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TESTS ON LAYERED DOUBLE-LAP COMPOSITE T-JOINTS

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Abstract: *This study represents an intermediary stage to optimize layered double-lap composite T-joints (CTJs) used to stiffen firefighter water tank walls and to restrain the water flow inside these tanks. CTJs with different width-to-thickness ratios and identical laminates architectures have been fixed on a specially designed table at different clamping lengths and their baffle have been subjected to static tensile loads until break. Further stage in the optimization process is required. More efficient CTJs clamping methods have to be designed restraining only the displacement of the double-lap connection laminate on their thickness.*
Keywords: *composite T-joint, baffle, double-lap joint, connection laminate, tensile test*

1. INTRODUCTION

The whole study started at the request of a firefighting vehicles manufacturer to reduce the weight of their vehicles. Every kilogram they win is a liter of water they can carry more, possibly saving the life of a human. Water tanks for firefighter trucks must be of minimum weight, while meeting the mechanical requirements of the component. Especially, the composite T-joint (CTJ) baffles used to increase the stiffness of the tank walls and to restrain the flow of water are for great importance. In the last two decades, extensive research has been carried out in the field of composite T-joints (CTJs). For instance, modelling and simulation of failure mechanisms and damage behavior of CTJs under various loadings using finite element analysis (FEA) are presented in references [1-9]. Design approaches and optimization methods have been used to improve the structural properties of these joints [10-13]. The Z-pinning technique to insert reinforcing fibers along Z-direction of CTJs leads in some conditions to a significant increase of the structural properties and delamination resistance of the composite structure [14-18]. The fatigue life and behavior of CTJs and adhesive lap joints for large composite panels have been also examined [19-21]. Interesting aspects regarding the behavior of CTJs used in marine applications are presented in references [22-24]. Especially in the double-lap area of sandwich CTJs attention has been paid using the nonlinear finite element analysis to estimate pull-out loadings until break [25-27]. Various geometrical configurations of composite adhesive joints have been used to analyze the influence of variations in the geometry of adherents on the mechanical strength of common joints [28-32]. The aim of this paper is to get experimental data obtained on CTJs with two width-to-thickness ratios useful to refine an existing finite element computing system.

2. TEST METHOD FOR CTJs

CTJs used in a firefighter water tank present a baffle laminate perpendicular to tank's sidewall by means of double-lap connection laminates. In some conditions, during full filled tank operation, cracks in connection laminates and delamination between connection laminates, tank's sidewall and baffle have been observed. To refine the finite element computing system, a special test method for CTJs has been developed. A table with adjustable clamping plates to fix CTJ samples at various clamping lengths has been designed. This table has been mounted on a "LS100 Plus" Lloyd Instruments materials testing machine (Fig. 1). Two types of CTJ samples with different width-to-thickness ratios have been clamped on this table and the baffle has been subjected to pulling loads until break (Fig. 2).

2.1. CTJ laminates

Following composite laminates with their symbols have been used during testing CTJs and presented in Table 1.

Figure 1: Table with adjustable clamping plates mounted on a “LS100 Plus” testing machine

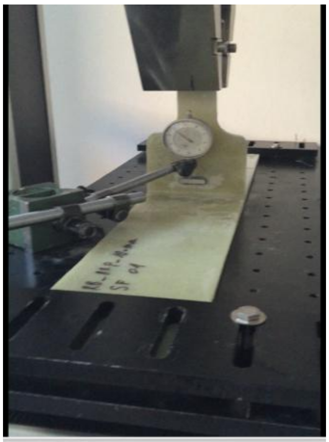

Figure 2: CTJ sample clamped on table

Table 1: Composite laminates used in tests

Laminate	Thickness (mm)
$[M_3/W/M/CM5]_{s'}$*	13.0 ± 0.3
$[M_2/W/M]_s$	6.8 ± 0.3
$[M_2/W/M]_{s*2}$	13.6 ± 0.3

The laminates symbols are:

- $[\ ]_S$: symmetric laminate in which all plies are mirrored on the mid-plane;
- $[\ ]_{S'}$: symmetric laminate in which all plies except the last one are mirrored on the mid-plane;
- X_y: *y* layers of material *X*;
- M: random mat 450 g/m²;
- W: woven roving 580 g/m²;
- *: gelcoat layer on one side;
- CMx: Lantor Coremat of *x* mm thickness.

2.2. Tests on CTJs with 3.33 width-to-thickness ratio

In order to get a correct approximation of the water tank’s behavior, the dimensions of the CTJs are very important. Following test types, CTJs dimensions, laminates and clamping lengths have been used:

- Static tests: baffle’s pulling until break on a special designed table with adjustable clamping plates (Figs. 1 and 2); Sample width: 60 mm; Baseplate’s laminate: $[M_3/W/M/CM5]_{s'}$*; Baffle’s laminate (vertical plate): $[M_2/W/M]_{s*2}$; Connection laminate: $[M_2/W/M]_s$; Baseplate’s clamping length: 300 mm; Number of samples used: 5.

2.3. Tests on CTJs with 6.66 width-to-thickness ratio

Following test type has been performed and following CTJs dimensions, laminates architectures and clamping lengths have been used:

- Static tests: baffle's pulling until break and up to 1500 N pulling load, on a special designed table with adjustable clamping plates (Figs. 1 and 2); Sample width: 120 mm; Baseplate's laminate: $[M_3/W/M/CM5]_{s'}$*; Baffle's laminate (vertical plate): $[M_2/W/M]_{s*2}$; Connection laminate: $[M_2/W/M]_s$; Baseplate's clamping lengths: 300 mm (five samples, three subjected until break and two subjected up to 1500 N), 500 mm (two samples subjected up to 1500 N) and 700 mm (two samples subjected up to 1500 N).

3. RESULTS

Regarding the CTJs with 3.33 width-to-thickness ratio, load-extension distributions of five samples have been presented in Fig. 3. Regarding the CTJs with 6.66 width-to-thickness ratio, the static test results are shown in Figs. 4 and 5.

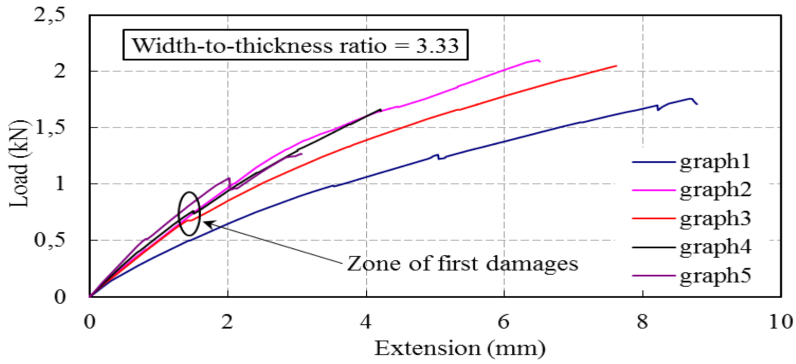

Figure 3: Load-extension distributions of five CTJ samples during baffle's pulling

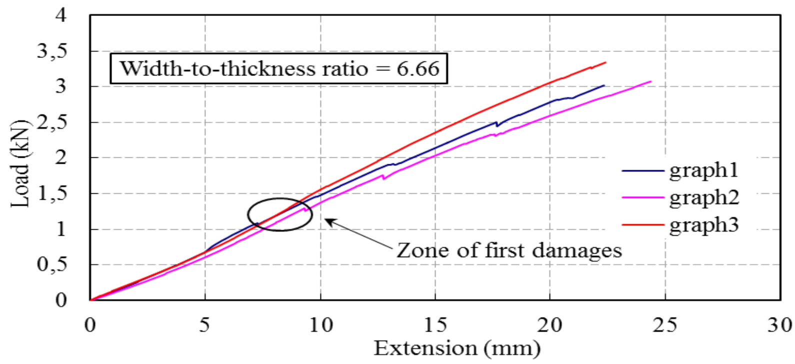

Figure 4: Load-extension distributions of three CTJ samples during baffle's pulling

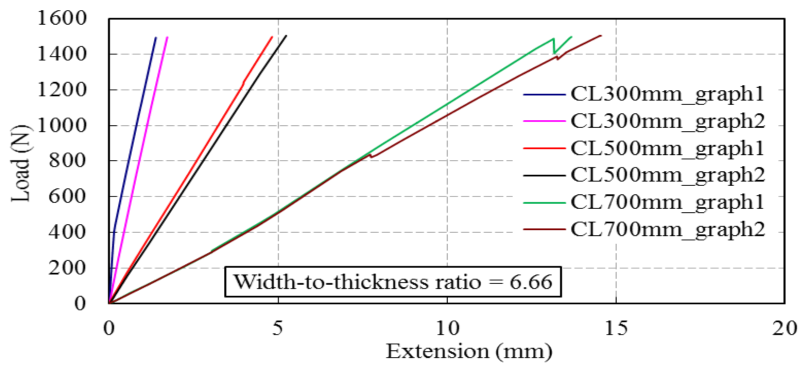

Figure 5: Load-extension distributions of CTJ samples with various clamping lengths

4. DISCUSSION

After testing two CTJs samples with 3.33 width-to-thickness ratio we have entered the results (load and stress at failure) into the FEA software and we have computed stresses in CTJ along various curve arc lengths. A stress at failure around 40/50 MPa has been computed at the interface between baffle, connection laminate and baseplate. During tests on two CTJs with 3.33 width-to-thickness ratio, small cracks appeared at the interface between baffle and baseplate leading to joint's break. Zone of first damages occurred between loads interval 0.5–0.75 kN and extensions 1.36–1.49 mm (Fig. 3). Experience and field situations have taught us that these data obtained on this CTJ were not sufficient to assure a product that resists the applied forces. Both load and stress at failure obtained in static tests on CTJs with 6.66 width-to-thickness ratio have been used as input data in the FEA software and stresses in CTJ along various curve arc lengths have been computed. A stress at failure around 85/95 MPa as well as a maximum 25 mm displacement has been computed at the interface between baffle, connection laminate and baseplate. Zone of first damages occurred between loads interval 1.07–1.27 kN and extensions 7.2–9.2 mm (Fig. 4).

5. CONCLUSION

A third stage to refine our final computing system is required in the optimization process of firefighter water tanks. To attain this end more tests have to be done especially using more efficient methods to clamp the CTJs, restraining their displacement only on their thickness direction. In our experimental tests on CTJs we have used a fixed clamping method. The reality is that in a firefighter water tank the CTJs allow small displacements between connection laminates and sidewall.

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