## 代表著作名稱

Evaluation on crashworthiness and energy absorption of composite light airplane

## 中文名稱

複材輕型飛機適墜性與能量吸收之評估

## 中文摘要

本研究主要目的在於探討使用鋁合金與三種不同的纖維複合材料(碳纖維/CFRP、玻璃纖維/GFRP、凱夫勒纖維/KFRP)做為輕航機座艙與機身在墜撞下之安全性差異。本文根據 MIL-STD-1290A 所規定的座艙壓縮量在各方向的壓縮量不得超過 15%的安全標準下，建立速度與角度的安全區域。CFRP 與 GFRP 座艙整體安全區域高於鋁合金座艙 38.56%與 32.12%，KFRP 座艙安全區域則略低於鋁合金座艙 4.74%。在整體座艙安全方面，無論是改變撞擊角度或是撞擊速度，斜樑 A 都是關鍵的結構件。在四種不同機身材料中，碳纖維複合材料做為座艙材料除了在 Y 方向撞擊時之變形量略高於鋁合金座艙之外，在墜撞時 X 方向與 A 方向的壓縮量都小於其他材料，而其整體座艙的安全性也都優於其他材料。鋁合金機身的能量吸收能力優於所有的複合材料機身。

# 参考著作

**A Crashworthiness Simulation for a Light Aircraft Constructed of Composite Materials**

*Transactions of the Canadian Society for Mechanical Engineering,* Vol. 39(4), 829-843, 2015

https://www.tcsme.org/Papers/Vol39/Vol39No4Paper7.pdf
http://www.nrcresearchpress.com/doi/abs/10.1139/tcsme-2015-0066#.W8tGidczaUk
https://doi.org/10.1139/tcsme-2015-0066

**A Simulation of the Fatigue Life of Light Aircraft Glass Fibre-Reinforced Composites Landing Gear**

*Materials Research Innovations,* Vol. 19(S9), 142-147, 2015

https://doi.org/10.1179/1432891715Z.0000000001947

**Optimization Analysis on the Crashworthiness of Light Aircrafts**

*International Journal of Manufacturing, Materials, and Mechanical Engineering,* Vol. 5(3), 1-22, 2015

https://www.igi-global.com/article/optimization-analysis-on-the-crashworthiness-of-light-aircrafts/129500
https://pdfs.semanticscholar.org/3006/42661f891e86176113fc584ca1893ea0c010.pdf
http://doi.org/10.4018/IJMMME.2015070101

**An Analysis of the Damage Tolerance of Light Aircraft Landing Gear**

*Transactions of the Canadian Society for Mechanical Engineering,* Vol. 37(4), 1147-1159, 2013

https://www.tcsme.org/Papers/Vol37/Vol37No4Paper8.pdf
http://www.nrcresearchpress.com/doi/abs/10.1139/tcsme-2013-0097#.W8tNyNczaUk
https://doi.org/10.1139/tcsme-2013-0097

# A simulation of the fatigue life of light aircraft glass fibre-reinforced composites landing gear

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This study uses finite element analysis software to conduct simulations and compares the fatigue behaviour of the aluminium alloy and glass fibre-reinforced composite that is used in light aircraft landing gear. The maximum stress, maximum strain and deformation of landing gear of different shapes (plate and tube shapes) are also determined. The results show that the composite landing gear weighs 45% less than an aluminium equivalent. Of the samples tested, plate-shaped glass fibre-reinforced composite landing gear exhibits the lowest maximum stress under a static load. Regardless of whether the landing gear is plate- or tube-shaped, the maximum strain and deformation for the composite landing gear are more than four times those for the aluminium alloy landing gear. The results for dynamic load show that plate-shaped glass fibre-reinforced composite and tube-shaped aluminium landing gear have similar maximum alternating stress under cyclic loading.

**Keywords:** Light aircraft, Landing gear, Glass fibre-reinforced composites, Fatigue, Finite element analysis

## Introduction

Composite materials have been undergoing development for more than 50 years. In the past, composite materials have not been used as the main structural material for aircraft, because there are significant differences between composite materials and traditional metals. For example, most composite materials are brittle and non-conductive and they are fabricated using adhesive bonding techniques, so engineers are concerned about lightning strikes, durability, impact resistance and fatigue. Although most of these concerns have been addressed, concerns regarding the diversity and manufacturing of composite materials remain unresolved. Approximately 53% of the aircraft body and wings of the newest Airbus A350 XWB are made from composite materials. Newly developed composite materials are also widely used in business jets, very light jets and other light aircraft. Recently, general aviation (GA) aircraft or light aircraft has undergone considerable development. In 2013, the number of GA aircraft increased by 4·3%. Currently, several companies produce light aircrafts that are made entirely from composite materials. For example, Aeroprakt Ltd. (Ukraine) produces several light aircraft that are made from composite materials, Cirrus Aircraft Corporation (USA) has designed composite wing structures for the Cirrus SR20 and SR22 and the Grob Aircraft (Germany) uses carbon fibre composite materials in the aircraft fuselage of the Grob G120A twin-seat trainer aircraft. Light aircraft can save passengers a considerable amount of time in airport transit and many light aircraft are purchased by private owners for short trips or recreation.

More than 90% of the structures for the CTLE aircraft produced by Flight Design (Germany) are made from carbon and aramid fibre composite materials. In 2013, the German Ministry of Economic Affairs funded research into flight cabin safety in light aircraft (Safety Box),[1] in order to develop passenger protection systems in the event of a crash. Flight Design used the findings of this research to develop a novel type of light aircraft that is made entirely from a carbon fibre composite material. This demonstrates that composite materials will inevitably be used for the development of aircraft in the future.

When a structure experiences repeated cyclical stress or strain, cracks are generated, which eventually lead to fatigue failure or damage under long-term loads. Aviation accidents owing to material fatigue have caused serious damage, despite accumulated experience and continuous research by the aerospace industry. Cracks can form on aircraft structures if there is repetitive loading on the aircraft fuselage during takeoff and landing. Therefore, in 2010, the United States Federal Aviation Administration (FAA) enacted the widespread fatigue damage (WFD) rule,[2] which limits the number of takeoffs, landings and flight hours for aircraft that

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# Optimization Analysis on the Crashworthiness of Light Aircrafts

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## ABSTRACT

*To protect passengers, large aircraft are equipped with multiple mechanisms to absorb impact energy during a crash. However, light aircraft rely only on the cabin structure to withstand the compression and energy generated during a crash. This study performed a topology optimization analysis on the model structure by using Abaqus/optimization and used strain energy as the objective function and cabin volume as a constraint to develop the optimal model. Subsequently, this work performed dynamic crash simulations based on the optimal and original models by using Abaqus/explicit. Compared with the original model, the optimal model yielded a 12% increase in the safety zone of the diagonal beams, a 13% increase in the X-direction safety zone, and a 10% increase in the overall safety zone. The results confirm that topology optimization can be used to effectively improve the crashworthiness of light aircraft.*

*Keywords:* *Abaqus, Cabin, Fuselage, Crashworthiness, Finite Element Method, Impact Angle, Impact Energy, Impact Velocity, Light Aircraft, Optimization Analysis, Safety*

## INTRODUCTION

With the increasing complexity involved in developing industrial products, determining the optimal design of a product is vital to ensuring product competitiveness. Optimization is crucial in designing products because it involves ensuring that products meet their functional requirements under existing constraints. This has led to the wide use of design-optimization technologies in various engineering fields. Technological advancements and increased public demand for safe and comfortable aircraft have contributed to the development of increasingly complex aircraft systems. When designing aircraft, engineers must consider numerous factors, such as aerodynamics, aircraft structure, aircraft performance, manufacture cost, and subsequent maintenance costs. Previous optimization techniques for aircraft primarily involved improving the aerodynamic configuration of wings and fuselage, and also to enhance the structural strength as well as reduce the overall weight. In the field of aircraft engineering, design op-

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# AN ANALYSIS OF THE DAMAGE TOLERANCE OF LIGHT AIRCRAFT LANDING GEAR

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## ABSTRACT

This study uses the finite element software, FRANC2D, and the life-time analysis software, AFGROW, to perform simulation analyses of the damage tolerance of the landing gear of light aviation vehicles. This study explores the effect that the initial crack positions and different materials have on the life cycle of landing gear under long-term loads. This study also compares the relationship between stress intensity factors and crack growth for four types of aluminum alloys, titanium alloy and alloy steel. The relationship between residual strength and life cycle, in the presence of existing cracks, is also investigated.

**Keywords:** damage tolerance; crack propagation; finite element analysis; light aircraft.

# ANALYSE DE LA TOLÉRANCE AUX AVARIES DU TRAIN D'ATTERRISSAGE D'UN AÉRONEF DE FAIBLE TONNAGE

## RÉSUMÉ

Pour cette étude, nous utilisons le programme d'élément fini FRANC2D, et le programme d'analyse AFGROW, pour exécuter des analyses de simulation de la tolérance aux avaries du train d'atterrissage d'un aéronef de faible tonnage. Cette recherche explore les effets que les positions de la première fissure, et les différents matériaux, ont sur le cycle de vie d'un train d'atterrissage sous des charges permanentes. Cette étude compare la relation entre l'intensité des facteurs de stress, et la propagation de fissures sur quatre types d'alliage : les alliages d'aluminium, de titane, et l'acier d'alliage. La relation entre la force résiduelle et le cycle de vie, en la présence de fissures existantes, est aussi investiguée.

**Mots-clés :** tolérance aux avaries ; propagation de fissure ; analyse des éléments finis ; aéronef à faible tonnage.