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Assessment of impact response of fiber metal laminates

Roman Starikov

A350 Airframe, A350 Stress Methods & Expertise, Airbus Operations GmbH, 21129 Hamburg, Germany

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ABSTRACT

Series of low velocity impact tests were carried out on different types of fibre metal laminates (GLARE®) with varying material constituents. Impact damages in the laminates and their extent were analysed. Relationship between the configuration as well as the properties of the laminates with different material constituents and the impact response in terms of indent was derived. This relationship resulted in an empirical method predicting the dent depth under low velocity impact in laminates with different configurations. The method is valid as long as there is reference impact data obtained on a composite material with the same constituents and identical boundary conditions.

1. Introduction

GLARE® (GLAss-REinforced) belongs to the family of fibre metal laminates (FMLs) and consists of thin layers of aluminium sheets and unidirectional prepreg layers of glass fibres embedded into an epoxy based matrix. In comparison with monolithic aerospace aluminium alloys, selection of GLARE® in the structural design is driven by its excellent resistance to fatigue crack growth, high tolerance to accidental damages, and superior residual strength properties [1,2]. Considering lower density of GLARE® laminates in comparison with monolithic aluminium alloys, potential weight saving benefits become obvious [3–5].

The most utilization of GLARE® material has been found on the Airbus A380, where it is widely applied as skin panels in the upper and side shells of the forward and rear fuselage barrels. At Airbus there are two types of GLARE® qualified to build skin panels, Standard and HSS (High Static Strength) GLARE®. Standard GLARE® is based on thin Al 2024-T3 and FM94 composite prepreg; whereas, HSS GLARE® consists of thin Al 7475-T761 and FM906 prepreg.

Various impacts by foreign objects are to be expected during the whole life of the aircraft. During the production assembly and in-service maintenance operation, either tools or wrenches can be dropped onto fuselage skin panels. In-service operation impacts can occur during landings or takeoffs due to stones and debris collided with the aircraft body. Hail storms and collisions with tracks and equipments on ground are another source of impact damages. This inquires aircraft structures to be damage tolerant with respect to dynamic impact loads. Therefore, when a new structural material is introduced in order to build a body of the aircraft fuselage, its resistance to dynamic impacts shall be addressed.

Certain research into the impact behaviour of Standard GLARE® has already been documented in the literature [6–14]. However, HSS GLARE® is relatively new and therefore the impact assessment of this FML is required. This paper presents the results of an experimental investigation into the impact behaviour of HSS GLARE® in comparison with Standard GLARE®. A relation between the impact response of different GLARE® laminates and their mechanical properties, assessed with the help of the Metal Volume Fraction approach, will be highlighted.

2. Materials and experimental procedure

A number of specimens was manufactured according to Table 1 and the specimen geometry shown in Fig. 1(a).

In the notation GLARE4A-3/2-0.4, 4A means 0°/90°/0° composite prepreg build-up sequence between two aluminium sheets regarding the aluminium rolling direction; 3/2 means the number of aluminium layers/composite lay-ups; and 0.3/0.4 means the thickness of aluminium sheets in mm. GLARE3 means that only one set of 0°/90° composite prepreg layers was used between two aluminium sheets. FM94 is 120 °C curing temperature GFRP, whereas FM906 has 180 °C curing temperature. Both types of GFRP prepreg have the same nominal thickness of 0.125 mm. The surface pretreatment of 2024-T3 and 7475-T761 sheets included the same

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E-mail addresses: roman.starikov@airbus.com, roman.starikov@gmail.com.

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Table 1
Specimens matrix.

Laminate	Constituents	Thickness [mm]	MVF
GLARE4A-3/2-0.4	2024-T3/FM94	1.95	0.615
GLARE3-5/4-[0.4-0.3-0.3-0.3-0.4]	2024-T3/FM94	2.80	0.630
GLARE4A-4/3-0.4	2024-T3/FM94	2.80	0.587
GLARE4A-5/4-0.4	2024-T3/FM94	3.60	0.571
HSS GLARE4A-3/2-0.4	7475-T761/FM906	1.95	0.615
HSS GLARE3-5/4-[0.4-0.3-0.3-0.3-0.4]	7475-T761/FM906	2.80	0.630
HSS GLARE4A-5/4-0.4	7475-T761/FM906	3.60	0.571

surface activation and priming processes qualified for the serial production of GLARE laminates.

The specimens were clamped between two support frames. The bottom plate had a circular opening with a diameter of 100 mm. Two low velocity dynamic impacts (LVI) were applied per specimen, as shown in Fig. 1(a), using a drop weight tower, as demonstrated in Fig. 1(b), with the help of a hemispherical steel impactor (tip radius $R = 8$ mm). All impacts were carried out in a range of 5–125 J. The impact tests were instrumented, i.e. the contact force was measured with a load cell in the nose of the impactor. After impact the impactor was caught to prevent rebound. The permanent deflection of the impacted laminates was characterized by the depth of induced dents, which was measured after impact using a micrometric dial gauge while the specimen was still clamped in the test frames.

After the impact tests the presence and length of cracks in the outer aluminium layers were NDT inspected by high frequency eddy current test; whereas, the size and shape of delaminations were assessed by manual through transmission ultrasounds test. The delamination size is further presented as delamination area of an ellipse, which length and width were measured during NDT inspections.

3. Results and discussion

3.1. Morphology of impact response

The impact behaviour of fibre metal laminates can be characterized by two distinct tendencies of the laminates to respond to applied dynamic load. First, the resistance to become dented as a result of plastic deformation of aluminium layers; and, second, the ability of the laminates to withstand cracking under dynamic impact loading. That type of impact damage, which did not show an impact crack on either side of the tested laminates, is referred to as *Dent* damage [6]. All tested laminates exhibited permanent indent deformation around the point of impact, which would make it easy to visually allocate the location of an accidental impact damage. Despite that in the case of *Dent* damage there is no complete penetration through the laminate, it is known that fibre failures, matrix cracking, and delaminations would be usually induced in the deformed region under the point of impact, depending on the amount of applied impact energy (see Fig. 2).

Delaminations are the main concern in regard to composite laminated materials when their impact behaviour is addressed. Usually delaminations take place at the interface between two adjacent plies with different fibre orientations. In GLARE® laminates the interface between the metal and composite layers is another potential site for impact delaminations to occur. The influence of interfacial adhesion strength between adjacent laminas on the impact behaviour of FMLs has already been highlighted in a number of investigations [15–17]. Since the strength of adhesion between the aluminium thin sheets and composite plies is stronger than that between two adjacent composite plies, impact delaminations developed mostly between composite plies (see Figs. 2–4).

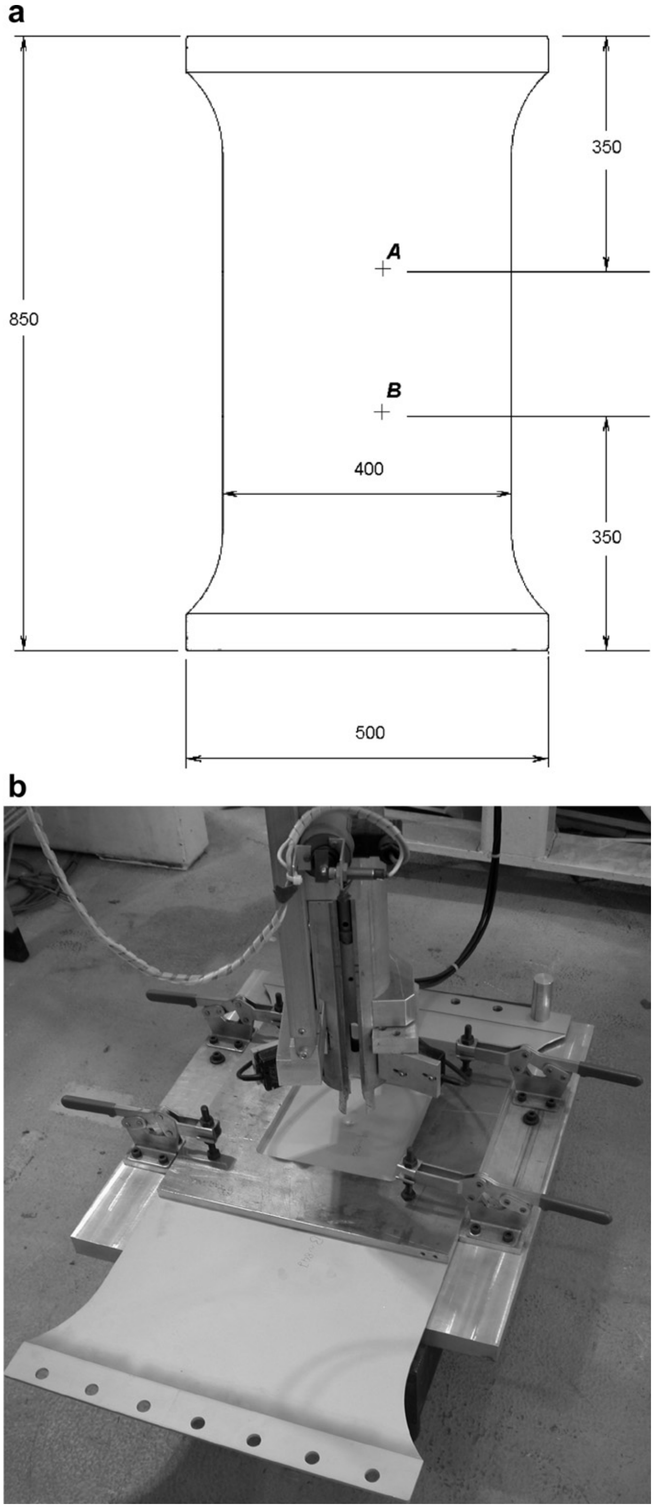

Fig. 1. (a) Specimen geometry. Dimensions in mm; (b) experimental set-up.

The second type of impact damage are dents with one outer aluminium layer cracked. Hereafter, this type of damage is referred to as *First Crack (FC)* and as an example is shown in Fig. 3.

Due to low velocity impact loading, the outer Al layer on the non-impacted, i.e. convex, side will be cracked in most cases, which can be detected by visual observation. As shown in Fig. 3, in the case of FC damage even the inner metal layers can be cracked.