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Novel fibre metal laminate sandwich composite structure with sisal woven core

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ABSTRACT

Fibre metal laminates (FMLs) have been widely used to manufacture airframe components. This work describes novel sisal fibre reinforced aluminium laminates (SiRALs) that have been prepared by cold pressing techniques and tested under tensile, flexural and impact loading. The pristine sisal fabric and the sisal fibre reinforced composites (SFRCs) were also tested to understand the difference in mechanical performance of the sisal fibre metal laminates. The SiRALs achieved not only the highest modulus and strength, but also the highest specific properties. The mean specific tensile strength and modulus of the SIRALs reached increases of 132% and 267%, respectively, when compared to the sisal fibre reinforced composites (SFRCs). Moreover, the mean specific flexural strength and modulus of the SiRALs were significantly higher than SFRCs, revealing increases of 430% and 973%, respectively. A delamination fracture mode was noted for SiRALs under bending testing. The SiRALs can be considered promising and sustainable composite materials for structural and multifunctional applications.

1. Introduction

Fibre Metal Laminates (FMLs) are hybrid composite structures based on thin shells of metal alloys reinforced by fibre polymeric materials (Cortes and Cantwell, 2006). These composites have been used in a wide variety of applications, ranging from the aerospace and the automotive to the biomedical. In comparison to pristine metal sheets, FMLs provide added functionalities such as high specific bending strength, acoustical absorption, vibration transmissibility and damping characteristics (Ochoa-Putman and Vaidya, 2011). The low fatigue strength of the aluminium alloys and the problems related to the damage tolerance in fibre reinforced composites has inspired different research groups to develop hybrid structural composite materials able to overcome the limitations of metal and polymeric reinforced composites (Vogelesang and Vlot, 2000). Examples of FMLs developed during the last two decades are the Aramid fibre reinforced Aluminium Laminate (ARALL), the Glass Laminate Aluminium Reinforced Epoxy (GLARE) and the Carbon Reinforced Aluminium Laminates (CARAL) (Sinmazçelik et al., 2011). The first generation of FMLs used in aerospace applications was based on epoxy thermosetting polymer matrices, which offered higher strength and stiffness and enhanced high temperatures performance compared to other polymer matrices. However, thermosetting-based composites are often brittle and require high processing temperatures and pressures. In comparison, FMLs made from thermoplastic-based composites offer improved toughness and have the potential advantage in manufacturing of requiring short process cycle times. These novel thermoplastic fibre–metal laminates can lead to a rapid and low-cost production of lightweight structural components (Reyes and Kang, 2007).

Increasing environmental concerns have encouraged researchers to develop ranges of recyclable composites based on natural fibres such as jute, kenaf, coir, sisal (Rao et al., 2010; Yusoff et al., 2016). The application of natural fibres in composite materials has been motivated by the need of producing structures that are environmentally sustainable, cost-effective, recyclable and with biodegradation properties to improve the life cycle of the structural components (Saheb and Jog, 1999; Santos et al.,

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Table 1
Mechanical properties of the aluminium metal sheets 2024 T3.

Designation	Density (g/cm^3)	Elastic modulus (GPa)	Yield stress (MPa)	Maximum strength (MPa)	Ultimate Strain (%)
Aluminium 2024 T3	2.70	71.10	381	496	15.90

2015). Natural fibres are also much less abrasive to tooling and moulds compared to synthetic ones. Moreover, sisal fibres exhibit acceptable levels of specific tensile stiffness and strength for structural applications (Silva et al., 2012a,b). The use of natural fibres as reinforcement in structures has rapidly taken place primarily within the automotive industry and in secondary structural designs. Renewable fibres of European origin such as flax and hemp have been used to manufacture door panels and car roofs (Beakou et al., 2008), and truss cores with complex architectures (Cicala et al., 2012). The use of natural fibres in FMLs such as mixed jute/carbon fibres (Vasumathi and Murali, 2013) and bamboo fibres (Zhang et al., 2000) has been shown to be successful in different applications (Sinmazçelik et al., 2011). A new generation of hybrid sisal fibre composites reinforced with micro and nano particles has been investigated for industrial applications (Silva et al., 2012a,b; Vieira et al., 2016; Ramzy et al., 2014). This work investigates the mechanical properties of FMLs containing an innovative core made of sisal fibre reinforced composite (SFRC). The mechanical results show the potential of SiRALs for industrial applications.

2. Materials and methods

2.1. Materials

The sisal fabric type plain weave with 1300 g/m^2 and 2 mm in thickness was supplied by APAEB Sisal (Brazil). The metal part of the SFRC structure consisted in aluminium alloy 2024 T3 with 0.40 mm of thickness. The epoxy polymer (Type M) and the hardener (HY951) were supplied by Huntsman (Brazil). Table 1 shows the physical and mechanical properties of the aluminium 2024 T3 (Iaccarino et al., 2007).

2.2. Preparation

The sisal fabric (plain weave) in pristine condition was tested without epoxy resin (Fig. 1a). The specimen was cut in the weft direction according to the prescribed dimensions recommended by the standard ASTM D3039 (2014). Epoxy polymer was also used at the grip of the sample to avoid slip and possible damage created by the clamps. The SFRCs were manufactured using a hand lay-up

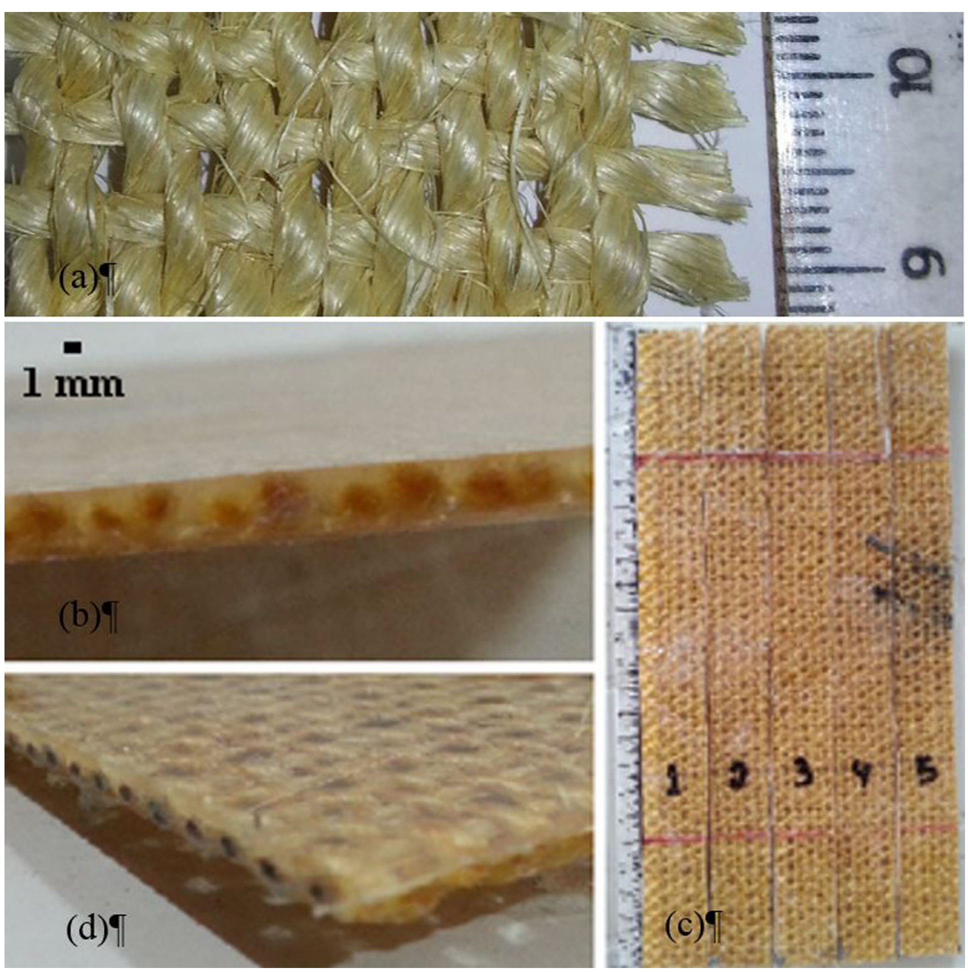

Fig. 1. Sisal fibre reinforced composites (a) sisal fabric (b) side view, (c) specimens according ASTMD3039 and (d) top view.