# Investigation of influence of tab types on tensile strength of E-glass/epoxy fiber reinforced composite materials

# Investigation of influence of tab types on tensile strength of E-glass/epoxy fiber reinforced composite materials

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**Abstract**

Mechanical response of E-glass/epoxy fiber reinforced composite was investigated in tensile loading. Different types of tabs were considered in order to evaluate their effects on the tensile strength of material. Specifically, two types of molded tabs and five types of bonded tabs were considered in the study. The influence of different amount of gripping pressures on failure mode and on tensile strength of specimens was also considered in the analysis.

The experimental results showed that the tabs configuration affected the tensile strength of the specimens. Starting from the experimental results, an appropriate testing methodology is proposed for E-glass/epoxy fiber reinforced composite specimens in order to reduce problems that may arise during the test and to optimize procedures for preparation of specimens.

*Keywords*: Twill weave fabric; Gripping pressure; Tensile strength; Manufacturing method;

## 1. Introduction

Tensile tests are used to measure mechanical properties of materials under tensile loading. For conventional isotropic materials, typical dog-bone or hourglass specimen geometries are adopted to drive the failure in the waist section under tensile loading. However, in case of composite materials, this type of waist gives rise to discontinuity in fiber orientation and is generally avoided, as recommended in several national standards [1-4]. For instance, depending on the fiber orientation and on the type of fabric, ASTM

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D3039 advises to use rectangular coupons with tabs for cross-ply and for unidirectional specimens and to adopt rectangular coupons without tabs for balanced, symmetric and random discontinuous fiber specimens.

Many research groups proposed a number of composite specimen geometries and tab materials specifically designed for tensile loading. In [5], Hoyo et al. proposed two types of specimen for unidirectional CFRP, namely, specimen with 10° tapered tabs and specimen with square cut tabs. Their results showed a small difference in the tensile strength (3% to 4%) and no significant difference in the macroscopic fracture behavior. In [6], Zureick and Nettles studied the effect of tab material on the tensile strength, by testing specimens with square tabs made of steel, aluminum, glass fiber-epoxy composite and unreinforced epoxy. They found that metallic tabs gave the maximum value of the stress concentration factor at the tabs tip and, consequently, the minimum value of the tensile strength, while epoxy tabs gave the minimum value of the stress concentration factor and the maximum value of the tensile strength.

This study investigated the effect of different tab geometries and materials on the tensile strength of cross ply E-glass/Epoxy fabric composite specimens. In the literature, to the authors' best knowledge, the effect of the manufacturing process of tabs on the mechanical properties of the specimens was not generally taken into account. Differently from the literature, the paper considers the effect of the manufacturing process of tabs as well as the effect of the gripping pressure on the experimental tensile test results. An analysis was also carried out to correlate, in terms of tensile strength, the locations of the failures in the specimens with the different types of tabs considered.

## 2. Materials and methods

### *2.1. Specimen material*

The material under investigation was a prepreg (twill 2X2 type) E-glass/epoxy composite with a mass of 300 g/m$^2$ and resin mass content of 33.3%. Fourteen prepreg layers were stacked together in order to obtain a coupon with lay-up $(0/90)_{14}$. Coupon geometry was obtained according to ASTM D3039. By joining the coupons together with different tabs configurations, seven types of specimens were obtained (Table 1).

Table 1. Nomenclature

| Tab material | Composite | | | Aluminium | | Steel | | Tabless |
|---|---|---|---|---|---|---|---|---|
| Manufacturing | Bonded | Molded | | Bonded | | Bonded | | - |
| Bevel angle | 30 | 30 | 90 | 30 | 90 | 30 | 90 | - |
| Acronym | TC30 | T30 | T90 | TAL30 | TAL90 | TS30 | TS90 | TL |

In the case of specimens with composite tabs, tabs were obtained with two different manufacturing processes: by bonding tabs on a manufactured coupon (specimens TC30), and by molding tabs with coupon during the manufacturing process (specimens T30 and T90). Composite tabs for TC30 specimens were obtained by stacking the same prepregs used for coupons in order to obtain tabs with lay-up $(\pm45)_{14}$.

### *2.2. Manufacturing process of specimens*

Three different types of moulds were manufactured from epoxy resin block to mould: a) TL specimens (coupons); b) T30 specimens; c) T90 specimens. In order to obtain accurate dimensions and good surface finish, moulds were produced with environmentally conditioned CNC milling machine. Then, plies were cut from prepreg E-glass/epoxy and stacked in each mould according to the desired lay-up (Fig. 1). Moulds were covered with vacuum plastic bag and subjected to vacuum pressure of 0.98 bar. Then, they were put into the autoclave and underwent the prescribed cure cycle (1.5 hour at 126 °C with 3 bar pressure followed by 4 hours at 126 °C with 1 bar pressure).After polymerization, both the tabs and the coupons were 2.5 mm thick.

Specimens TC30, TAL30, TAL90, TS30, and TS90 were prepared by bonding the coupons with the corresponding tabs. Loctite® Hysol® 9466 was chosen and used for bonding tabs with coupons.

Surfaces, which were going to be bonded, were abraded with a sandpaper having 100 grade of grit in order to remove contamination. Surfaces, which belonged to the gage area, were protected by masking with self-adhesive tape.

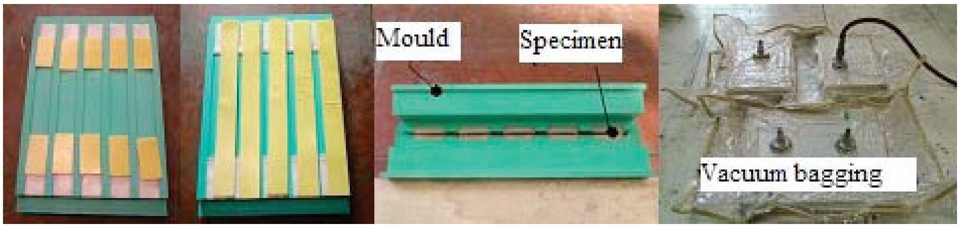


Fig. 1. Typical specimen preparation

*2.3. Experimental setup*

Five specimens for each configuration were tested under tensile loading with a servo-hydraulic testing machine (INSTRON-8801) with a capacity of 100 kN. Each specimen was clamped by means of hydraulic wedge grips. The machine was equipped with a standard load cell and a crosshead displacement measuring device. During the mount phase of the specimen, the maximum applied load was controlled and set lower than 0.2 kN in order to avoid specimen damage. According to ASTM D3039, specimens were subjected to monotonic tensile loading with a stroke rate of 2 mm/min.

Five T90 specimens were instrumented by strain gages to measure Young's modulus ($E_x$) and Poisson's ratio ($\nu_{xy}$), according to ASTM D3039. To measure shear modulus ($G_{xy}$), five specimens with stacking sequence $(\pm 45)_{10}$ were also manufactured and instrumented with strain gages, according to ASTM D3518. To acquire the strain gages data, a NI WLS-9163 data acquisition board was used. To acquire load and crosshead displacement data from the machine, a NI DAQCard-6062E was utilized. All data were acquired with a sampling rate equal to 1 kHz.

## 3. Experimental results

*3.1. Elastic properties of composite laminates*

According to ASTM standards strain ranges were chosen for the determination of both $E_x$ and $G_{xy}$. The strain range considered for $E_x$ was 1000-3000 $\mu\varepsilon$, while, for $G_{xy}$, the strain range considered was 2000-6000 $\mu\varepsilon$. The obtained mechanical properties are summarized in Table 2. Results are in good agreement with the literature [7].

Table 2. Elastic properties

| Composite | Weave type | Fiber volume fraction | $E_x$(Gpa) | $G_{xy}$(Gpa) | $\nu_{xy}$ |
|---|---|---|---|---|---|
| E-Glass/Epoxy | 2×2 Twill | 0,4 | 23,77 (0,36) | 3,25 (0,07) | 0,142 (0,008) |

Note. Values in parentheses are standard deviations

### *3.2. Gripping pressure effect*

Nine preliminary tests were performed to evaluate the influence of hydraulic gripping pressure on mode of failure. Three different gripping pressures (50, 40 and 35 bar) were chosen for the analysis. For each gripping pressure three TL specimens were tested. Results showed that the gripping pressure that eliminated failure at the gripping area was 35 bar (Fig. 2). All subsequent tests were performed with this gripping pressure.

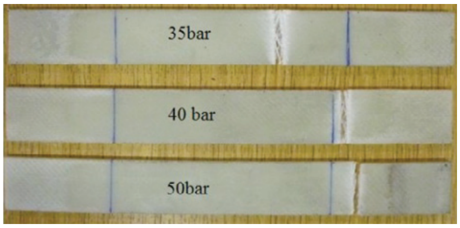


Figure 2. Effect of gripping pressure

### *3.3. Specimen configuration effect*

Typical stress-strain curves obtained from tensile tests on each specimen configuration are shown in Fig. 3.

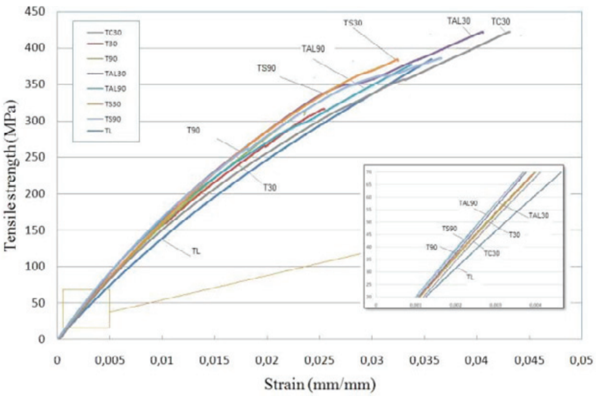


Fig. 3. Stress-strain curves for each specimen configuration

Stress-strain curves given in Fig. 3 were calculated by dividing the measured load by the average cross section of the specimens and the crosshead displacement by the nominal gage length of the specimens. As shown in Fig. 3, the stress-strain curves of each specimen type exhibited different value of apparent elastic modulus. Regardless of the material type, specimens having tabs with a 90° bevel angle exhibited higher apparent elastic modulus, while specimens having bonded tabs with a 30° bevel angle showed the maximum tensile strength.

It must be pointed out that, except for unbonded specimens (TL, T30 and T90), curves showed an abrupt load drop before final failure. Therefore, interaction among tab material, adhesive interface and specimen material gives reason for this kind of result.

Tensile strengths for all types of specimens have been reported in Fig. 4.

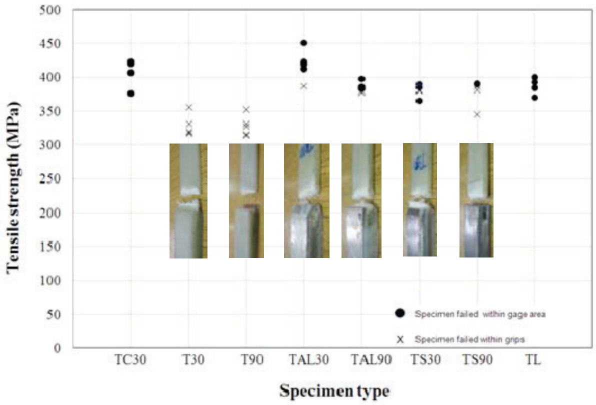


Fig. 4. Tensile strengths for each specimen configuration and typical gripping area failures

As shown in Fig. 4, only in the case of TL and TC30 specimens all the failures occurred in the gage area.

In the case of molded composite tab specimens, T30 and T90, premature failures occurred generally at a significant lower tensile load than TL specimens and bonded tab specimens. All T30 and T90 specimens failed at the tabs tip and some of them showed an extended delamination area (Fig. 5). Due to the change in cross-section at the tab tip, residual stresses were induced in the specimens during the manufacturing process. This caused the premature failures observed in T30 and T90 specimens.

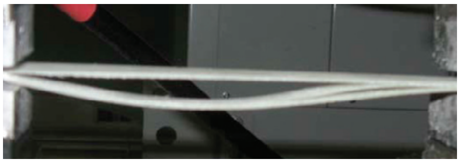

Fig. 5. Delamination in a molded tab specimen

The maximum tensile strength was achieved by TAL30 specimens. In some configurations (TS30 and TS90), due to high stress concentration factors, failures occurred frequently within the gripping area and lower tensile strengths were found (Fig. 4). According to [6], this could be explained by considering the higher stiffness of steel material, which doesn’t allow a sufficiently smooth load transfer from tabs to coupon.

Finally, the effects of introduction of tabs on the tensile strength of specimens were analyzed by observing normalized tensile strength values. Normalization was obtained by dividing the tensile strength of tabbed specimens by the tensile strength of tabless specimens. Interval plot (Fig. 6) of normalized values showed that TAL30 and TC30 specimens reported a significantly higher tensile strength. While, T30 and T90 specimens showed a significantly lower tensile strength. As a general result, specimens with 90° bevel angel tabs showed lower tensile strengths than the corresponding specimens having 30° bevel angel tabs.

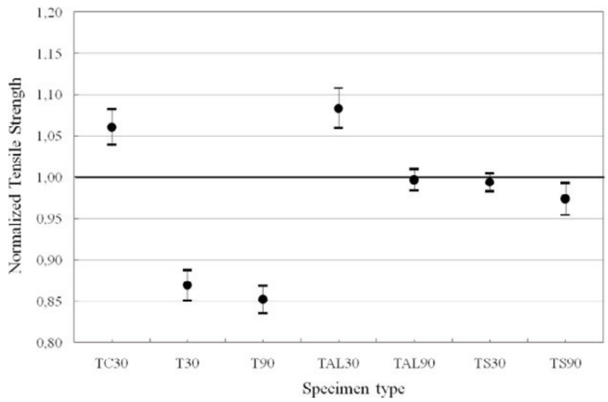


Fig. 6. 95% confidence level interval plot for mean values of normalized tensile strengths

## 4. Conclusions

Gripping pressure, specimen geometry profile, tab material and manufacturing procedure affect the tensile strength of fabric type E-glass/epoxy specimens under the same test conditions. Determination of the appropriate gripping pressure (35 bar) assured occurrence of failures in the gage area for tableless specimens. Significant decreases in tensile strength induced by residual stress were observed when tabs were molded and manufactured together with coupons. Due to a lower stress concentration factor, specimens with 30° bevel angel tabs showed higher tensile strengths than the corresponding specimens having 90° bevel angel tabs. As general final result, at least for the material under study, tensile tests can be performed without adding tabs but by careful regulation of the gripping pressure. Moreover, if tabs are added to specimen, they must be bonded and $30^0$ bevel angle tabs made of composite or aluminum material should be preferred with respect to the other tab types.

Further research and tests should be performed to other composite materials in order to extend results obtained in this study.

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