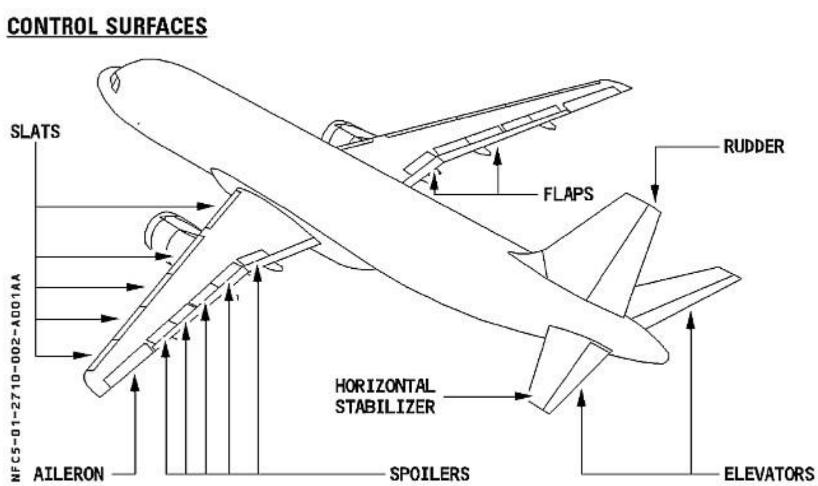
1.1 An introduction to spoiler

In aviation, the definition of a spoiler is a plate or surface used to destroy the air flow around the wing. Most airliners are assembled with spoilers, usually are in a pair on the left and right wing. They are long and narrow in shape with hinges at their leading edges and located on the upper surfaces of the wings. When they are in the retracted position, they are flush with the wing skin. On the other hand, they can be raised to different angle positions to serve different purposes. The fundamental principle of a deflected spoiler is to spoil the smooth flow over the wing surface in order to reduce the wing lift. In fact, different kind of aircraft utilizes different spoiler design and function for varied intentions.

Spoiler is a multitasking flight control surface to assist the aircraft in flight performance and can be categorized into three main functions. First, spoilers are employed during flight for air-braking purpose. The spoilers can slow down an aircraft by speed reduction and also assist an aircraft to descend. Sometimes during flight, relatively small spoilers are deployed at controlled angles to enhance descent rate. Spoilers are very common in gliders (sailplanes) where the rate of descent is crucial to make sure the exact landing spot is achievable. Pilot also can lower the aircraft nose to increase the descent rate, but this generates an extreme speed of landing. Assistance from spoilers ensures safe landing speed airflow.

Second, an aircraft in flight can perform roll motion by deploying spoilers only on one wing. Sometimes during high speeds, the rudder effect is restricted, thus, spoilers are used with or in place of ailerons for roll control, mainly to reduce adverse yaw.

Finally, spoilers act as lift dumpers on the ground. They are special type of spoiler which span almost as far as the length of the wing and only two positions deployed and retracted available to lift dumpers. Their function is to dump as much lift as possible during landing. Therefore, they must not be deployed in flight as they completely stall the aircraft. Moreover, they improve the efficiency of the wheel brakes by applying the full weight of the aircraft on the wheels. Prevention of the aircraft 'bouncing' on the runway, a common problem with older aircrafts can be eliminated by lift dumpers deployment. Besides that, they also help to slow down the aircraft on the runway by significantly increasing the drag. Mostly, airliners deploy the lift dumpers automatically on touchdown. Airbus A320 is an example of aircraft which utilises the lift dumpers during landing.



The flight controls are electrically or mechanically controlled

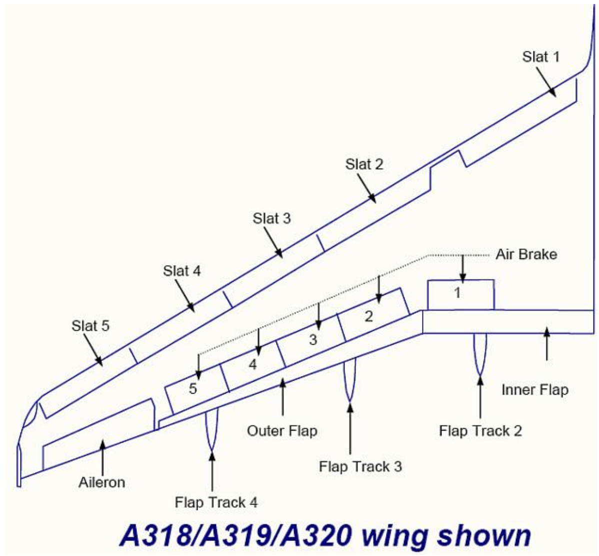


Figure 1.1 Airbus A320 spoiler location [1]

1.2 Background of the problem

Weight reduction of an aircraft is a crucial issue therefore composite and honeycombs are applied wherever is possible instead of metals. Most of the parts made from honeycomb are secondary structures, not primary structures. Sandwich panels are widely used as secondary structures in aviation field. Most components of the wing control surface outside the main torque box are made of composites, for example, spoilers, ailerons, flaps, and slats. Secondary structures are those which would not cause immediate danger upon failure. Spoilers are the secondary parts which use the honeycomb sandwiches as their internal fillers and are covered by carbon fibre skins. Honeycomb structures have gained prominence in applications because of their high structural efficiency and design versatility. Spoiler sandwich panels of aircraft A320 are composites with paper-honeycomb cores within two thin and strong carbon fibre reinforced plastic (CFRP) skins.

However, it is renowned that the honeycomb structures are susceptible to water ingression. Water infiltrates the honeycomb components and leads to corrosion and/or adhesive bond degradation, which compromises the structural integrity of the components. Temperature and pressure differences during take-off and landing generate great stress on the honeycomb structures which induces water ingress through direct and indirect methods. The former is capillarity-type action, water entry via capillarity action due to defections such as cracks, adhesives, fibre matrix interfaces or imperfections, examples, around fasteners. The latter, indirect water ingression due to diffusion takes place at the molecular stage through the composite face sheets and over long duration of time, moisture also found even in an undamaged composite sandwich panels. On the other hand, composites are exposed to the environment when aircraft services or repairs and causes absorption of moisture into honeycomb cores by diffusion. Any fluids such as hydraulic fluid, water, kerosene or de-icing agents in any state (liquid, gas vapour, or ice) causes corrosion, cell rupture, node bond breakage inside the composite and further induces layer delaminations and skin disbands [2]. Furthermore, trapped water (in liquid or vapour state) in the honeycomb structure could promote structural damage (node bond failure) due to continuous freeze-thaw cycles in normal flight operations [3, 4].

Sandwich panel failures have caused severe damages and/or losses of control surfaces [5]. A common failure mode is the skin-to-adhesive disbond at the interface between the face sheet and the adhesive layer. Sometimes during the aircraft in service, the adhesive layer was found vanished from the detached skin material. Besides that, the heating temperature during service induces an internal pressure and when it goes beyond the flatwise tension strength (FWT) of the adhesive fillet, a cohesion fillet bond failure is created. The rupture of adhesive layer, the fractured adhesive was on the core cell walls and face sheet. Another type of failure form is adhesion fillet bond failure at the bonding face between the core cell-walls and the adhesive used to attach the core to the face sheets in the production of the panel. Lastly, node bond failure at the cell nodes due to degradation of the core cell-wall attachment generated at some point in original fabrication of the core material. It has been observed that in flight failure of bonded panels on RAAF F-111 and USN F/A-18 aircraft as a result of fillet bond failure and critical node bond disband have occurred on several panels throughout the overhaul heating repairs. The outer skins of the control surfaces were peeled off and to the extent of torn from the hinges. Owing to repair the degraded sandwich panels, a lot of hard-work and high maintenance costs are required.

1.3 **Problem statement**

Although honeycomb core is a light weight and strength effective material, water ingression is a major inherited problem. The spoiler is a sandwich panel where honeycomb core is its main structure, should have been troubled by moisture issue. Therefore, an alternative structure as the spoiler main strengthening component is desirable.

1.4 **Research objective**

The aim of this study was to conduct the design and analysis of an improved composite structure for coreless spoiler for A320. Airbus A320 spoiler panel 2 was the baseline reference. The coreless spoiler was based on the concept of removing the honeycomb core as the filler in order to avoid structural failure due to degradation of honeycomb structure.

1.5 Research scope

Some scopes of study have been highlighted in this project as a guideline listed as below:

(a) Understand the spoiler design requirements of Airbus spoiler.

(b) Obtain the design loadings on the spoiler.

(c) Achieve weight reduction in coreless spoiler.

(d) Analysis on composite structure using FE.

(e) Generate methodology of the structural design and analysis of the structural components of the spoiler under such loadings in Abaqus.

1.6 Thesis outline

This report consists of six chapters, which were introduction, literature review, methodology, result and discussion and conclusion. Chapter One was the introduction which covered the definition and function of the spoiler, the background of the problem, the objective and scopes of the study. The literature review is placed in Chapter Two. It contained the previous researches on moisture problem of honeycomb core, requirements and FAA regulations, optimizations, different types of configuration layout, materials, topics related to laminate and lamina and finite element method.

Research methodologies were discussed in Chapter Three such as detail plan on how to execute this study, tools and modeling of the spoiler in order to achieve the objective. Chapter Four focused on presentations of results from FE and analysis on the outcomes. Optimized design was shown in this chapter. The last chapter, Chapter Five provided the conclusion of the analysis in Chapter Four and recommendations for future work on the improvement of spoiler performance itself.

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