# Tensile Behaviour of Fabric Reinforced Plies

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*Nowadays world is exposing a continuous spreading of composites applications and, as a consequence an enforcement of scientist efforts toward such materials design, testing and modelling. Since polymer reinforced materials are covering a huge area of applications it is obvious that the researchers interest is oriented to these materials study in all its aspects. Fabric reinforced polymers represent a very attractive solution from the manufacturers' point of view, especially in the case of thermoset polymers where the lay-up method is the most used to form composites. This study is about tensile behavior of lamina or plies of thermoset matrix fabric reinforced materials. The aim of the study is to determine the role of the matrix and the role of fabric (fibers type, specific weight) on the tensile response to gather valuable information regarding the design of layered materials.*

*Keywords: fabric reinforced composites, thermoset polymers, tensile tests*

Discovery of artificial fibers generates progresses all around the human activity due their properties considered (from certain points of view) superior to the ones of natural fibers and because, unlike the natural fibers, they can be produced with higher lengths allowing more complicated ways of weaving without knots. In the case of glass fibers, carbon fibers and aramid fibers the lack of lateral filaments (that are characteristic for natural fibers) is not allowing their package into what generally is called fiber. In fact the above mentioned fibers (glass, carbon, aramid) are extremely thin their diameter being of micrometers and their use in this form is almost impossible in composites production, excepting the ones with randomly distributed long fibers. The term of fiber with respect to glass, carbon and aramid fibers refers actually to fascicle of fibers (filaments) stacked together by mechanical (twisting) or by chemical means and these types of fibers can be weaved in order to get fabrics. The natural fabrics are rarely used in their very thin form of individual fibers (silk and linen) but often in their twisted aspect with several individual fibers forming threads with the integrity guaranteed by the mechanical interaction between lateral filaments or between lateral filaments of a fiber and the neighbor fiber. The presence of lateral filaments ensures, on another hand, a good transfer of loadings from matrix to fibers when those are used to reinforce a material to form a composite. In this case the transfer is less anisotropic than in the case of synthetic fibers because of the random distribution of lateral filaments. It is expected that in the case of natural fibers reinforced orthotropic composites (in most cases the polymer matrix ones but occasionally also the ceramic matrix ones) the elastic response of the material at of-axis loadings (at small angles) to be superior to the artificial fibers reinforced composites response in the same conditions. In the case of axial loadings, depending on the nature and quality of matrix-fiber interphase, it is expected that artificial fiber reinforced composites to have a better behavior than the natural fibers reinforced composites.

The design of composites properties is still a complex attempt and it is based mostly on the researcher expertise. It is natural to form composites (of all kinds) to solve one issue but the tendency to multi-functionalize the materials requires more attention on how the components of the composites really interact. There are many studies regarding, for instance, the composite laminates mechanical properties (both empirical and theoretical) [1-10] but they are just few studies regarding the fabric reinforced laminates (or layered fabric reinforced polymers) even if creating various stacking sequences of various fabric it could be possible to solve more than one mechanical property [11-18]. Also the use of hybrid fabrics (made of combinations of the three above mentioned types of artificial fibers) could be used to get better mechanical properties of materials with some difficulties generated by the different quality of interphase. Of course other solution could be to use different polymers at different levels (layers) in the same material but this is problematic because the polymers have to be, at least, chemical compatible and miscible in their pre-polymer phase [19-27].

Since the wet lay-up method to form fabric reinforced composites is very simple and can be easily technologized is natural to think about using divers polymers in the same material and it also possible to think a modification of the

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polymer in order to solve the interphase quality problem (use of starch, carbon black, clay, talc or other substances that allow small modifications of pre-polymer mixture behavior).

Regarding the layered or laminate composites it is well known the fact that changing the spatial orientation of a layer it is possible to reduce the anisotropy of the system but we really don't know what is happening between two layers made of different fabrics (dissimilar type of matrix-fiber interphase). From other empirical studies regarding the fabric reinforced epoxy plies [28] it is known that failure mechanism of a fabric reinforced epoxy ply (axial tensile loading) starts with matrix breaking followed by its effect of guillotine over the fibers but always along a thread of filaments perpendicular on the loading direction. Also it was experimentally proved that the matrix thickness has a major influence on the values of breaking parameters (loading, deformation, energy, and strength). Even the matrix-fiber interphase quality is very important for the final properties of the composite material when is about the tensile loading response of a fabric reinforced ply the rigidity of matrix plays a very important role.

Since the composite evolution is toward multi-functionalization it was considered important to develop a study regarding the tensile behavior of plies at different orientations of loading with respect for the two main directions of the fabric (the warp direction and the weft direction).

## Experimental part

### *Materials and methods*

Eighteen different fabrics (Table 1 – for carbon fiber fabrics; Table 2 – for glass fiber fabric; Table 3 – for the aramid fiber fabric; and Table 4 for hybrid fabrics for all these tables the abbreviations used in [32] were kept) were used to form fabric reinforced plies with three different epoxy resins: *Epiphen RE4020-DE4020* (*Bostik*), *Epoxy Resin C* and *Epoxy Resin HT* (both from *R&G Faserverbundwerkstoffe GmbH*). Regarding the epoxy systems it has to be said that the *Epiphen* system is having the longest pot life (about 45 minutes) while the other two epoxy systems are little faster so it is expected that the interphase fiber-*Epiphen* to ensure a larger value of specific area with consequences in loading transfer. The *Epiphen* epoxy system is used to impregnating, stratify and bond [29] while the other two systems are designed for laminating and bonding [30, 31]. Since the producers are not giving information about chemical composition of products it is expected to form polymer matrix materials with the same properties (the products presentations contain guaranties for excellent adhesion to all type of carbon, glass and aramid fibers).

**Table 1**

PROPERTIES OF CARBON FIBER FABRICS

| | FT | FS | SW$[g/m^2]$ | WpY $[cm^{-1}]$ | WtY $[cm^{-1}]$ | MT [μm] |
|---|---|---|---|---|---|---|
| CF120 | Torayca T300 1K 67tex | 100%C | 120 | 9 | 9 | 130 |
| CF160 | AKSAKA™ A-38 3K 200tex | 100%C | 160 | 4 | 4 | 180 |
| CF240 | AKSAKA™ A-38 3K 200tex | 100%C | 240 | 6 | 6 | 290 |
| CS61 | Tenax® HTS40 | 100%C | 61 | 4.5 | 4.5 | 90 |
| ST72 | Tenax® IMS60 24K | 100%C | 72 | 0.42 | 0.42 | 120 |
| TF60 | Pyrofil™ HR40 12K | 100%C | 60 | 0.5 | 0.5 | 80 |
| TF76 | Torayca® M30SC 18K | 100%C | 76 | 0.5 | 0.5 | 110 |
| CT160 | Torayca ® T700SC 2K | 100%C | 160 | 0.5 | 0.5 | 170 |

**Table 2**

PROPERTIES OF GLASS FIBER FABRICS AND OF THE MATERIALS CONTAINING GLASS FIBERS

| | FT | FS | SW$[g/m^2]$ | WpY $[cm^{-1}]$ | WtY $[cm^{-1}]$ | MT [μm] |
|---|---|---|---|---|---|---|
| G25 | Glass EC5 – 5.5tex | 100%G | 25 | 22 | 22 | 20 |
| G108 | Glass EC5 – 11tex | 100%G | 108 | 23.7 | 22.8 | 90 |
| G163 | Glass EC9 – 66tex | 100%G | 163 | 12 | 12 | 120 |
| G280 | Glass EC13 – 66x3tex | 100%C | 280 | 8 | 7 | 220 |
| CVS | | | 30 | | | 120 |
| CAVS | | | 30 | | | 140 |

**Table 3**

PROPERTIES OF ARAMID FIBER FABRIC

| | FT | FS | SW$[g/m^2]$ | WpY $[cm^{-1}]$ | WtY $[cm^{-1}]$ | MT [μm] |
|---|---|---|---|---|---|---|
| A61 | Kevlar-49 22tex | 100%A | 61 | 13.5 | 13.5 | 100 |

**Table 4**
PROPERTIES OF MIXED FIBER FABRICS

| | FT | FS | SW[g/m$^2$] | WpY [cm$^{-1}$] | WtY [cm$^{-1}$] | MT [μm] |
|---|---|---|---|---|---|---|
| M188 | Carbon – Torayca 3K C 200tex<br>Aramid – Kevlar 49 158tex | 50%C<br>50%A | 188 | 5 | 5 | 260 |
| M107 | Carbon – Tenax ® UTS50 12K<br>Aramid – Twaron ® HM3360dtex | 50%C<br>50%A | 108 | 0.5 | 0.5 | 150 |
| M68 | Carbon – Torayca 3300 1K J 67tex<br>Aramid – Kevlar 49 22tex | 50%C<br>50%A | 68 | 6.5 | 6.5 | 110 |

**Table 5**
VALUES OF ELASTIC MODULUS FOR TESTED MATERIALS E[GPa]

| | $E_0$ | | | $E_{30}$ | | | $E_{45}$ | | | $E_{90}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | E | H | C | E | H | C | E | H | C | E | H |
| **CF120** | 22.45 | 37.03 | 20.94 | 4.79 | 5.07 | 4.84 | 3.50 | 3.15 | 3.25 | 19.76 | 37.05 | 12.25 |
| **CF160** | 25.62 | 32.18 | 36.02 | 4.71 | 4.30 | 6.85 | 2.61 | 4.14 | 4.93 | 25.21 | 32.95 | 34.11 |
| **CF240** | 22.58 | 28.38 | 24.85 | 5.83 | 7.34 | 2.73 | 8.42 | 4.82 | 3.49 | 22.61 | 29.81 | 15.57 |
| **TF60** | 8.30 | 22.39 | 10.75 | 4.04 | 2.49 | 5.56 | 4.09 | 5.49 | 4.18 | 9.35 | 20.37 | 11.57 |
| **TF76** | 16.43 | 24.55 | 26.29 | 4.61 | 3.62 | 3.62 | 2.52 | 2.19 | 2.56 | 24.01 | 29.27 | 24.55 |
| **CT160** | 30.49 | 24.10 | 24.01 | 3.87 | 6.41 | 5.17 | 3.06 | 1.42 | 3.39 | 27.64 | 24.54 | 22.99 |
| **CS61** | 19.37 | 21.86 | 20.59 | 3.17 | 4.07 | 3.24 | 2.20 | 1.26 | 2.56 | 20.70 | 24.19 | 17.68 |
| **ST72** | 15.36 | 22.01 | 7.95 | 5.12 | 2.93 | 5.09 | 2.96 | 5.63 | 3.06 | 15.75 | 24.63 | 16.16 |
| **G25** | 6.63 | 8.43 | 8.62 | 4.75 | 5.28 | 3.84 | 4.15 | 2.91 | 3.57 | 4.74 | 9.69 | 5.64 |
| **G108** | 11.08 | 17.35 | 12.37 | 5.01 | 4.73 | 6.17 | 3.99 | 3.72 | 4.84 | 10.47 | 14.35 | 13.42 |
| **G163** | 8.69 | 14.94 | 9.29 | 3.35 | 2.53 | 3.09 | 1.74 | 1.25 | 2.13 | 9.81 | 15.33 | 11.94 |
| **S280** | 8.09 | 15.42 | 8.42 | 2.60 | 4.18 | 3.61 | 3.71 | 2.42 | 2.67 | 10.03 | 12.32 | 10.55 |
| **CVS** | 3.25 | 4.32 | 3.71 | 3.65 | 3.95 | 3.69 | 3.83 | 3.59 | 3.26 | 4.32 | 3.36 | 3.70 |
| **CAVS** | 3.13 | 4.49 | 3.79 | 3.00 | 4.10 | 3.40 | 3.15 | 3.48 | 3.44 | 3.70 | 3.44 | 3.06 |
| **M107** | 18.60 | 18.23 | 15.87 | 4.66 | 5.74 | 5.17 | 3.83 | 3.08 | 3.15 | 13.64 | 14.87 | 15.11 |
| **M68** | 13.04 | 24.70 | 15.36 | 4.49 | 3.39 | 3.42 | 3.68 | 0.48 | 2.62 | 14.68 | 20.70 | 15.03 |
| **A61** | 10.15 | 23.80 | 15.17 | 2.66 | 2.05 | 1.52 | 1.24 | 2.09 | 2.53 | 9.08 | 24.67 | 17.70 |
| **M188 (2)** | 16.32 | 21.87 | 12.42 | 1.91 | 4.16 | 2.79 | 2.06 | 3.32 | 0.96 | 15.46 | 30.93 | 11.14 |
| **M188 (1)** | 21.20 | 29.49 | 20.83 | 1.53 | 4.51 | 2.34 | 1.17 | 3.22 | 1.63 | 17.23 | 26.34 | 18.98 |

In order to ensure a large number of samples, from each fabric and for each epoxy system two single layer fabric reinforced polymer were formed. The samples were formed between two plates of glass covered with polypropylene with the materials dimensions were of 600x600mm, of course the material thickness depends of fabric thickness but for all the materials it was ensured the same pressure during polymerization by uniformly distributing a weight on the top plate of glass. As per manufacturing process, like in the case of wet lay-up method the fabric was imbued with the pre-polymer mixture (the resin-hardener blend) and was placed between the two plates of glass. The require samples were cut out by scissors (with inevitable effects on the samples edges).

The tensile tests were done on an *Instron* testing machine equipped with a 25kN loading cell and they were applied for four directions: along warp direction (0°); at -30° (clockwise) relative to warp direction; at -45° relative to warp direction; and along the weft direction (90°). The orientation of loading was given by the way the sample was cut out from the formed material i.e. the samples for inclined tests were cut out at -30°, and respectively, -45° with respect to warp direction of the fabric as was described in [32].

### *Testing method*

All the tests were done at a loading speed of 5mm/min with an imposed stop condition of a drop of 40% from the loading force. During the tests, based on the use of *BlueHill* software (provided by Instron), length of the sample and the loading force were recorded and on their basis the evaluation for elastic modulus values was computed for ten samples in the case of axial loadings (0° and 90°) and for five samples in the case of inclined loadings (-30° and -45°).

## Results and discussions

Generally, the failure of the ply takes place along of one horizontal thread of weft or of warp (depending on the loading direction in the case of axial loading) and is random for the inclined loadings. That is why in the following the presentation will contain separate presentations of the results with respect to the angle of loading direction relative to the main direction of the fabric namely the warp direction. It is to be said before starting the results that the fabrics were placed into three classes (to avoid crowded graphic representations). In the first class all the carbon fabric were placed (eight materials) their denomination being CF (carbon fabric) followed by the specific density, in the same class were placed some special fabrics made of spread carbon filaments their denomination having some connections with their commercial names (two digits) followed also by the specific density. The next class is the glass fiber fabrics and the materials are denoted with G followed by their specific density. In this class two other materials are included namely CAVS and CVS these are two materials obtained from large stripes of carbon fiber mats and aramid fiber mats but they are stabilized together by a very thin mat of glass fibers on one face of the fabric. The last class contains the only pure aramid fiber fabric A61 and three of the mixed fabrics obtained by alternation of carbon fibers and aramid fibers threads both un warp and the weft of the fabric. A special case in this class is the M188 fabric that is obtained both from carbon fiber threads and aramid fibers threads (as well as all M denoted materials) but on the warp the sequence is two threads of carbon fibers one thread of aramid fibers while in the weft the sequence is one carbon fibers thread and two threads of aramid fibers (at the end, the presence of each type of fiber is 50%). That is why for M188 material two tests were performed and their results should by symmetrical (one along warp direction denoted (1) and one along weft direction denoted (2) and, respectively the inclined load tests).

It is realistic to consider that for all the fabrics the technological requirements impose a pre-tension of warp elements (untwisted threads or stripes) and at the end these pre-tensions to have effects over the fabric reinforced plies responses at tensile loading along warp or along weft direction. Another technologic aspect (regarding the fabric realization) is connected to the way in which the fabric producer is deposing the very thin of polymer (absent in the technical sheet of the product) is deposed to maintain the fabric integrity and in this manner is keeping the pre-tension along the warp. Prior to materials formation some adhesion tests have been performed for each pair polymer-fabric to avoid some situations of lack of interphase polymer-matrix.

The results for the axial loading of ply samples along the warp direction are presented in fig. 1. The lowest response is the one corresponding to the TF60 fabric a very thin fabric that probably fails because of the matrix fracture while the best responses correspond to the CF240 and CT160 fabrics (the first is normal the second is with spread threads) first for Epiphen and HT epoxy resins and the second for C epoxy resin. It is easily to notice that for the traditional fabrics (CF) the response is proportional to the specific density (i.e. with the number of filaments of carbon on the loading direction). What is to be noticed is that the response of CT160 with respect to the CF160 response. These are two fabrics are containing (theoretically speaking) the same amount of carbon filaments along the loading direction and along the transverse direction and the different response could be explained by the continuity (discontinuity) of the polymer-fibers interphase which is of better quality in the case of spread threads (CT160). Another remarkable fact is that in the case of brittle resins (epoxy resin C and epoxy resin HT) the aspect of the loading curves is different from the case of epoxy resin Epiphen excepting the case of ST72. The loading curves are showing a very short zone of elastic response and after that all the curves are showing horizontal segments (increase of $\Delta l$ at a constant loading) and the last segment is elastic up until the break. In the case of epoxy resin Epiphen (less brittle than the other two) the response is elastic from the very beginning (excepting the ST72, mentioned above). The same behavior is observable for the axial loading on the weft direction fig. 2. In this case some differences can be observed regarding the maxim values of the loading force (reduced comparing to the case of warp direction loading) meaning that the pre-tension hypothesis is right. Regarding the second class of fabrics the results for axial loading along warp direction and along weft direction are given in fig. 3. and, respectively, fig. 4. All the responses are lower than the correspondent cases of carbon fiber tested materials with an emphasis on CVS and CAVS (special type of fabrics) and G25 (the thinner material used to form plies). In these three cases the responses corresponding both warp and weft along loadings are poor (lower value of the slope – elastic constant). In the other three cases the response seems to be again proportional to the amount of glass filaments along the loading direction.

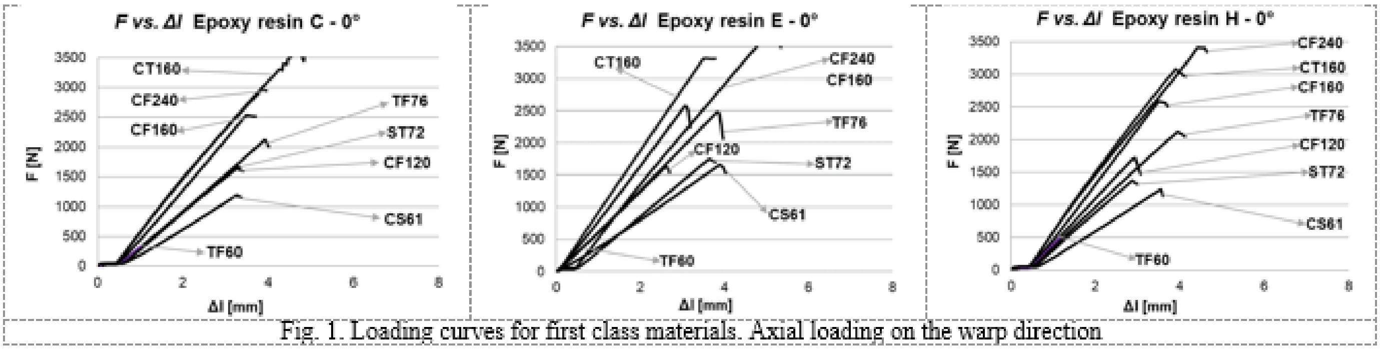

Fig. 1. Loading curves for first class materials. Axial loading on the warp direction

In the case of second class materials it is very clear that the CAVS and CVS materials are not suitable to be used as reinforced materials but they could be used as final layers (because their general aspect). For the second class materials it seems that the pre-tension of the warp is important for all glass fiber fabric reinforced materials (higher responses comparing with the weft direction loaded materials). Another interesting aspect regards the fact that, basically, the epoxy resin C and epoxy resin HT matrix materials are responding in the same manner. Both the last two mentioned polymers are with relative short pot time and that could lead to a weaker response comparing with epoxy resin Epiphen due, perhaps, to the lower quality of interphase with the glass fiber.

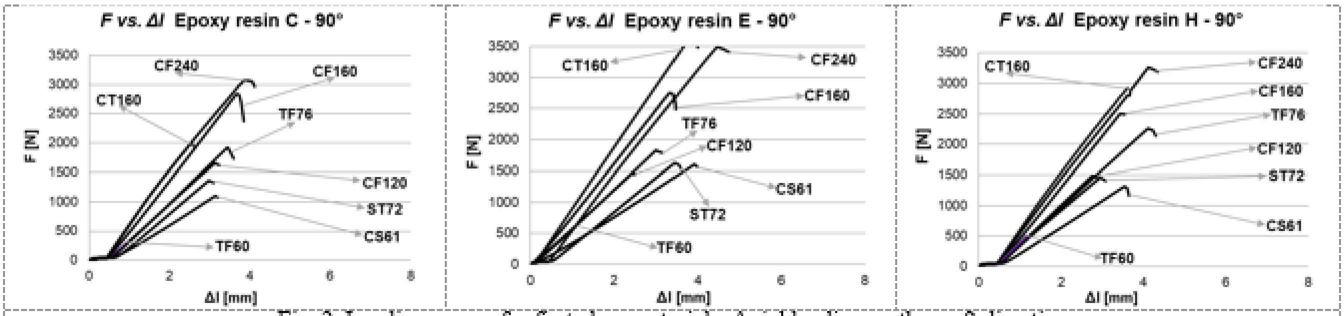

Fig. 2. Loading curves for first class materials. Axial loading on the weft direction

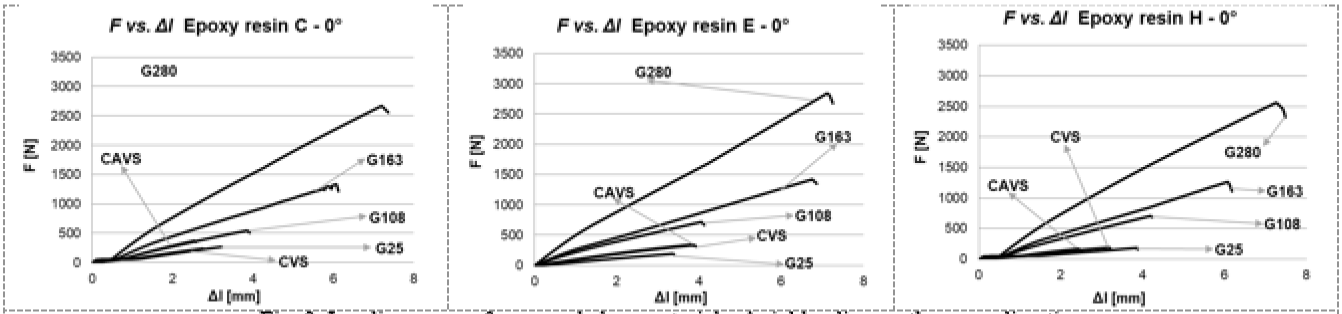

Fig. 3. Loading curves for second class materials. Axial loading on the warp direction

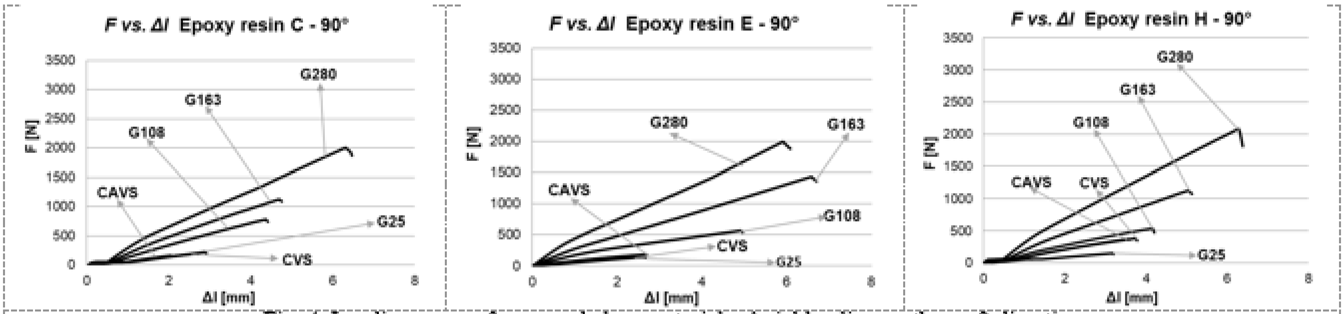

Fig. 4. Loading curves for second class materials. Axial loading on the weft direction

The third class of materials includes one aramid fiber fabric and three carbon fibers – aramid fibers fabric. The results of axial tensile tests for the materials in this class are presented in fig. 5. and fig. 6. and, as it was mentioned before, there are two curves for the M188 materials because in this case the axial loading on the warp direction is different from the axial loading on the weft direction due to the different content of carbon threads and aramid threads. Unlike the other thin materials, in this case the A61 reinforced material is giving better responses especially with the epoxy resin C and epoxy resin HT (on both loading directions). As well as in the case of carbon fiber reinforced materials, both in the cases of second and third classes materials the loading curves for the brittle resins matrix are showing the same aspect with the horizontal intermediary segment. That could mean that firstly the materials responses is an elastic one corresponding to composite behavior then the matrix fails (at micro level) and, finally just the fibers are loaded.

As per inclined loadings, for the thick carbon fiber reinforced materials – fig. 7. and fig. 8. – the responses are mainly flow like but the flow amplitude varies with the loading angle (is larger at 45°) and with the fiber content. The irregular undulations of the final part of CF240 (for both inclined tests) signify the fact that failure of threads is progressive because, perhaps, the resin is not penetrating to the middle of the thread and is letting some carbon filaments out of matrix. At this type of loading the thin materials TS60, CS61 the loading curve is short and linear denoting an elastic response up until the break.

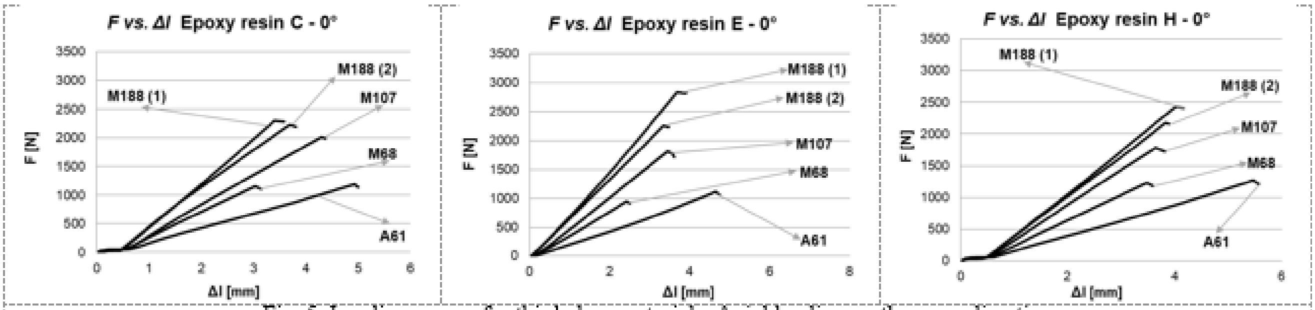

Fig. 5. Loading curves for third class materials. Axial loading on the warp direction

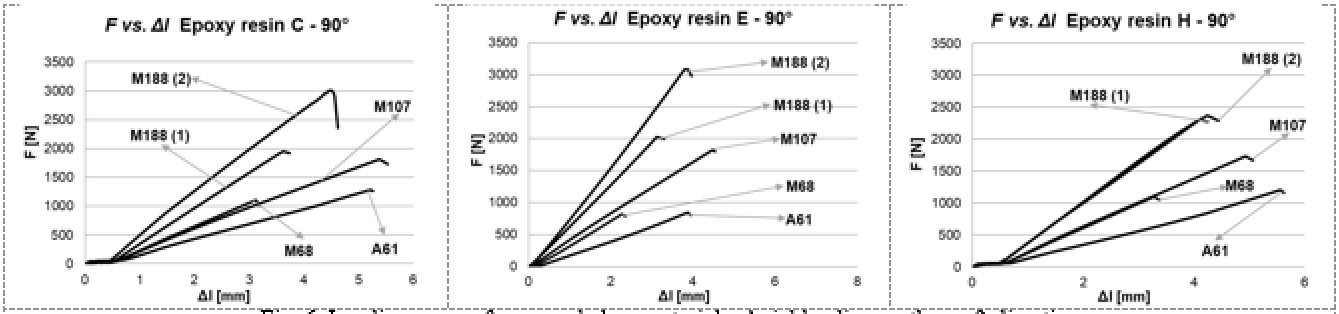

Fig. 6. Loading curves for second class materials. Axial loading on the weft direction

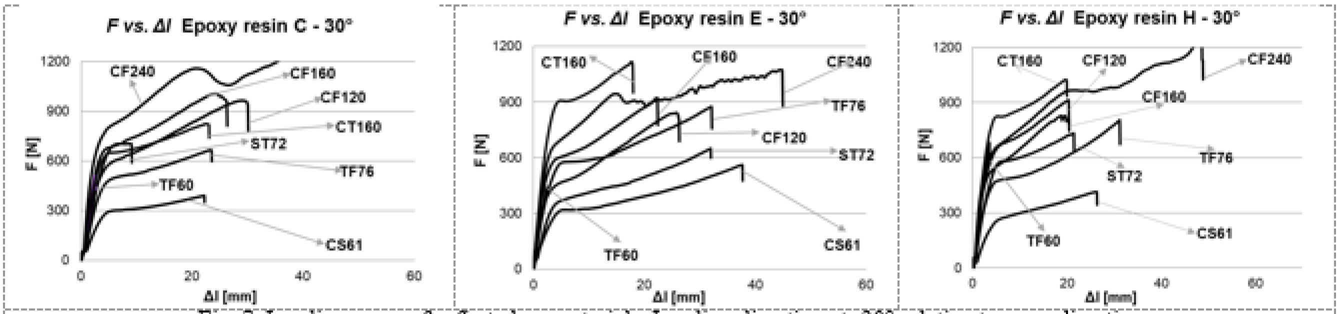

Fig. 7. Loading curves for first class materials. Loading direction at -30° relative to warp direction

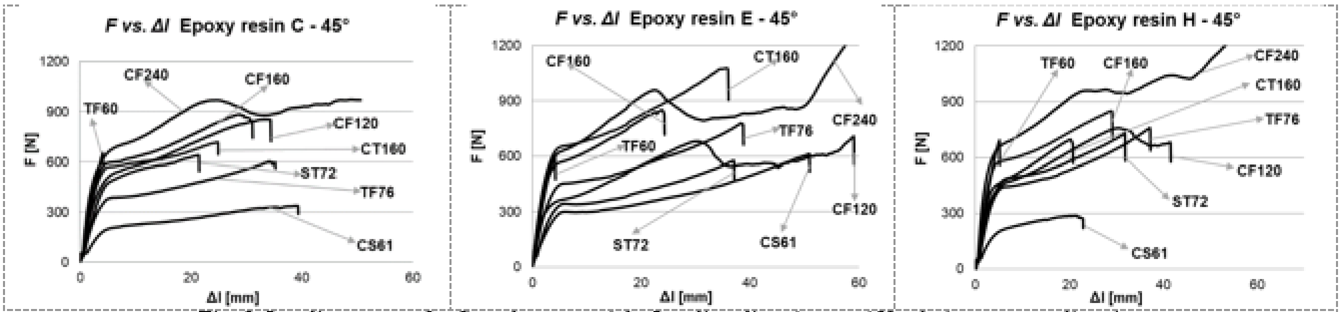

Fig. 8. Loading curves for first class materials. Loading direction at -45° relative to warp direction

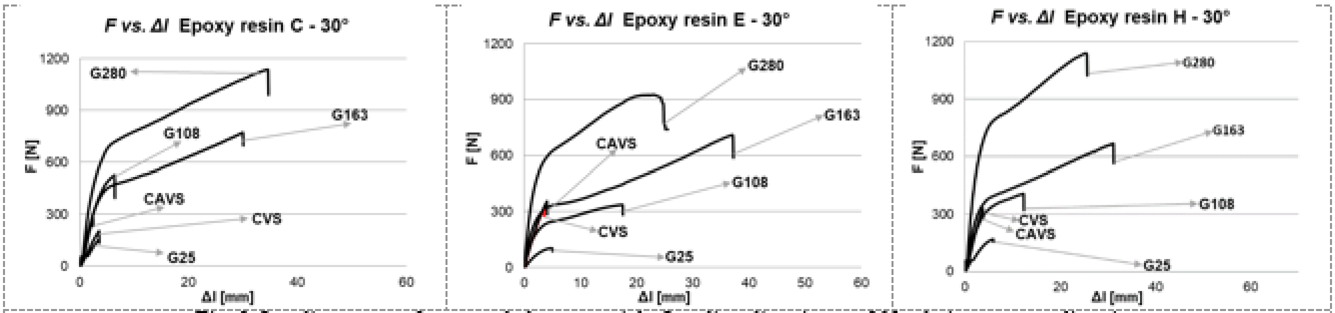

Fig. 9. Loading curves for second class materials. Loading direction at -30° relative to warp direction

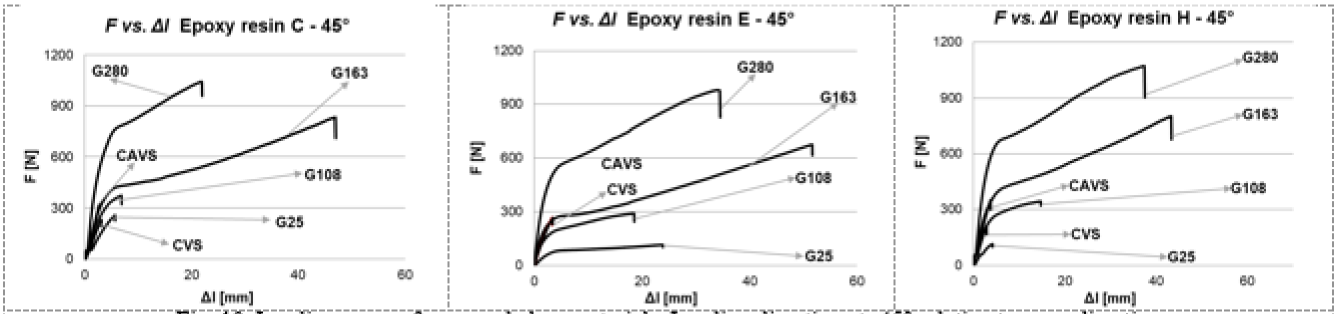

Fig. 10. Loading curves for second class materials. Loading direction at -45° relative to warp direction

In the case of second class materials – fig. 9. and fig. 10. again the responses seem to be dependent on the amount of the fibers and in the cases of CAVS and CVS the material response is poor, as well as the case of G25. The flow of tested materials are less larger than the case of carbon fiber materials but also it is noticeable the fact that G280 does not present any undulation at the flowing part meaning that, in this case, the quality of the interphase is higher.

The third class of materials results are presented in fig. 11. and fig. 12. The M188 farbic reinforced materials have similar responses for both loadings (along warp direction and along weft direction) for the epoxy resin Epiphen matrix but completely different responses for the other two polymer matrix (epoxy resin C and epoxy resin HT). Again the flow seems to depend on the fiber content but the slopes of the curves on the flowing domain is lower than the other two cases materials.

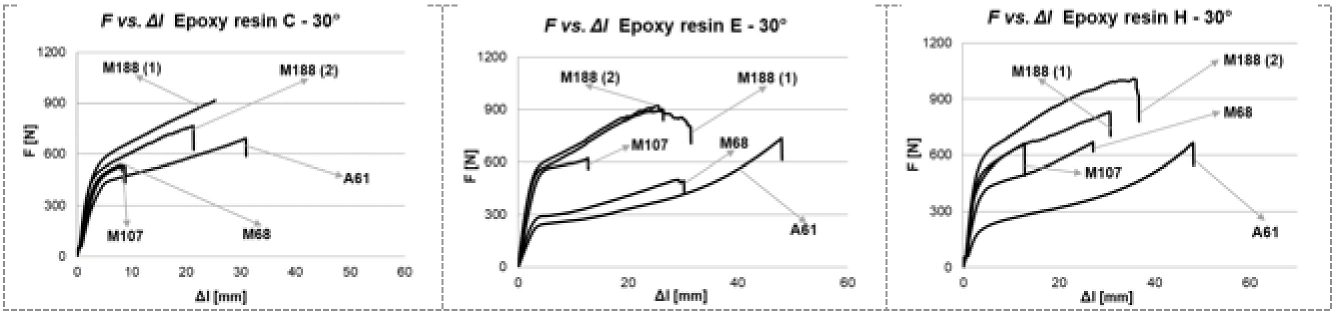

Fig. 11. Loading curves for third class materials. Loading direction at -30° relative to warp direction

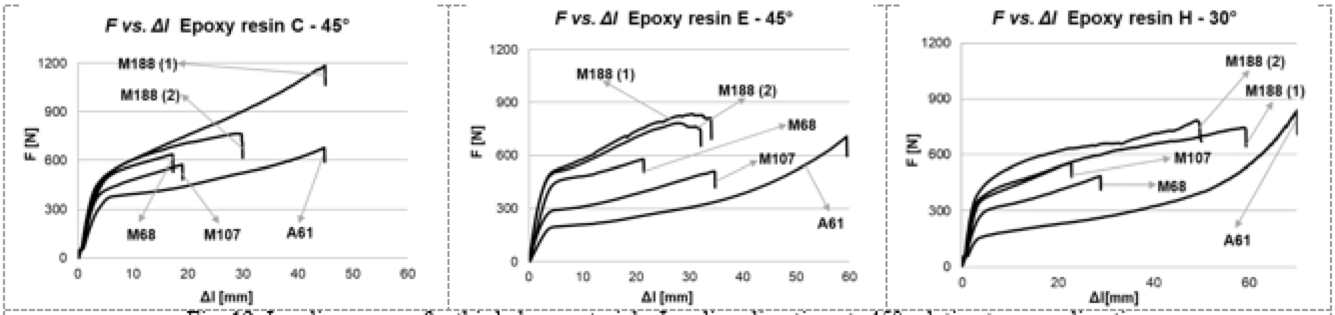

Fig. 12. Loading curves for third class materials. Loading direction at -45° relative to warp direction

For off-axis loadings (both at 30° and 45° relative to the warp direction) the elastic response of materials is short and the samples are failing soon after especially in the case of light fabrics reinforcements. In the case of high specific weight fabrics it was observed a tendency to curve of the samples and the deformation is permanent. The same observation regards also the axial loaded samples that not break during the tests and some of failed samples.

Of course the above analysis took into account just some qualitative details. More quantitative details could be get from the table 5. containing the Young modulus values for all tested materials. The $\sigma$-$\varepsilon$ curves for the presented materials are respecting the same profile with the loading curves but, of course, the effort values are higher because the material evaluation which is depending on transverse area of each material. Even in this case it has to be said that the elastic modulus values are determined for the entire curve (somehow a linear elastic response) even if each curve present firstly an pure elastic response followed by the flow.

## Conclusions

Eighteen types of fabrics were used to reinforce three epoxy resins in order to analyze their response at tensile tests. This is, in our opinion, the widest attempt in analyzing the failure of fabric reinforced plies and the most common fabrics were used. All the samples were prepared in the same way and this is why we consider that our results could be useful even for other researchers and especially for the composites properties designers.

The initial adhesion tests showed that all the fabrics offer a good behavior to each of the three epoxy resins. All the fabrics manufacturers are guarantying best results when the fabrics are used with epoxy resins without accepting to give information about the greasy film that covers each fabric. Without knowing such details it is difficult to understand and to explain all the phenomena that take place during the tests. Anyway, the obtained results allow the conclusion that the relative short pot-time resins (epoxy resin C and epoxy resin HT) are giving responses of fiber-like type due, in our opinion, to the fact that the matrix fails at the very beginning of the test. Two of the used fabrics have the same specific weight and for them it is obvious that for this type of resin the response is better when the fiber threads are spread (CF160 and CT160) showing that in the case of classic fabric the matrix had not penetrated the entire thread letting out of composite the middle region of the thread.

Unlike the other two epoxy resins, the Epiphen epoxy resin shows different responses of composite-like type, especially during the initial segment of elastic response signalizing the fact that the matrix is more connected to the fibers – the long pot-time allows the pre-polymer to penetrate inside the thick threads.

All the axial loaded samples (both on the warp direction and on the weft direction) are failing on a perpendicular direction on the loading direction, generally between two adjacent threads (of weft when the loading is applied on warp direction or of warp when the loading is applied on the weft direction) and for thicker materials that can be observed smashed fibers (the ones from the inside of threads). The failure mechanism seems to be generated by a guillotine effect produced by the two parts resulting from the matrix when this fails along a thread perpendicular on the loading direction). It is interesting the fact that even the aramid fibers (known for their high shearing modulus) are failing in the same mode.

For the inclined loadings at 30° and 45° relative to the warp direction large flowing segments are visible and at a first view it seems that the length of the flowing segment depends on the number of fibers (threads dimensions) and with the length of the fibers. A more careful analysis shows that the longest flowing segments correspond to the 45° because all the fibers have the same length of $2\sqrt{2}$ cm while in the case of 30° 50% of the fibers have a length of $2\sqrt{3}$ cm and 50% have a length of 1 cm.

For the unbroken samples it was noticed the fact that they are deformed – twisted around loading direction, curved such as the loading direction becomes a cylinder generator – and these deformations are permanent denoting matrix and fibers reorganizations due to visco-plastic response of each type of reinforced matrix.

Crossing analyze of the results shows that mixed fabrics (made of carbon fibers and aramid fibers) do not represent a reinforcement solution due to the different interphase fiber-matrix realized with each type of fiber and perhaps it is better to use mono-fiber fabrics even if two layers will replace one.

The axial loadings along the warp direction showed that the hypothesis of pre-tension is reasonable due to the obtained results showing that, generally, the values of elastic modulus along warp direction is higher than the value of the same parameter determined by loading on the weft direction.

The test of ply theory, regarding the elastic constants in an arbitrary system of coordinates, failed because it is almost impossible to determine the Poisson coefficients for such samples. An image analysis could solve this problem but it is quite difficult to video monitor such samples because the image is disturbed by the geometrical model of the fabric. An analysis regarding the results obtained for the inclined loadings showed that it is possible to convert the value of elastic modulus at 30° loading into the value of elastic modulus at 45° loading simply reasoning as in the case of vector components $E_{45}=E_{30}(2/3)^{1/2}$ and this leads to a good approximation.

Taking into account the failure mode of axial loaded samples and the failure mode of inclined loaded samples it is possible to get more relevant data studying bi-laminar systems with the two plies reinforced with the same fabric or with different fabrics. In this case during the tensile tests one ply will be axially loaded while the other one will be loaded on an arbitrary direction (with respect to the warp or weft of the fabric direction). The loading transfer between matrix and reinforcement will be ensured by the uniform distribution of polymer because in this case due to the wet lay-up method the both sheets of reinforcement will be kept together inside a polymer block, unlike the case of bonding together two prepreg plies. Such tests could offer also valuable information about nesting effect (polymer pockets) over the general behavior of fabric reinforced laminates.

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