IMPTEST
Impact Test Campaign

State of the art – Background

Reduced weight and more efficient engines of future aircraft are vital to satisfy European and international goals for reducing the emissions and climate impact of aviation. The structural weight is primarily reduced by increased use of polymer composites, which combine superior mechanical performance with low weight. Open rotor jet engines with an uncontained fan section are considered as a promising concept for reduced fuel consumption. For design reasons such engines are likely to be mounted directly on the rear part of the fuselage.

Failure of rotating aircraft engine components may result in high velocity fragments that may easily damage the fuselage or other primary structure of the aircraft. The risk is particularly serious for open rotor engines mounted on the fuselage. Thus, a reliable and lightweight shielding is crucial for the fuselage sections threatened by such high velocity impact.

Objectives

The project IMPSHIELD is aimed on design and manufacture of three concepts for protective shields of composite material, capable of preventing penetration by projectiles of different sizes and velocities relevant for representative aircraft. The project IMPTEST is aimed to compare the impact performance of these composite shields with conventional metal shields exposed to projectiles with a velocity of several hundred m/s. The following issues were studied:

- Determination of the penetration velocity for each shield and projectile size.
- Ranking of the shield considering performance versus weight.
- Determination of the deflections during and after impact.
- Inspection and description of the resulting damage after impact.
- Influence of impact angle on penetration velocity and damage.
- Influence on the impact performance after aging in hot/wet conditions.
- Influence of the temperature on the fibre properties of composite shields.

Description of work

Shield concepts were developed in IMPSHIELD using previous design experience, available material data and suitable manufacturing techniques for each material system. The appropriate layup and shield thickness were tailored for a specific projectile size using finite element simulations and available material data. The shields were then manufactured by hot pressing of dry fibre preforms with only a small amount of binder material between fibres and plies.

Impact testing in IMPTEST was performed with a gas gun at Imperial College London. The shields were placed in a test frame inside a bullet proof catcher tank. Oblique impacts were tested using a modified test frame. High speed cameras were used to record the projectile velocity before and after impact, as well as the shield deflection during impact.

After testing the high speed photography was evaluated to determine the penetration velocity of each shield concept, as well as the maximum shield deflection. The weight loss and shape after impact were also carefully measured. Finally the resulting damage was investigated using back face illumination, cutting of sections and use of microscopy. After evaluation of the penetration threshold velocities the shields were ranked with respect to their performance per unit weight.

Results

The project has provided the following main results

- The composite shields with polymer fibres provided 2-3 times higher penetration velocity per unit weight than conventional aluminium and titanium shields.
- Penetration is primarily controlled by the velocity component perpendicular to the shield surface.
- Aging in hot/wet conditions did not significantly reduced the ballistic performance of the composite shields.

a) Timeline & main milestones

The project comprised three phases involving the following tasks and results:

Phase 1: Ranking of the shield concepts in impact tests perpendicular to the shields, and selection of two concepts to be studied further in phases 2 and 3.
Phase 2: Tests of shield performance and damage during oblique impact. Month 21-
Phase 3: Tests of perpendicular impact performance after hot/wet aging. Tests of temperature influence on fibre properties.

b) Environmental benefits

The main environmental benefit is weight reduction of the shields for protecting the aircraft fuselage against potential debris at engine failure. It has been estimated that saving one kg of structural weight saves more than 10 tons of CO_2 emissions during the lifetime of an aircraft.
Furthermore, development of reliable shields is a condition for introduction of open rotor aircraft engines, which are expected to reduce aircraft fuel consumption by about 15%.

c) Dissemination / exploitation of results

During the project the results have been disseminated to the associated aircraft manufacturers, i.e. Dassault and Airbus in France and Spain, who are expected to explore the concepts further in design of future aircraft.

After the project has been completed the results will be disseminated in scientific journals focused on composite materials, impact and aviation.

d) Communication

Project leaders were:

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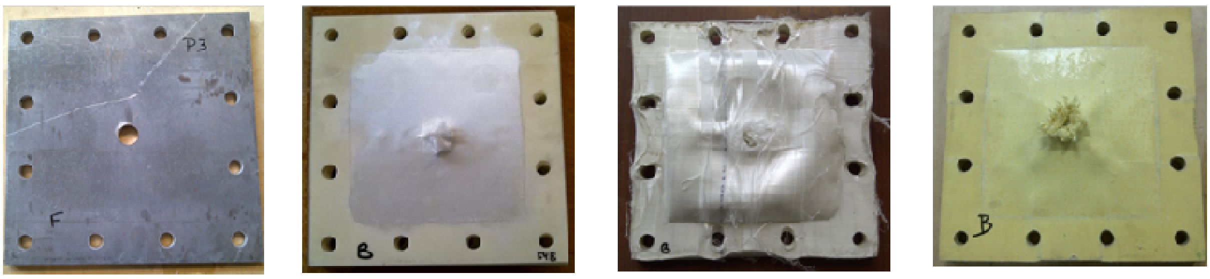
Gas gun catcher tank | Sabot stripper | Specimen test frame

Figure 1: Gas gun test unit

Projectiles with propeller plugs (sabots) | Projectile before impact | Projectile after impact

Figure 2: Projectiles used in tests



Metal shield | Glass fibres | UHMW Polyethylene fibres | Aramid fibres

Figure 3: Examples of shields after testing

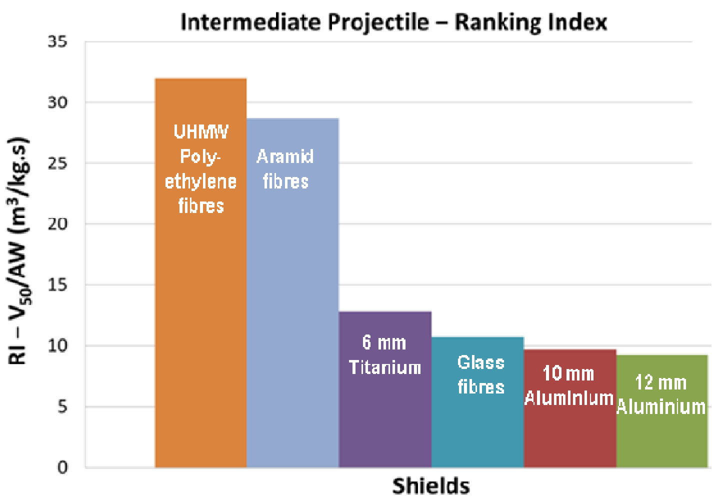


Figure 4: Ranking index of the shields for an intermediate size projectile

Project Summary

Acronym:	IMPTEST
Name of proposal:	Impact Test Campaign
Involved ITD	Smart Fixed Wing Aircraft ITD
Grant Agreement:	278368
Instrument:	Clean Sky
Total Cost:	399,999
Clean Sky contribution:	299,999
Call:	SP1-JTI-CS-2010-04
Starting date:	01/04/2013
Ending date:	31/12/2015
Duration:	32 months
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