DAMAGE TOLERANCE OF COMPOSITE STRUCTURES WITH THERMAL SHIELD

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Summary The aim of this paper is to present a study on the influence of the cork thermal shield on composite panels during a low velocity impact. The results show the good mechanical behaviour of the thermal shield during the impact. Indeed, the thermal protection acts like a mechanical protection during the impact and reveals it before having damage in the laminate.

STUDY OBJECTIVES

Composite materials have been increasingly introduced in airframe and spatial applications in the last decade because of their interesting characteristics. Nevertheless, damage induced in these materials by impacts by foreign objects during the life of the structure can cause drastic reductions in the strength of the structure and, for this reason, the problem of impact on laminated structures has been a subject of intense research efforts [1]. Aeronautical and spatial structures are often subjected to accidental damages. Consequently, it is essential to define a damage tolerance demonstration as soon as a new project begins.
Damage tolerance was introduced at the end of 1978 for aircraft structures [2]. It is intended to ensure that, with serious fatigue, corrosion, or accidental damage occurring within the operational life of the airplane, the remaining structure can withstand reasonable loads without failure or excessive structural deformation until the damage is detected. In the military and spatial launchers fields, the damage tolerance concept only begins to appear.
This study focuses on the influence during low velocity impact of the cork thermal shield [3] used for civil and military launchers' fairing.
The purposes are to complete the characterisation works performed on laminates used for the launchers' fairing considering damage tolerance demonstration. Damage phenomena will have to be examined on cork shielded composite panels, induced by a low velocity impact.

EXPERIMENTAL STUDY

Two composite materials, with carbon fibres and epoxy matrix, are used in this investigation : a high modulus unidirectional composite M46J/M18 with 18 plies $(0°/60°/0°/-60°/0°/60°/90°/-60°/0°)_S$ of 3.78 mm-thickness and a high strength unidirectional composite T300/914 with 28 plies $(0°/60°/0°/-60°/0°/60°/90°/90/-60°/0°/-60°/0°/60°/0°)_S$ of 3.64 mm-thickness. Experiments are carried out on shielded and unshielded panels to analyse the thermal protection influence on impacted damaged monolithic and sandwich panels. The detectability criterion and the delaminated areas are determined. Post-Impact Compression Loading tests are being conducted in order to define the residual strength and the allowable damages for impacted composite structures.

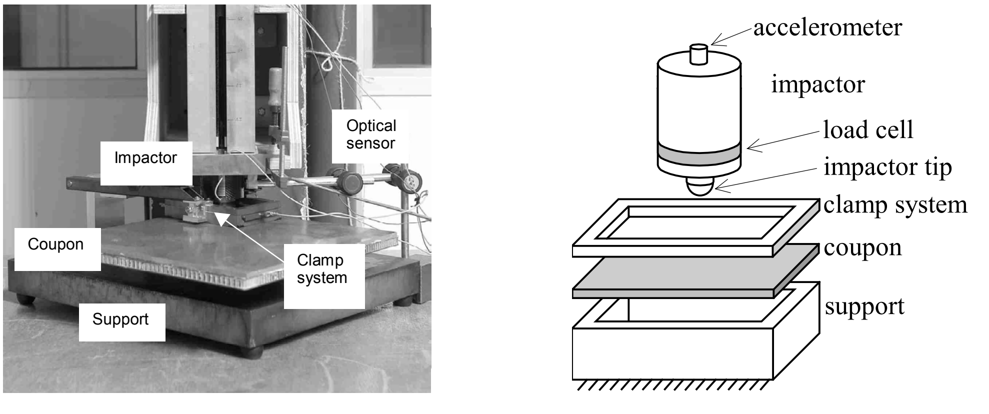

Figure 1 : Impact apparatus

The apparatus used to impact the composite coupons is shown in Figure 1. It consists in dropping an impactor, equipped with a load cell and an accelerometer, on a laminate panel, clamped by a 125 x 75 mm² window. The velocity is measured owing to an optical sensor. Ultrasonic waves analyses are then realised on the impacted coupons to evaluate the delaminated area.

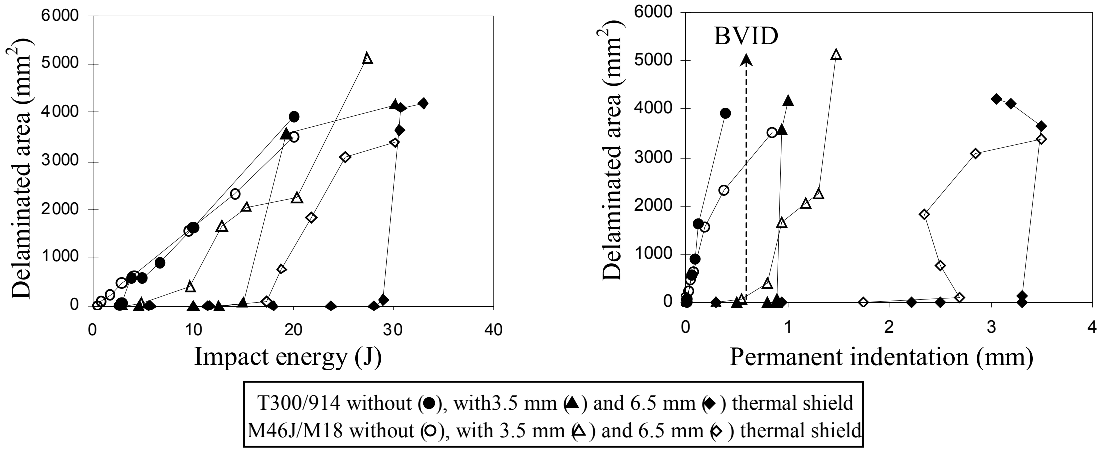

Figure 2 : Delaminated area versus impact energy (a) and permanent indentation (b)

RESULTS

The delaminated area evolution versus the impact energy of the projectile is drawn in figure 2a for laminate panels without thermal shield and with cork thermal shield of 3.5 and 6.5 mm-thickness, for the two studied materials. This figure shows that, for shielded panels, delamination appears at higher impact energy, in particular for low delaminated area. So the thermal protection acts like a mechanical protection during an impact. This result is valid for the two materials, even if the M46J/M18 material is more brittle than the T300/914, without or with thermal shield.
In figure 2b, the delaminated area is reported versus the permanent indentation measured after the impact. This figure shows that permanent indentation for shielded panels is much more important than for the unshielded panels for the same delaminated area. Besides, damage threshold appears at a higher permanent indentation than the BVID (Barely Visible Impact Damage) [4] aeronautic threshold of 0.6 mm. Thus, the thermal protection, in addition of having a mechanical protection function, reveals impact before having damage in the laminate.

CONCLUSIONS AND PERSPECTIVES

Impact tests have been conducted in order to define the behaviour laws of shielded composite structures used for launchers fairing versus impact damages. This preliminary study allows to demonstrate the beneficial effect of thermal shield to the damage tolerance concept. The thermal shield has a mechanical protection function on the composite structures and reveals the impact before the damage appears in the structure.
Post-impact compression loading tests are being performed and will allow to study the thermal shield influence on the residual strength.
Numerical analyses are equally in progress. The purpose is to be able to foresee a damage on an impacted shielded structure without having to realise costly experimental tests. Finally, from simple numerical models of impacted shielded laminate coupons, the engineer should be able to comprehend the damage phenomena on a more complex impacted structure (a launcher fairing for example).

References

[1] Abrate S.: Impact on composite structures, Ed. Cambridge university press, 1998.
[2] Rouchon J.: Certification of large airplane composite structures, recent progress and new trends in compliance philosophy, 7th ICAS congress, Stockholm, 1990.
[3] Davis J.B., Morgan P.E.D., Oka K.S., Barney A.O., Hogenson P.A.: Damage-Tolerant thermal protection systems, AIAA Space Conferences & Expositions, 2000
[4] Rouchon J.: Fatigue and damage tolerance aspects for composite aircraft structures, Delft, 1995.