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Single lap shear stress in hybrid CFRP/Steel composites

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Abstract

A critical parameter in a hybrid CFRP/steel composites is the shear stress between CFRP plies and steel foils. This paper presents an experimental and numerical research on the single lap shear stress in hybrid CFRP/Steel specimens in accordance with DIN EN ISO 1465. Four different types of specimens were tested: Vacuum basting surface treatment and pickling treatment. For each type of surface treatment two types of specimens were tested: Dry specimens and specimens immersed in water for 1000 h. The results show that vacuum blasting surface treatment is the one that withstands a higher shear stress and is simpler and less hazardous than pickling surface treatment. The results also show that this type of composite has low sensitivity to water absorption. A significant difference between the displacement measured by digital image correlation and the displacement measured by a LVDT was observed. Finite element models are able to predict the maximum shear stress of hybrid composites provided that the constitutive parameters of cohesive elements are validated by experimental results.

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Keywords: Single Lap Shear, Composites, Experimental Techniques, Cohesive Elements

Nomenclature

CFRP	Carbon Fibre Reinforced Polymer
DIC	Digital Image Correlation
FEM	Finite Element Method
SLS	Single Lap Shear

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1. Introduction

CFRP materials have outstanding mechanical properties. However, CFRP bolted joints still represent a challenge in design (Camanho & Matthews 1997). Its low bearing strength, high notch sensitivity, and dependence on lay-up configuration all contribute to difficult design solutions that are solved by increasing the thickness of the CFRP in the vicinity of a bolted area. The German Aerospace Agency has been developing a hybrid solution of CFRP and metallic foils in the vicinity of the bolted areas that significantly increases its bearing strength (Fink & Kolesnikov 2005), (Kolesnikov et al. 2008). Initially the metallic material was Ti alloy (Fink et al. 2010), (Camanho et al. 2009), (Fink & Camanho 2011). Economic consideration led to the replacement of Ti alloys for austenitic steel 1.4310.

The adhesion between CFRP and the steel foils is critically important. The critical factor for this property is the surface treatment of the steel foils. Previously, a test program involving a 3 point bending of hybrid beams fibre demonstrated that vacuum blasting surface treatment is the best surface treatment available and also ensures shear stress values almost identical (≈99%) to the shear stress between CFRP layers (Lopes et al. 2014).

This paper presents the research of Single Lap Shear (SLS), tests between CFRP and austenitic steel. Two different types of surface treatment with two different types of environmental conditions, a total of 4 different types of specimens were tested.

2. Specimen manufacturing

The specimens were manufactured in accordance with DIN EN ISO 1465. The materials used were CFRP 8552/AS4 UD prepreg from Hexcel with 134 g/m^2 (Hexcel Composites 2000) and austenitic steel 1.4310 (X10CrNi18-8). The Tensile Stiffness of austenitic steel 1.4310 is $E = 178\,GPa$ (De Freitas et al. 2006). The mechanical properties of the CFRP are presented in Table 1.

Table 1 - CFRP Material properties

Material	Tension	Compression
8552/AS4 UD	$E_1 = 131.606\,GPa$	$E_1 = 115.543\,GPa$
	$E_2 = 9.238\,GPa$	$E_2 = 9.858\,GPa$
	$\nu_{12} = 0.302$	$\nu_{12} = 0.335$
	$G_{12} = 4.826\,GPa$	

The austenitic steel was subjected to two types of surface pre-treatment: vacuum blasting and pickling. Each of which was subjected to two different environmental conditions: dry specimens and specimens immersed in water for 1000 hours. Thus 4 different types of specimens were tested with 7 specimens for each type. The vacuum blasting of the steel foil was performed with 105 µm corundum particles. The pickling is performed in a H2SO4-HF-H2O2-bath. Essential constituents of this nitrate-free solution are hydrofluoric acid and an oxidizing agent. All metallic sheet surfaces were treated with an AC-130 sol-gel post-treatment after pre-treatment and then added to the laminate stacking within one hour. Two plates of austenitic steel were bonded with a CFRP layer in between. The length of the overlap is 5 mm. The width of the specimens is 10 mm. The thickness of the CFRP layer is 0.13 mm. The dimensions of the specimen are presented in Figure 1.

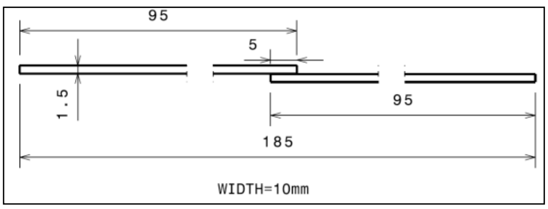

Figure 1 – Dimensions of the SLS specimens (mm).