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Publication date
2016

Document Version
Final published version

Published in
Proceedings of the Brazilian Conference on Composite Materials

Citation (APA)
de Barros, S., Teixeira De Freitas, S., Banea, M. D., Budhe, S., Arouche, M. M., & dos Santos, B. L. (2016). Adhesion quality of steel-CFRP interface bonding. In S. H. Pezzin (Ed.), *Proceedings of the Brazilian Conference on Composite Materials: Gramado, Brazil*

ADHESION QUALITY OF STEEL-CFRP INTERFACE BONDING

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Abstract: In this work, peel tests were used to assess the adhesion quality between carbon fiber reinforced polymers (CFRP) and carbon steel plates. The tests were performed according to the ASTM standard of floating roller peel tests (D3167–97) with a new specimen layup. The layup and geometry of specimens was defined in order to have the CFRP as the rigid substrate and the steel plate as a flexible substrate. The aim is to assess the adhesion quality of the interface in dry-conditions (short-term) and after ageing (long term). Specimens were inside the salt spray cabinet for 30 days to absorb the moisture. Results show that peel load are not significantly affected by the ageing condition. The specimens tested at dry-conditions and ageing condition showed a cohesive failure within the adhesive layer, which indicates a good adhesion between the CFRP-Steel interfaces. Long term durability is suggested by keeping the specimen for longer duration in order to observe the degraded trend and adhesion quality of the joints.

Keywords: Peel test, Adhesion, Steel, CFRP, Durability.

1. INTRODUCTION

Nowadays, multi material structures (hybrid joint) design is introduced, especially in automobile sectors, as it fulfilled the necessary condition such as lightweight and more resistant structure, etc. Researchers [1-2] also found the positive influence of multi material bonding on the performance of bonded structures. But, still mechanical adhesion properties are not well developed and documented in the literature for multimaterial bonded joints. With the increasing use of composite over metals, attention should be paid about the adhesion quality in the presence of environmental effect in order to assure the long term durability of the multimaerial bonded joints.

Most of the research in composite-to-metal bonded joints are limited to coupon tests. Some authors combine SLJ with DCB or T-peel tests in order to evaluate the durability of bonded composite-to-aluminium joints, for example, against humidity, or the effect of different surface pre treatment [3,4]. Double cantilever beam (DCB) hybrid specimens are used to characterize the crack propagation behavior and giving input data for fracture mechanics. [5]. Nevertheless, both studies were more focused on evaluating the effect on the mechanical properties rather than on evaluating the adhesion properties of the joints. However, limited research available for evaluating the adhesion properties of composite-to-carbon steel joints: are the adherents properly bonded together? And will this bond endure for a long time under the adverse condition of the environment?. To answer of this, it's extremely important to evaluate the adhesion properties under the environmental conditions to avoid in-service interfacial failure of adhesive bonded joints. Also, to avoid interfacial failure in service of bonded composite parts, it is essential to guarantee good adhesion properties at the interfaces.

Currently, interface adhesion is assessed by destructive testing. Since adhesion is one of the key components for guarantying the integrity of bonded joints, new peel tests have been developed in order to assess the adhesion quality of composite-to-metal bonded joints [6]. For metal bonding, a widely accepted industrial test to secure a proper bond is the standard floating roller peel test. A cohesive failure when peeling-off the aluminium part ensures that the adherends are properly bonded and that this bond will endure. This is a fast and reliable these type of peel test for metal bonding with diverse objectives, including adhesives screening, effect of surface pre-treatments, bond durability, etc. [7-8]. Diverse studies have also investigated the adherends effects in the floating roller peel test. It has been found that the peel strength measured is a combination of the true interface adhesion strength plus work expended in the plastic deformation of the thin adherend. Therefore the mechanical characteristics of the thin adherend have a significant effect on the measured peel load [9-10].

In this research, the adhesion properties of bonded composite - carbon steel joints are evaluated under the influence of salt water spray. In order to study the durability of adhesion quality, the specimens were immersed in salt water spray for the different duration. The roller peel test performs to determine the adhesion properties of the composite-meal bonded joints.

2. MATERIALS AND MEHODS

Peel specimen was produced type of carbon steel as a flexible to Carbon fiber reinforced polymer (CFRP) as a rigid panel (fig.1). The standard floating roller peel specimens were based on the ASTM standard D 3167 [11]. In order to study the long term durability of the joint, the specimens were inside the salt spray cabinet for the different duration of time. During testing, the flexible adherend (steel) is peeled off from the rigid adherend (CFRP). Specimens were 25 mm in width, 5 mm in thickness and 300 mm long. Standard floating roller peel tests (FRPT) were performed on both ageing and non ageing specimens at room temperature (RT) conditions.

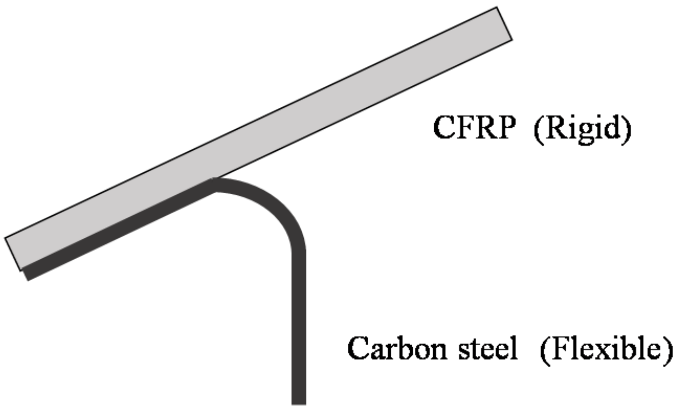

Figure 1: Floating roller peel test specimen CFRP-Carbon steel

The experimental procedure was based on the ASTM standard D3167 [14]. Testing was carried out using an electro mechanic Zwick machine with maximum capacity of 20 kN, coupled with a load cell of 1 kN. The testing speed was 125 mm/min. Figure 2 shows the tests set up of the peel test. A total of three specimens was tested in each condition. During tests, the load and the cross head displacement were recorded.

Figure 2: Floating roller peel test set up

3. RESULTS AND DISCUSSIONS

The maximum and minimum peel loads of both ageing and non-ageing specimens tested are given in table 1. There is no significant difference in maximum peel load between the ageing and non ageing specimen except only at minimum load. There is a quite significant reduction in peel load from maximum to minimum for the ageing specimen. It implies that degradation of adhesion takes place, but the difference between them is limited.

Table 1: Maximum and minimum peel load of ageing and non ageing specimen

Specimen condition	F_{max} (N)	F_{min} (N)	Difference in force (N)
No-ageing	79.90	61.02	18.89
	83.09	64.38	18.71
	69.37	59.93	9.43
Ageing (30 days in salt spray cabinet)	80.19	48.38	31.81
	73.36	55.62	17.74
	80.97	36.85	44.12

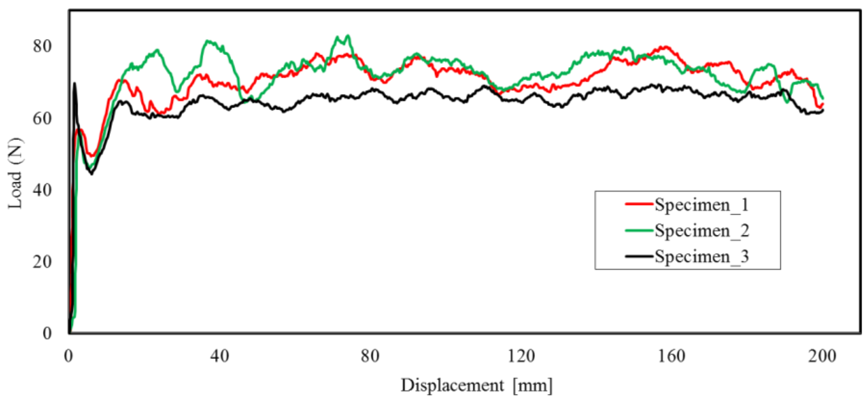

Figure 3: . Load displacement curve of steel-CFRP non ageing specimen

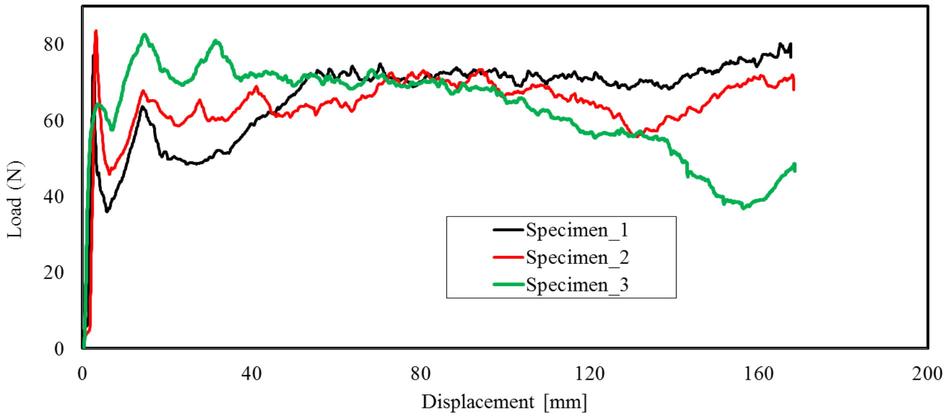

Figure 4: . Load displacement curve of steel-CFRP non ageing specimen

Figure 3 and 4 represents the load-displacement curve of ageing and non ageing specimen respectively. The trend of both the ageing and non ageing specimen curves is similar except at the starting point and at the end there is fall down of the load values for the ageing specimens. This trend of ageing specimens is related to the absorption of moisture at the starting and end of the specimen and which lead to degrades the surface at the particular location.

The fracture surface of the ageing specimen confirmed that the moisture ingress in through the edges and it's not affecting the complete adhesion surface as shown in fig.5. Cohesive failure was observed as a dominant failure mode, it implies that the interface is not affected by the ingress of moisture or the moisture ingress is not low over the span of time. From fracture specimen (fig.5), it's clearly seen that only edges of the specimen are affected by the moisture. It implies that, moisture ingress only at the edges of the specimen during the 30 days of time, If it more time in the presence of salt spray, then would possible for more degradation of joints. Because within 30 days, the moisture ingression is not up to the depth of the joint interface. Cohesive failure was the dominant failure observed in both the conditions, ageing and non ageing, it indicates a good adhesion quality of the bonded joints. The cohesive failure mode remains same in ageing condition also, this is one of the possible reasons to maintain the higher peel load.

Figure 5: Fractured specimen after peel test

4. CONCLUSIONS

The adhesion properties of bonded joints were evaluated under the influence of ageing using a floating roller peel test. Peel tests were performed on CFRP-to-Steel adherend joints, in which steel as a flexible and CFRP as a rigid adherend.

The results show that the peel load are not significantly affected by the ageing conditions. In both ageing and non ageing specimen, a cohesive failure observed, which lead to more resistant in both conditions. There is no degradation of joints (interfacial failure) revealed from the fracture surface of the specimen. Moisture ingress takes place at the edges of the specimen only, not completely through the adhesion surface which is revealed from fractured surface. Cohesive failure as a dominant mode observed in both cases which is indication of good adhesion.

Longer duration in salt spray can degrade the adhesion joints, need to continue the study with keeping specimen for long durations to evaluate the adhesion properties and failure behavior for long durability.

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