

Lightweight Composite Air Cargo Containers

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ABSTRACT

Air cargo containers are used to load freight on various types of aircrafts to expedite their handling. Fuel cost is the largest contributor to the total cost of ownership of an air cargo container. Therefore, a better fuel economy could be achieved by reducing the weight of such containers. This paper aims at developing innovative, lightweight design concepts for air cargo containers that would allow for weight reduction in the air cargo transportation industry. For this purpose, innovative design and assembly concepts of lightweight design configurations of air cargo containers have been developed through the applications of lightweight composites. A scaled model prototype of a typical air cargo container was built to assess the technical feasibility and economic viability of creating such a container from fiber-reinforced polymer (FRP) composite materials. The paper is the authoritative source for the abstract.

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INTRODUCTION

The role of air transport in providing rapid and intercontinental connections has made it an essential economic and social conduit throughout the world. In 2010, the air transport industry transported approximately 43.3 million tons of freight worldwide, up from 30.4 million in 2000, which account for nearly 40 percent of all goods by value. Many developing countries today depend heavily on air cargo for their exports as other modes of transportation are unreliable or non-existent [1]. This demonstrates clearly that the air transport sector is undergoing an optimistic growth rate while at the same time eliciting growing concern, due to its environmental impact and its vulnerability with respect to energy security. These issues have put the sector at the forefront of the tide in achieving energy efficiency. Efforts have been made on every front to improve efficiency through better technology, optimized operation, as well as energy-saving infrastructure.

According to the International Energy Agency, aviation used 246 million tons of oil equivalents (Mtoe) of energy in 2006, which represented 11 percent of all transport energy used. Aviation's energy usage is expected to triple to about 750 Mtoe by 2050, according to the IEA's baseline scenario; as a result, aviation would account for 19 percent of all energy used [2]. The growing demand in energy along with rising fuel costs is endangering the air transport's optimistic growth. Traditionally, fuel costs were less than 15 percent of airline operational costs; however, they have risen substantially since 2003. Fuel costs rose to around 33 percent in 2008 and exceeded 40 percent for carriers with lower labor costs [2]. However, some studies suggest

that aviation overall warming impact is much higher given its emissions of the greenhouse gases such as NO_x , CH_4 , and H_2O among others, as well as differential effects of emissions at different altitudes.

With a growing sense of urgency for sustainability actions among consumers and governments around the world, air transport industry is under pressure to operate in sustainable manners [3]. Freight transportation is a large and fast growing contributor of GHG emissions, especially carbon dioxide (CO_2) that accounts for more than 90 percent of GHGs [4]. Aviation causes about 2 percent of total man-made carbon emissions according to the Intergovernmental Panel on Climate Change (IPCC). Aviation emitted about 810 million tons of CO_2 in 2006, which represents about 12 percent of all transport CO_2 emissions [5]. The industry is growing by around 5% a year in the longer term but efficiencies already in place mean aviation CO_2 emissions are growing by just 2 to 3 percent. Therefore, it is vital to develop new technologies in order to reduce the overall emissions. This could be best achieved by lowering fuel consumption through enhancing aviation efficiencies.

UNIT LOAD DEVICE

A unit load device (ULD) is a pallet or container used to load luggage, freight, and mail on an aircraft. It allows a large quantity of cargo to be bundled into a single unit, thus leads to fewer units to load [5]. As a result, it saves ground crews time and effort and helps prevent delayed flights. Because of regulatory requirements as well as practical considerations, the shape, size and maximum weight of a ULD for each type of aircraft have been standardized. Typically, ULDs are shaped as boxes, which can include sloped surfaces which

conforms the ULD to the aircraft's fuselage when the ULD is placed in the cargo compartment as shown in Figure 1. The container is made of several panels that are joined together to form the ULD and define an enclosed storage volume. The ULD is often constructed from a metal such as aluminum or one of its alloys that are able to tolerate the tough handling conditions the container experiences through transfer and transport situations.

Lightweighting aircraft and freight transport hardware by using new materials and composites was envisioned as a means that can significantly improve fuel efficiency and reduce greenhouse gas emission. Previous research efforts on lightweighting heavy-duty trailers have shown that a reduction of about 50% in the structural weight of a 14.63 m (48 ft) long heavy trailer will improve its fuel consumption by about 6% [6, 7]. However, operators of long-haul highway transportation systems are expected to load always their vehicles up to the maximum allowable gross weight (for example 80,000 pounds), so that any reduction in the structural weight of vehicle is likely to result in the transportation of heavier cargo loads for the same amount of fuel consumption. Assuming that a typical long-haul vehicle travels, on average, 100,000 miles per year, a reduction of 3,250 pounds for example, in the empty weight of the vehicle would translate into an annual saving of 350,000 gallons of fuel for every 1000 tons of freight cargo transported by that vehicle during the year. This significant weight reduction will also result in an improved payload, and reduce the freight cost. This research aims at extending the lightweighting concepts developed for heavy duty vehicles [7] to be applied for air cargo containers. The work also aimed at providing quantitative measurements of physical, structural, cost and performance characteristics of the scaled models of lightweight cargo containers and floor pans, as compared to the similar models of the currently used corresponding structures.



Figure 1. ULD Cargo Containers in Airbus A300 [8]

ULDs are designed to meet the requirements of Technical Standard Order TSO-C90, Cargo Pallets, Nets, and Containers; or other FAA-approved certification requirements. ULDs that are designed and manufactured to meet the aforementioned requirements are called "Certified ULDs" [9]. Containers that are designed to meet different design criteria are considered "Uncertified ULDs". These design criteria may be industry standards such as Society of Automotive Engineers (SAE) Aerospace Standard (AS) 1677, General Requirements for Uncertified Cargo/Baggage Containers [10];

International Standards Organization (ISO) Publication No. 4118, Non-certified Lower-deck Containers for Air Transport [11]; International Air Transport Association (IATA) ULD Technical Manual (UTM) 50 [12]; or other FAA-accepted standard.

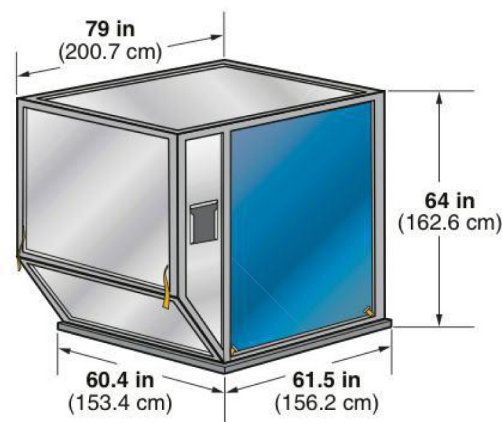


Figure 2. Dimensions of LD3

The performance requirements and test parameters for airworthiness approval of a unit load device determine the ultimate load capabilities under defined restraint conditions. The ULD ultimate load is defined as the maximum expected limit load multiplied by a factor of safety of 1.5. For a typical LD-3 container shown in Figure 2, the maximum gross weight is 15,567 N (3,500 lbs) and its ultimate load is 23,350 N (5,250 lbs). The current tare weight of this aluminum container is 805 N (181 lbs).

The base of the ULDs are designed to have a minimum area load capacity of 10 kPa (209 lb/ft²). The base edges shall have a minimum vertical stiffness EI value of 5,000 N.m² (1.75×10⁶ lb.in²).

LIGHTWEIGHTING APPLICATIONS

Several lightweight designs have been developed to reduce the tare weight of Air Cargo containers [13, 14]. It has been reported that such new designs adopted glass fibers and thermoplastic matrix. Unfortunately, the amount of information available on these design details is very limited. These design configurations could be further enhanced and optimized by the selective use of sandwich concept wherever high stiffness and strength to weight ratios are desired, for example the container base.

Sandwich construction is an attractive structural design concept since by the proper selection of materials and geometry, constructions having high stiffness-to-weight ratios can be achieved [14]. The facings are made of high-strength material, such as steel, and composites such as graphite/epoxy while the core is made of thick and lightweight materials such as foam or honeycomb [15]. The faces carry the majority of the axial loading and transverse bending stress [16, 17]. The core resists the shear loads, increases the stiffness of the structure by holding the facing skins apart, and it provides continuous support to the flanges or facing skins to produce a uniformly stiffened panel.