

Textile-Based Luggage Containers for Onboard Blast Protection

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ABSTRACT

The rise in worldwide terrorism has required measures be taken to harden aircraft against catastrophic in-flight failure due to concealed explosives. The risk that a small quantity of an explosive could get undetected cannot be neglected, and the introduction of countermeasures to reduce the effects of on-board explosions should be considered. This is the idea behind of the European research project FLY-BAG where a blastworthy textile luggage container for the protection of aircrafts from on-board explosions from explosives hidden in luggage in the cargo holds has been developed.

The FLY-BAG concept is based on the development of an advanced flexible anti-blasting cover and composite floor system able to resist a small to medium explosion by controlled expansion and full containment of the pressure generated by the explosion whilst, at the same time, preventing hard luggage fragment projectiles (shrapnel) from striking the main structure of the aircraft at high speed.

A multi-layered flexible structure has been invented to resist the large overpressure generated by the gas expansion which is integrated with a lightweight sandwich floor and wall elements designed to absorb the shock holding loads of the explosion. The flexible textile layer is made from an innovative combination of different reinforcing textile

structures which deforms in a controlled way during the explosion.

The realization of these components, their processing, full-scale blast testing, and demonstration of applicability into airplanes (Meridiana Airbus A319 and A320) has been a 2-year investigation involving research centres, testing laboratories, industrial partners, universities, and specialised high-tech SMEs. It has comprised material optimisation, manufacturing, material testing, laboratory testing, numerical modelling and verification, and finally full scale blast testing and installation trials inside Airbus airplanes.

The final prototype successfully survived a series of blast tests of growing intensity up to the maximum targeted charge value, without significant damage.

The prototype was also fully demonstrated during one installation trial inside one of the Airbus A319 of the partner Meridiana.

INTRODUCTION

Civil aviation is constantly under threat posed by terrorist attacks. Disasters such as Lockerbie in 1988, and even the recent parcel bomb attempts in October 2010, have shown that checked luggage and parcels are possible channels for smuggling explosive devices onboard: despite the continuous

improvement in security screening, the possibility that a small-medium quantity of an explosive, below detection threshold but still sufficient to cause critical damage, can get undetected exists and cannot be neglected. As a consequence, supplementary layers of protection are needed to protect airplanes from in-flight on-board threats. This is the idea behind FLY-BAG.

PAST RESEARCH

EFFECTS OF INTERNAL BLASTS ON AIRFRAMES

Research into the effects of internal explosions on civilian aircraft was stimulated by the terrorist attack on PanAm flight 103 in 1988 which killed 270 people when a Boeing 747 airliner was destroyed above Lockerbie, Scotland by an explosive device. The generally accepted forensic analysis of this event suggests that a hole of $\sim 50\text{cm}$ diameter was formed in the fuselage by the initial reflected pressure, and that this hole rapidly enlarged to $\sim 5\text{m} \times 1.5\text{m}$ due to subsequent reflections and the build-up of quasi-static pressure [1]. This localised damage led to the separation of the front section of the fuselage, and the subsequent break-up of the aircraft. Investigations indicated that the explosive device contained $\sim 3\text{--}400\text{g}$ of Semtex high explosive ($\sim 4\text{--}500\text{g}$ TNT equivalent) and was positioned 2 feet ($\sim 60\text{cm}$) from the nearest fuselage panel, although these figures are highly speculative since they are based purely on forensic evidence.

Two main contributions to damage arise from a detonation in a closed volume: intense, localised shockload from the detonation, typically occurring in the first few milliseconds after detonation and mainly striking the closest surfaces to detonation point, and build-up of quasi static pressure (QSP) from multiple reflections of the shockwave within the volume, typically lasting for several seconds after detonation (see Figure 1). Both contributions are critical in causing the failure of an airframe.

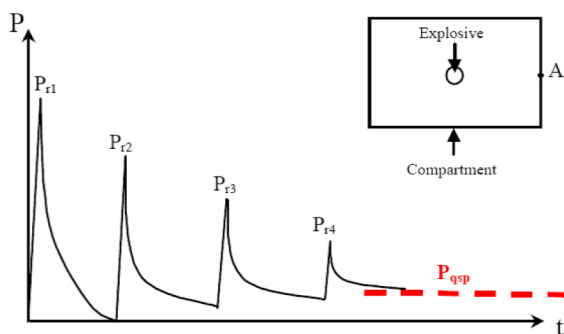


Figure 1. Multiple peak reflections giving rise to Quasi Static Pressure.

As a direct result of the Lockerbie disaster, research work was conducted in the UK and in the USA into the effects of internal blast loads on airframes. A recent experimental and finite element study has been conducted in the UK, in which small samples of airframe panels were pulse-pressure tested [2]. This study concluded that typical airframe panels can be severely damaged (although not breached) by pulse pressure loads with a peak of $30\text{--}40\text{kPa}$ and duration of $20\text{--}30\text{ms}$. An earlier UK investigation involved destructive testing of obsolete airliners by internal detonations [3]. Tests were conducted both with and without retrofitted protective measures to the aircraft fuselage, with internal pressurisation of the fuselage to simulate in-flight pressure conditions. An example of the damage caused by an internal explosion on a non-strengthened aircraft is shown in Figure 2.



Figure 2. Destruction of wide-body aircraft by internal explosion (from [3]).

Several related studies have been conducted in the USA since the early 1990s. These involved both the investigation of effects of the detonation of a “bare charge” inside an empty cargo hold and the assessment of the intensity of the explosive shock when the detonation occurs in a Unit Load Device (ULD) which is full or partially full of luggage.

The impetus for this work is the realisation that the shock loading on an aircraft fuselage from even a relatively small explosive detonation is likely to cause severe damage to the airframe, but that realistically the detonation would not happen in an empty hold; rather, there would likely be significant quantities of luggage present, and this would have a mitigating effect of the loading.

The first such published study [4], was funded by the US Federal Aviation Authority (FAA) and involved detonations of explosive charges inside a strong steel box with the same dimensions as an LD-3 luggage container. Experimental measurement of the shock pressure-time history were made at different points on the surface of the box, the charge located at different positions and with the box otherwise empty, partially filled or fully filled with luggage.

Table 1. HULD projects in the 1990s (adapted from [7]).

	Galaxy	Jaycor	Contemporary	Foam Offset	Telair ¹
Skin material	GLARE (Al/fiberglass composite)	Composite (no details were published)	E- glass composite	Al with inner foam layer	Kevlar multilayer
Joints	Aluminium frame/rivets	Integral/moulded	Unknown	Aluminium frame/rivets	Aluminium frame/rivets
Weight	150 kg	>200 kg	500 kg	115 kg	ca. 170 kg
Unit price	20,000 \$	Unknown	Unknown	2,000 \$	Unknown

¹

Figures for the Telair HULD are calculated by combining data from <http://www.telair.com/02-01News/02Feb8-B.html> and <http://www.telair.com/2005News/2005may-04.html>

The study concluded that the mitigating effect of the luggage was very significant:

“The peak pressures show a 35% reduction from bare charge values when the explosive is in the top piece of luggage and a 99% reduction when the explosive is in the third piece of luggage from the top. The quasi-static overpressure shows a 40% and 98% reduction from bare charge values for the respective cases above.”

More recent follow-up studies [5,6] included the use of detailed high-speed video investigations of the failure of ULDs due to internal blast. The video records allowed the researchers to measure the velocity of the blast wave emerging from the ULD (Figure 2). Since the velocity of the blast wave correlates to the intensity of pressure, this work indirectly measured the mitigation of the shock that would impinge on the airframe when the blast wave had passed through luggage and the wall of the ULD.

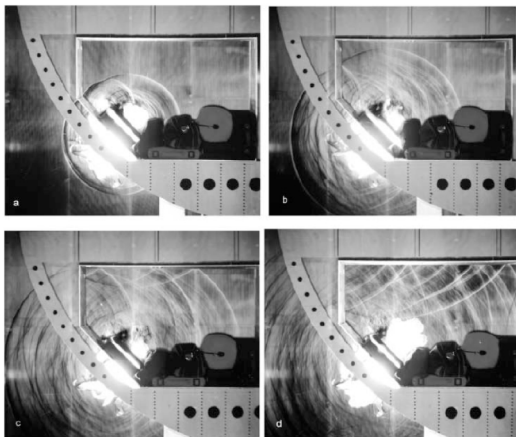


Figure 2. Blasts in mockup luggage container showing shock reflection and breaching of mock-up fuselage (from [6]).

Obviously, all data concerning threat levels and the magnitude of charges used in FAA and CAA tests are confidential; however, considerations from the abovementioned publicly available literature allowed the FLY-BAG team to define a realistic threat level for its own tests: this “design threat” charge, not specified here for confidentiality, was used in all calculations and in the final full scale tests.

HARDENED UNIT LOAD DEVICES

The idea of reinforced air cargo containers is not entirely new: the research efforts performed in the 1990s in the USA and UK led to the development of several prototypes of reinforced containers, named Hardened Unit Load Devices (HULDS).

Four different HULD concepts were tested by the Federal Aviation Administration between 1997 and 1998: Jaycor and Galaxy HULDS, developed in conjunction with FAA, a third HULD concept developed by Contemporary Products (funded independently), and a “foam offset” retrofitting of a standard aluminium LD-3 container [7]; a fifth HULD was developed between 1998 and 2002 by Telair Inc. The main characteristics of the past HULD attempts are reported in Table 1.

The Jaycor, Contemporary and “foam offset” prototypes failed, while the Galaxy and Telair HULD passed the FAA certification test. High purchasing cost of the Galaxy system made its large scale application impossible, while the Telair one briefly made an appearance on the market in 2003; however, the reaction from airlines was cold due to its weight and scarce user-friendliness and the product virtually disappeared.