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Influence of laminate thickness on composite durability for long term utilisation at intermediate temperature (100–150 °C)

Jacques Cinquin [a,*], Bruno Medda [b]

[a] EADS Corporate Research Center, 12 rue Pasteur, 92152 Suresnes Cedex, France
[b] AIRBUS Toulouse, 316 route de Bayonne, 31060 Toulouse Cedex 03, France

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ABSTRACT

To increase the utilisation of composite material, new domain of application should be investigated such as intermediate temperature (up to 150 °C) for long term utilisation. Under these conditions, oxidation could not be neglected.

This paper investigates material durability with the shape ratio influence of sample on oxidation behaviour during ageing at isothermal temperature. Weight loss evolution is discussed according to different shape ratio. Evolution of mechanical properties is also investigated to compare the thickness influence on the evolution of properties with ageing time.

The weight loss due to oxidation could be assimilated to a degraded material flux going out of the sample from the exposed surface (and edges). A first estimation gives a coefficient of 2.3 for the degraded material quantity going out of the sample per cm^2 of laminate edges compared to cm^2 of laminate surface. In fact we have 2.3 times more degraded material going out of edges per cm^2 than going out of surface per cm^2.

1. Introduction

Composite materials are more and more used to replace metallic structures in aeronautical applications. The main advantage is weight reduction. To increase the use of composite material on aircraft, new fields of application should be investigated such as intermediate temperature (up to 150 °C) for long term use. In this temperature range, material durability is a critical aspect and need to be understood to design safe structures [1,2]. Micro-cracks under ageing conditions and material constitution have been studied by different laboratories [3–7]. An interesting methodology, micro-indentation, has been proposed to follow the properties evolution during ageing [8]. Today, it is assumed that micro-cracks occur under thermal cycling ageing conditions [9,10], but also under isothermal ageing conditions with oxidation [11,12]. The oxygen diffusion kinetics in the matrix is one of the most important parameter controlling the oxidation rate [13,14]. Some authors relate the fact that oxidation is favourable in the fibre direction in composite [15].

2. Definition of material samples and ageing conditions

We have selected an epoxy based material reinforced with intermediate modulus carbon fibre. The total area weight of the pre-impregnated material is 413 g/m^2. The resin content is 35% by weight. The individual ply thickness on the composite laminate is about 0.26 mm. Two kinds of laminates have been produced. One with 20 plies directed lay up $(0, +45, -45, 0, 90)_{2sym}$ that gives a laminate of 5.15 mm thick, and one with 100 plies directed lay up $(0, +45, -45, 0, 90)_{10sym}$ that gives a laminate of 26 mm thick. The carbon fibre content by volume in these laminates was about 60%.

The cure cycle used to produce these laminates is presented in Fig. 1. The duration and the temperature of the final dwell were defined to optimize the epoxy/amine conversion ratio close to 100%. This has been validated by residual enthalpy and glass transition determination after curing by DSC.

2.1. Samples for weight loss experimentation

Different geometries of samples have been machined as presented in Table 1. The shape ratio is defined according to the following formula and is the ratio between the surface and the volume of the sample.

* Corresponding author. Tel.: +33 1 46 97 32 68; fax: +33 1 46 97 37 30.
E-mail address: Jacques.cinquin@eads.net (J. Cinquin).

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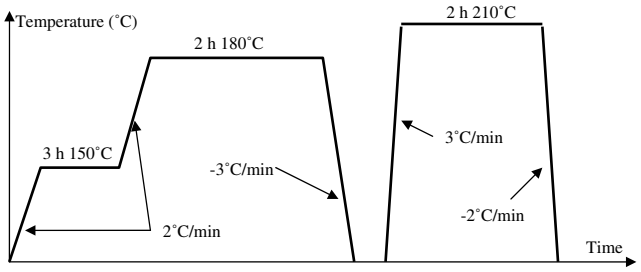
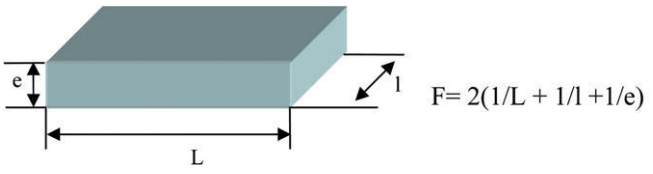


Fig. 1. Optimized cure cycle used to obtain 100% conversion ratio on the epoxy amine material.

Table 1
Sample geometry for weight loss experimentation

Sample (mm^2)	Lay up (plies)	Thickness (mm)	Shape ratio	Edge surface (%)
A: 45 × 50	20	5.15	0.473	18
B: 45 × 50	100	26	0.166	52
C: 10 × 10	100	26	0.477	84



Type A and C samples present a very close shape ratio. The main difference between these samples is the nature of the surface. For type A samples, the exposed surface is a 82% moulded surface with fibre direction parallel to the surface. For type C samples, the exposed surface is a 84% machined edge with fibre direction mainly not parallel to the exposed surface.

2.2. Samples for micro-cracks observation

Large samples 300 × 100 mm have been prepared for machining from this large sample individual test specimens of 25 × 100 mm after different durations of ageing as presented in Fig. 2. Face 1 has been exposed to the oxidative environment all the time of ageing. Face 3 just machined has not been exposed to oxidative environment during thermal ageing. Face 2 has been exposed to oxidative environment during the time between the previous sample machining and the last one. (10,000 h if we machine a sample each 10,000 h).

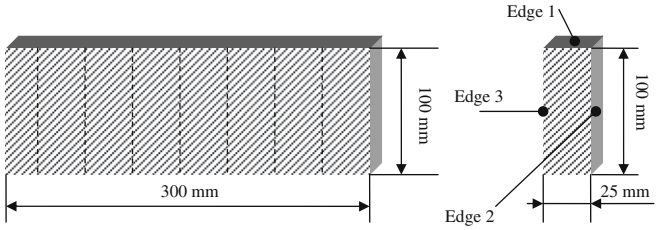


Fig. 2. Samples for micro-cracks observation.

2.3. Samples for open hole compression tests

Open hole compression samples defined in Fig. 3 have been machined.

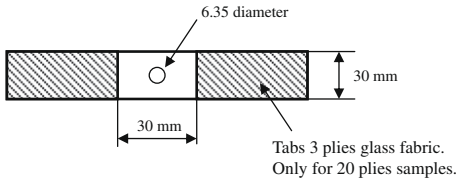


Fig. 3. Open hole compression samples.

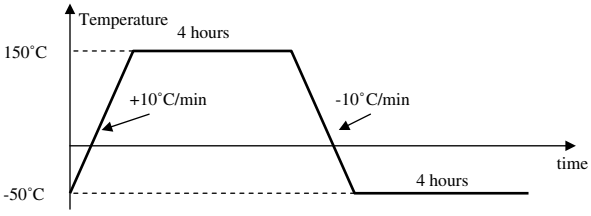


Fig. 4. Thermal cycle applied on composite samples.

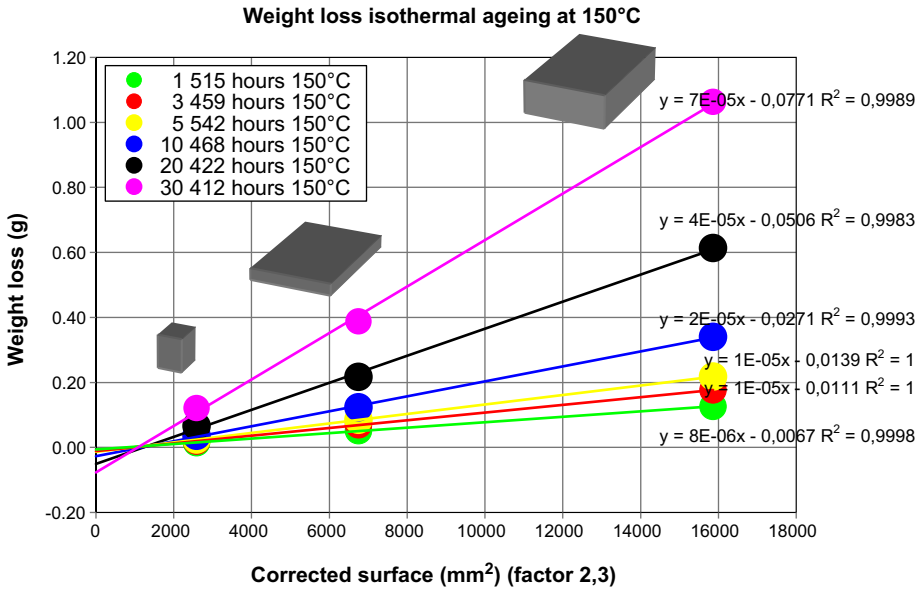


Fig. 5. Weight loss evolution during isothermal ageing at 150 °C.