Optimization Analysis on the Crashworthiness of Light Aircrafts

Pu-Woei Chen, Tamkang University, New Taipei City, Taiwan
Yung-Yun Chen, Tamkang University, New Taipei City, Taiwan

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-
timization and various novel algorithms have proven to be reliable technologies in aircraft design and relevant simulations. Airbus designed its A350 XWB by using optimization software that analyzed the structural load of the aircraft and removed any unnecessary structural components, thereby reducing the overall weight of the aircraft by 30%. In addition, optimization simulation facilitated a structural redistribution that increased the structural strength, improved the aircraft performance by 30%, and reduced the production costs by 50% (Gardiner, 2011). Because aircraft design involves large and complex systems, various constraints must be considered. Thus, in 2009, the Collaborative and Robust Engineering using Simulation Capability Enabling Next Design Optimization project was established in Europe with the aim of developing an optimization analysis technique for aerodynamics-structures interaction in airframe design (CRESCENDO, 2013). In the 1990s, Dassault Aviation began using optimization techniques to simulate the aerodynamics of new aircraft during the early stages of development. However, the process necessitates the use of high-speed computers to solve grid-computing systems with millions of nodes (Quang et al., 2012) The company used an optimization technique to develop the FALCON 5X 16-passenger business jet, resulting in an optimised aerodynamics and fuselage performance that facilitated 15% reduction in fuel consumption.

Small business jets are classified as general aviation (GA) aircraft. In general, GA aircraft is used to describe all non-military aircraft and aircraft not used by commercial airlines. In 2013, GA aircraft shipment worldwide grew by 4.3% from the previous year (GAMA, 2013). Currently, there are 6,645 light sport aircrafts (LSAs) in the United States (FAA, 2013), and this is expected to grow 2% annually. Compared with general commercial airlines that have regular flight schedules, the rapid growth in GA aircraft sales is primarily because flights via GA aircraft are more convenient, enabling passengers to avoid delays and the need to transfer flights. LSA and other types of light aircraft are also used for short trips and personal leisure purposes. However, safety issues remain the primary factors that hinder the rapid development of GA. Therefore, in this study, we investigated the safety of light aircraft by integrating crashworthiness and topology optimization of the aircraft structure. In November 2013, the United States government successfully introduced the Small Airplane Revitalisation Act, demanding that the Federal Aviation Administration (FAA) improve their certification mechanisms to reduce the costs and time required for new aircraft to enter the market. Concurrently, the bill stipulates that the FAA improve the safety of small aircrafts because it was the biggest concern of potential consumers. For example, from 1998 to 2007, there were 4.03 fatalities per million flight hours for regular flights, but there were 22.43 fatalities per million flight hours for GA flights. The National Transportation Safety Board reported that the fatality rate for aircraft accidents in 2012 was 18% for regular flights and 97% for GA aircraft (NTSB, 2012). Therefore, using optimization techniques while complying with the regulations, satisfying safety conditions, and meeting market demand is crucial to ensuring the continuous development of small aircraft.

**LITERATURE REVIEW**

Structure topology optimization is to achieve the optimal structural redistribution of a structure by optimizing a design objective within the constraint limits. This method enables companies to effectively improve the primary design and conceptual analyze of their products during the early stages of product development. Current topology optimization techniques have evolved from the conceptual design stage to one that also includes analyzing the feasibility of manufactured products. Such feasibility analyzes focus on the shape symmetry and optimal design for products of various thicknesses (Zhou et al., 2011). However, most of the current studies on aircraft design optimization have used for large transport aircraft. For example, the
Behavior of the Lubricating Film between Sinusoidal Roughened Surfaces: Theoretical and Numerical Approaches with MATLAB Applications
[www.igi-global.com/article/behavior-of-the-lubricating-film-between-sinusoidal-roughened-surfaces/135491?camid=4v1a](www.igi-global.com/article/behavior-of-the-lubricating-film-between-sinusoidal-roughened-surfaces/135491?camid=4v1a)

Transcritical Carbon Dioxide Refrigeration as an Alternative to Subcritical Plants: An Experimental Study
[www.igi-global.com/chapter/transcritical-carbon-dioxide-refrigeration-as-an-alternative-to-subcritical-plants/136752?camid=4v1a](www.igi-global.com/chapter/transcritical-carbon-dioxide-refrigeration-as-an-alternative-to-subcritical-plants/136752?camid=4v1a)