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Evaluation of hygrothermal effects on the shear properties of Carall composites

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Abstract

Fiber metal laminates are the frontline materials for aeronautical and space structures. These composites consists of layers of 2024-T3-aluminum alloy and composite prepreg layers. When the composite layer is a carbon fiber prepreg, the fiber metal laminate, named Carall, offers significant improvements over current available materials for aircraft structures. While weight reduction and improved damage tolerance characteristics were the prime drivers to develop this new family of materials, it turns out that they have additional benefits, which become more and more important for today's designers, such as cost reduction and improved safety. The degradation of composites is due to environmental effects mainly on the chemical and/or physical properties of the polymer matrix leading to loss of adhesion of fiber/resin interface. Also, the reduction of fiber strength and stiffness are expected due to environmental degradation. Changes in interface/interphase properties leads to more pronounced changes in shear properties than any other mechanical properties. In this work, the influence of moisture in shear properties of carbon fiber/epoxy composites and Carall have been investigated by using interlaminar shear (ILSS) and Iosipescu tests. It was observed that hygrothermal conditioning reduces the Iosipescu shear strength of CF/*E* and Carall composites due to the moisture absorption in these materials.

Keywords: Metal/fiber composites; Hygrothermal effects; Shear strength properties; Iosipescu shear test; Carall

1. Introduction

Fiber-metal laminates (FML) are composed of alternating layers of fiber-reinforced plastic (FRP) laminae and aluminum-alloy sheets. They offer some superior mechanical properties, compared with either conventional polymer composites or high-strength monolithic aluminum alloys [1–5]. Aluminum/carbon fiber laminates (CARALL) were originally developed at Delft University of Technology at the beginning of 1990 [6–10]. The FML is a material laid up by a thin sheet of high-strength aluminum alloy interleaved by a fiber/epoxy layer. So, they are good candidates as structural materials used in advanced aircraft [6–9].

CARALL laminates show higher strength values and the stiffness can be as twice as high compared to ARALL (Aramid Reinforced ALuminum Laminates) or GLARE (GLass Aluminum REinforced). Fatigue performance is also higher when compared with GLARE but the specific weight of CARALL varies between values valid for ARALL and GLARE depending on applied type of carbon fibers [6–9].

In recent years, developments in carbon fiber production resulted in a large variety of fibers having a broad range of mechanical properties. Strength and stiffness were the main driven motion for structural applications. The high stiffness of carbon fibers allows for extremely efficient crack bridging and therefore very low crack growth rates. At the same time, the presence of a metal layer in the composite is very favorable for the impact properties [10]. Also, the combination of high stiffness and strength with good impact properties gives to carbon/aluminum laminates a great advantage for space applications. Other applications for this material are impact absorbers for helicopter struts and aircraft seats [10].

Aluminum in contact with carbon fiber is often thought to lead to galvanic corrosion problem. A simple but effective solution was found: placing proper isolation between the carbon fibers and the aluminum sheets, such as epoxy resin or thermoplastic polymers [10].

Aircraft operate in a wide variety of environments, ranging from cold, dry, air conditions at cruise altitude to hot, humid

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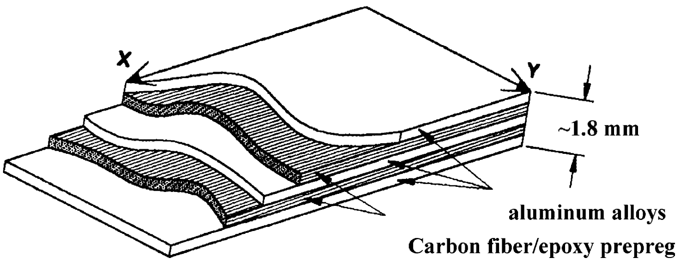

Fig. 1. Configuration of Carall laminate (3/2 lay up).

air-conditions in tropical environments. At the same time, commercial aircraft are used for periods up to 30 years. It is therefore important that the materials from which aircrafts are build maintain their properties during their entire lifetime, even in the most severe environments [10–12].

The bond between the carbon fiber and the epoxy matrix plays a very important role in stress transfer in composites. In general, the influence of moisture in composite materials is most notably present in polymer matrix and also affects the fiber/matrix interface. Polymers, such as epoxies, are prone to absorb moisture when exposed to humid environments. This takes place through a diffusion process, in which water molecules are transported from areas of high concentration to areas of low moisture concentration [10–15].

In Carall, basically only the outer aluminum layers are exposed as a result of its lay-up design. The prepreg layers are only exposed through free edges of the laminate and holes. Moisture and chemicals however can penetrate the composite lamina at free edges. Thermal degradation due to elevated temperature exposure is also important, since it can affect the structural integrity of the composite laminate [10–15].

Interlaminar shear strength is governed by the adhesion between fibers and matrix and between aluminum and epoxy. It is well known that determination of shear properties of advanced composites is challenging than other semi-static mechanical tests. One of the main difficulties in shear tests is to induce a pure shear stress state in the gauge section of a constant magnitude. This is a special concern for composites with high anisotropy and structural heterogeneity. The ideal shear test must be simple enough to perform, require small and easily fabricated specimens, enable measuring of very reproducible values for both shear modulus and shear strength at simple data procedure [16–18].

Different devices for the study of the shearing properties of composites are proposed in the literature [18–22]. One of the most used shear test, which allows a nearly pure-shear stress state at the shear plane, was proposed by N. Iosipescu [23]. This test coupon, named Iosipescu shear, was originally designed for measuring shear strength and modulus of isotropic metals [19,20]. Subsequently, it was extended for testing composite

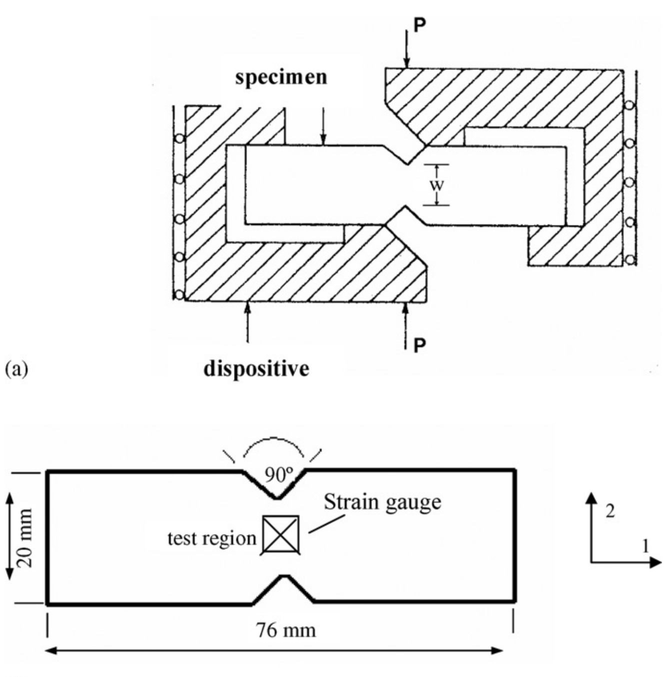

Fig. 2. Iosipescu test scheme: (a) Iosipescu dispositive; (b) specimen configuration.

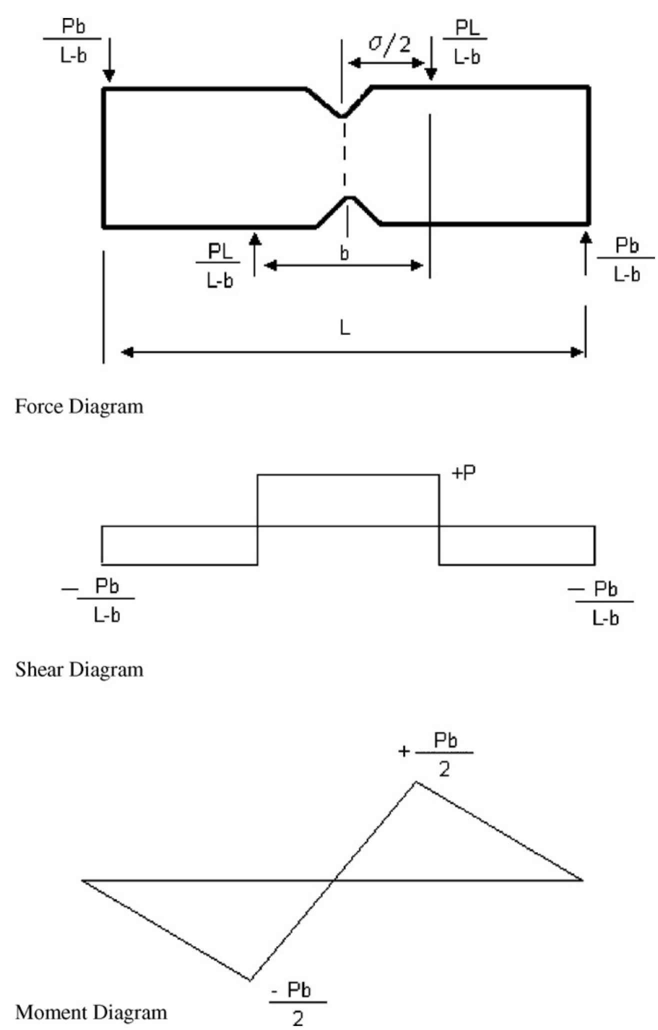

Fig. 3. Idealized force, shear and moment diagrams for Iosipescu test.