Accepted Manuscript

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PII: S1359-8368(18)31618-4

DOI: 10.1016/j.compositesb.2018.07.059

Reference: JCOMB 5826

To appear in: *Composites Part B*

Received Date: 20 May 2018

Revised Date: 23 July 2018

Accepted Date: 29 July 2018

Please cite this article as: Qin G, Na J, Mu W, Tan W, Yang J, Ren J, Effect of continuous high temperature exposure on the adhesive strength of epoxy adhesive, CFRP and adhesively bonded CFRP-aluminum alloy joints, *Composites Part B* (2018), doi: 10.1016/j.compositesb.2018.07.059.

Effect of continuous high temperature exposure on the adhesive strength of epoxy adhesive, CFRP and adhesively bonded CFRP-aluminum alloy joints

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Abstract

To investigate the degradation mechanism of adhesively bonded CFRP (carbon fiber reinforced plastics)-aluminum alloy joints applied to high speed EMUs (electric multiple units) after experiencing continuous high temperature environment, bulk specimens, CFRP plates and adhesive joints, including thick-adherend shear joints (TSJs), scarf joints (SJs) with scarf angle 45° (SJ45°) and butt joints (BJs) were exposed at 80℃ for 30 days and then tested every 10 days. Chemical analysis, such as fourier transform infrared spectroscopy (FTIR), thermogravimetric Analysis(TGA) and differential scanning calorimeter (DSC) were conducted to analyze the variations of composition, glass transformation temperature (T_g) and thermal stability of the adhesive Araldite® 2015 and CFRP. Bulk specimens were also used to investigate the mechanical properties (failure strength, Young's modulus, strain) of the adhesive Araldite® 2015.The failure strength of CFRP after thermal exposure was tested with consideration of different surface treatments, and scanning electron microscopy (SEM) was also used to investigate the fracture surfaces of CFRP. The failure strength and failure surfaces of CFRP-aluminum alloy joints were analyzed to study the rules of degradation process. The results show that the post curing behavior of the adhesive Araldite® 2015 was verified by the composition analysis, leading to the obvious improvement of T_g, thermal stability, tensile strength and Young's modulus. However, CFRP degraded after thermal exposure, resulting in the slight decreases of T_g and thermal stability. The shear and normal strength of degraded CFRP dropped sharply because of the modification of epoxy matrix and decrease of interlaminar strength, although it regained to approximately 90% of unaged CFRP after the improvement of surface roughness. For adhesively bonded CFRP-aluminum alloy joints, with increasing proportion of normal stress and exposure time, the failure strength of adhesively declined faster because of the larger areas of fiber tear and interface failure, illustrating that the effect of CFRP degradation and interface failure were more obvious than that of post curing behavior of the adhesive Araldite® 2015. Therefore, CFRP degradation and interface failure were the main causes for the degradation of adhesively bonded CFRP-aluminum alloy joints subjected to thermal environment.

Key words: CFRP; Thermal degradation; Chemical analysis; Mechanical testing; Adhesion strength;

1. Introduction

The increasing requirements for lightweight components in the aerospace, marine, automotive and railway industries have led to a trend of reducing weight by employing lighter alloys, composites, or stronger materials. Moreover, multimaterial applications is becoming the key to success for industries where energy efficiency is essential to minimize operating costs [1, 2]. As most of the EMU carbodies are overall load bearing structure

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