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Research Article

PRELIMINARY STUDIES OF RIVETED JOINTS AT FEED FORCE

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ABSTRACT
The aim of the study was to determine the feasibility of riveted joints in composites materials. Static tensile test method was used. In the test one type of glass fabric was used (Interglas 92140) from which two types of composite samples were prepared. In each sample the same type of fiber with the same fiber orientation – 3 layers - was used. The samples had dimensions of 100×100 mm and thickness of approximately 1 mm. The composite probes were located in a metal frame with a screw connection which was made of screws with nominal thread pitch M5. Screws were tightened with constant torque. It was to provide an axial force to the sample during the tensile test. The frame was placed between cross-bars of tensile machine INSTRON 8516. The samples were stretched at a speed of 0.05 mm/s at a distance up to 15 mm. During the tensile test displacement of the samples and pull force were registered. Depending on the fibre orientations and the value of feed force, damage models were described. On the basis of the results the possibility of usage of aluminium rivet nuts connections in composite materials was determined.

Keywords: laminates; damage mechanics; mechanical testing; joints/joining.

INTRODUCTION

Composite materials, especially reinforced in glass fibres, are widely used in structural applications, for their well-known favourable strength-to-weight ratio. Due to their heterogeneous nature and depending on the manufacturing process, composites present, however, a variety of defects or imperfections which can lead to different failure modes. Stiffness and strength of composites are directly related to the presence of such defects and the prediction of the residual fatigue life still remains an open issue. Nevertheless, for structural composite parts of aeronautical, naval and transport industries, verification of fatigue strength and life prediction are fundamental for design and dimensioning [1].

Joining parts made from composites is very popular in industry. Generally, there are two types of joints in composite structures: mechanical and adhesively bonded ones. Mechanical joints have several advantages and disadvantages compared to adhesively bonded joints in assembling composite parts. For instance, mechanical joining requires rivets or/and bolts through holes, which results in stress concentrations, ultimately leading to possible failures while the adhesive joints do not require holes and they distribute the load over a larger area than mechanical joints [2, 3].

This study focused on fiberglass composites in the context of riveted joints. It analyses the impact of the low additional feed force of damage forces [4]. The research in the paper refers to other similar studies which focused on the applicability of a riveted joint [5, 6].

EXPERIMENT DETAILS

The specimens

Test samples were made of one type of glass fabric. To create samples of perpendicular fibers symmetrical Interglas 92140 fabric was used.

The basic weight of fabric was 390 [g/m^2]. The composite laminates were fabricated by the hand lay-up technique in an autoclave according to the manufacturer`s recommended curing procedure [7, 8]. Two series of samples, differing in fiber orientation, were made ("×" $[-45_2/45]_S$ and "+" $[0_2/90]_S$).

In the process of lamination, the adhesive epoxy resin Epidian 53 was combined with Z-1 hardener in a ratio (10:1). The heating process of the samples was performed in order to improve the mechanical properties. Gelling process composites were made under pressure. The aftercure process according to the manufacturer lasted 8 hours at 60 °C. In each sample the same type of fiber with the same fiber orientation – 3 layers was used. Measured volume fiber ratio was established at about 35%.

The samples had dimensions of 100×100 mm (Fig. 1) and thickness of approximately 1 mm. Holes of diameter ϕ6 mm were drilled in the middle of the test area and a metal pin was placed there. At the edges of the sample 11 holes were made. The holes were drilled with drill bits for composites treatment. The test area had dimensions of 60×60 mm.

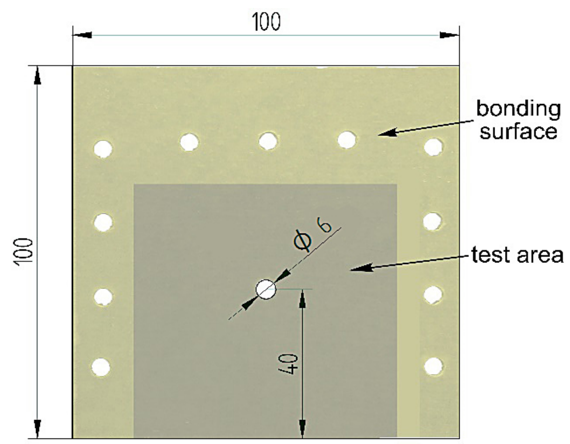


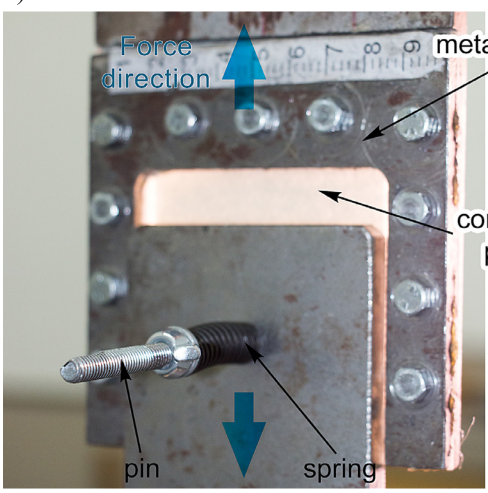
Fig. 1. Geometry parameters of the sample

The samples were placed in a metal frame (see Fig. 2a). Its aim was to provide an axial force to the sample during the tensile test. The sample was placed in a frame with a screw-glued connection which was made of screws with nominal thread pitch M5 and two-component epoxy resin. The screws were tightened with constant torque. Screws as well as glue provided a uniform feed force on the whole contact area of the frame with the sample.

During the test a pin was used. This is an Allen`s screw M6 with a total length of 90 mm. It was made for a metric thread of total length of 60 mm. It is used to compress the spring and produce the appropriate fixed feed force. The feed force induced by compression of the spring with a butterfly screw on the appropriate fixed length. A foil extensometer of dimensions 2×3 mm and a thickness of 60 microns (Fig. 2b) was glued on the pin.

The extensometer was mounted on a flat surface at a distance of 65 mm from the end of the pin between its threaded part and the head. In the middle of the pin there is ϕ1 mm hole through which the cables were conducted. Its aim was to measure the active feed force acting during the test. Feed force came from cylindrical springs. Characteristics of the springs was linear. During the test 2 springs and 5 different fixed feed force values were applied. The following section compares the value of the maximum and minimum values of tensile composite sample.

a)



b)

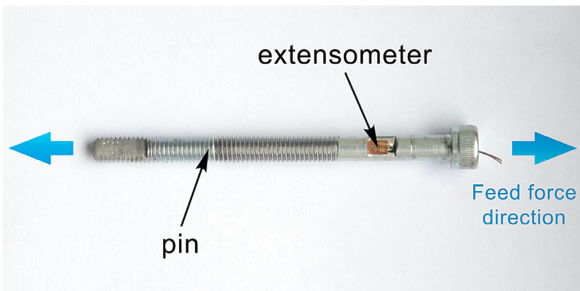


Fig. 2. a) set-up of test, b) pin with extensometer

Carrying out the experiment

The aim of the experiment was to conduct a series of tests on the tensile machine INSTRON 8516 with metal pin. The samples were stretched at a speed of 0.05 mm/s at a distance up to 15 mm. During the tensile test displacement of the connection and pull force were registered. The feed force values were also recorded by the a foil extensometer. It measure active feed force head displacement as a function of the tensile machine.

The test was divided into three parts. In the first part the samples were tested with an oblique arrangement of the fibers (“×” $[-45_2/45]_S$). In the second part the samples with simple fiber orientation (“+” $[0_2/90]_S$) were tested. To compare the results, the tested samples had the same dimensions and were made of aluminum. Composite samples were tested: 18 oblique samples and 16 simple ones. There were used 5 different constant feed forces coming from two helical springs. For each constant force 3 identical samples with the same arrangement of the fibers were examined. The results of the forces as a function of position are average values. Feed force applied during the tests wasproduced on the surface of the screw head of approximately 35 mm^2.

Forces analisis

The following graphs show the force versus the displacement of the testing machine head (Fig. 3a and Fig. 4a). Generally, plots of force against displacement can be divided into a few parts:

- fast linear growth of the force,
- the maximum,
- stabilization of the force at a constant value.

Other graphs show clamping force of displacement of the head (Fig. 3b and Fig. 4b). In addition, using 4 different feed forces, compressing the spring by an equal distance of 5 mm. Graphs clamping force from the head position are increasing and stabilizing at a constant value. All graphs are shown due to fibers orientation.

For the oblique fibers “×” maximum value of the force in function of the position varies from 1.29 to 1.38 kN (approximately 1.35 kN). The maximum values occur at the head position of 1.5 to 2.5 mm. Having achieved maximum, strength stabilizes at a constant level of approx. 0.8 kN. This represents 60% of the maximum value.

For the simple fibers “+” maximum value of the force in function of the position varies from 1.40 to 1.49 kN (approximately 1.45 kN). The maximum values occur at the head rrposition of 2 to 3 mm. Having achieved maximum feed force stabilizes at a constant level of approx. 0.9 kN. This represents 62% of the maximum value. The difference between the maximum average feed force values the forces between a system with a simple orientation of the fibers “+” and between the oblique arrangement “×” is approx. 100 N.

For the oblique fibers “×” constant spring pressure results in permanent differences of maximum feed force. The maximum feed force in the

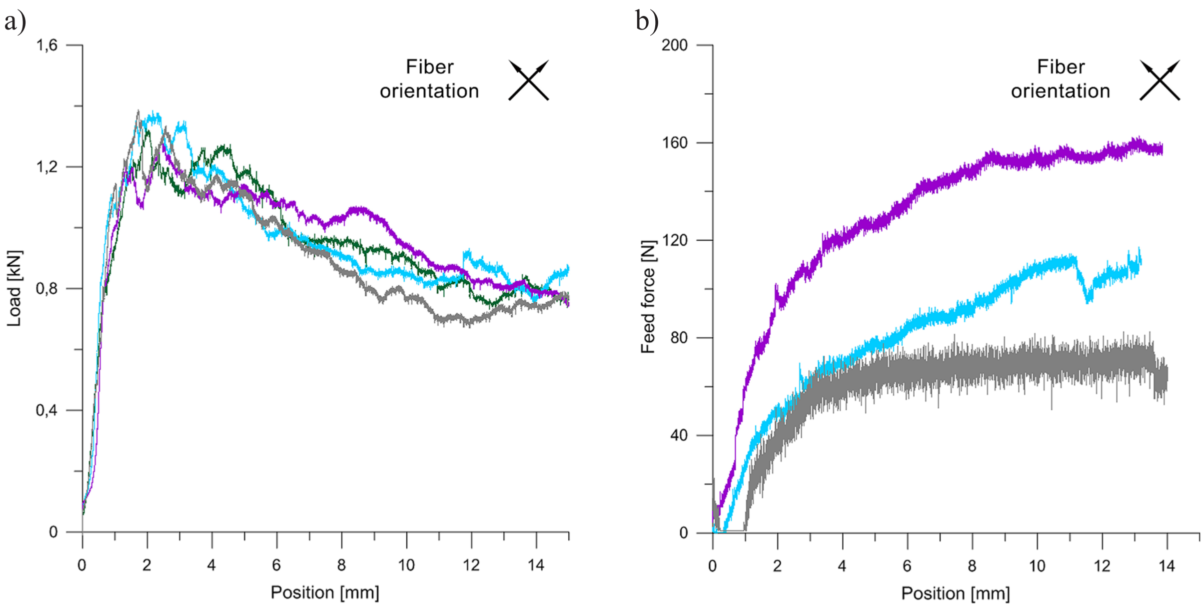


Fig. 3. Force vs. position for oblique arrangement fiber orientation samples “×” a) for pull force b) for feed force change

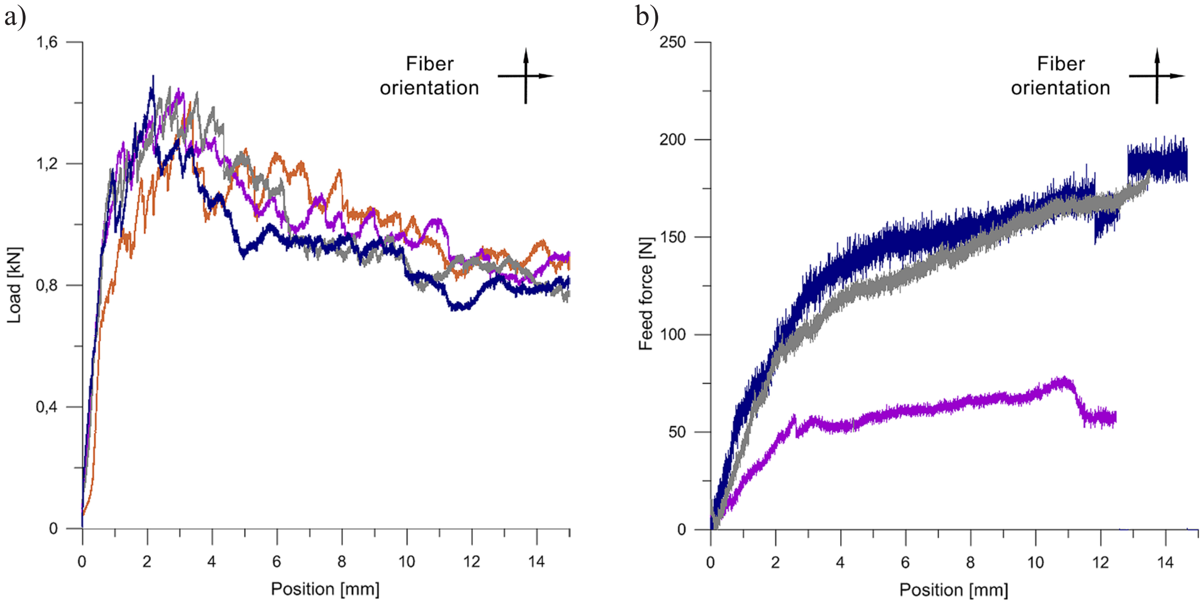


Fig. 4. Force vs. position for simple fiber orientation samples "+" a) for pull force b) for feed force change

arrangement of the fibers was 160 N. In a simple fiber system "+" solids despite the compression of the spring, the value of which is linear, there were different values of maximum forces. One of them, despite the expectations is about 90% higher. In general, the maximum feed force obtained here is 190 N. It is about 26% higher in samples with an angled arrangement of the fibers. The nature of the feed force curves as a function of position is growing and tending to a constant value. The curve has a number of collapses due to the breakage of individual fibers and the collection of the damaged material directly below the pin.

Failure analisis

In the available literature four types of damage models in composite materials can be identified [9]. In the conducted tests, there was no destruction of the composite probes (Fig. 5a and Fig. 5b). Destruction during the test with high probability concerned only pin`s area. The samples were stretched to a length of 15 mm.

From the arrangement and simple fiber orientation bearing type damage model may be observed. The damage appears locally in the specimen in a small distance from the hole only. Single fibers broken by the pin and pulled out of the composite are visible in the back view. The small amount of damaged fiberglass is visible around the pin. Fiber orientation did not affect either the nature of the destruction of the damage character in composite samples.

CONCLUSIONS

The performed studies allow to draw several conclusions:

1. At low pressure forces, the nature of the force curves as a function of head position is similar. There are slight differences in the forces which are in a manner dependent on a small spring pressure. Comparing the two types of fiber orientation, similar fibers have higher strength. The difference is negligible.
2. During the analysis, the feed force value at the head position function was compared. These values were obtained using a strain gauge. Higher values with the same spring compression values were obtained for the straight fibers. Feed force differences between fibers orientation are low.
3. One model of damage occurring in the composite samples was defined. Damage is dependent on the feed force, but it does not modify this model.
4. When conducting future research one should take into account the high feed force and their impact on the strength as a function of head position and models of damage in composite samples.
5. Real research in the future will be supported by FEM analysis, which will allow to define models of riveted joints in composite materials.

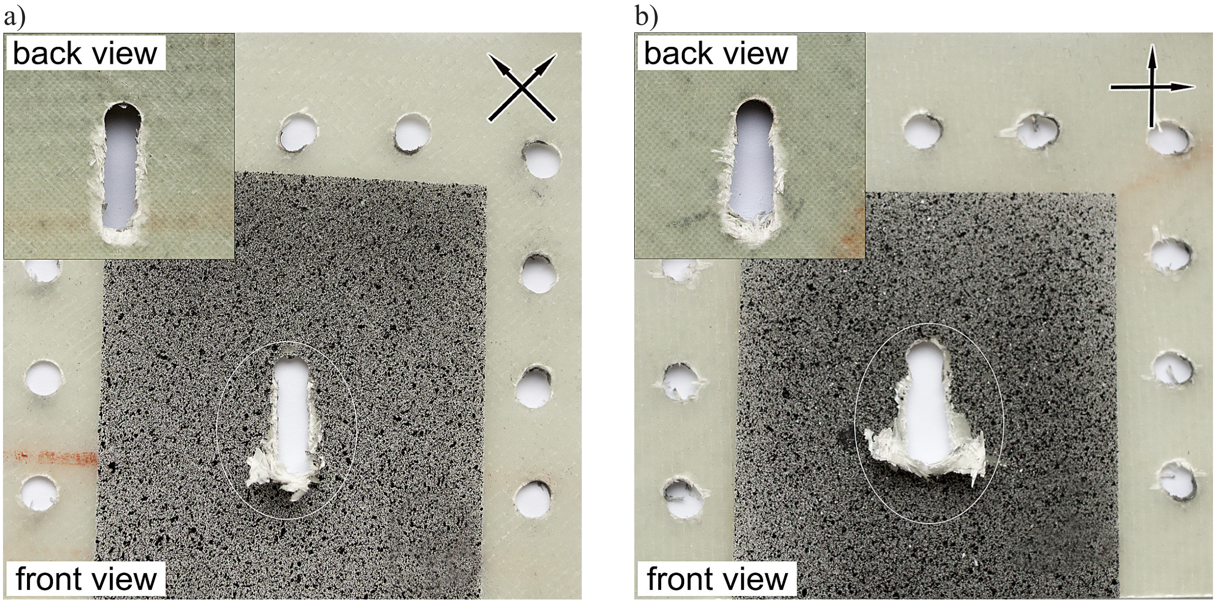


Fig. 5. Damage of specimens
a) arrangement fiber orientation "×" b) simple fiber orientation "+"

REFERENCES

1. Colombo C., Vergani L.: Influence of delamination on fatigue properties of a fibreglass composite. Composite Structures. 1; 107, 2014, 325–333.
2. Deng J.H., Tang C., Fu M.W., Zhan Y.R.: Effect of discharge voltage on the deformation of Ti Grade 1 rivet in electromagnetic riveting. Materials Science and Engineering A, 591, 2014, 26–32.
3. Gibson R.F.: Principles of composite material mechanics. 3rd ed. Boca Raton: CRC Press: Taylor & Francis Group, 2012.
4. Cao Z., Cardew-Hall M.: Interference-fit riveting technique in fiber composite laminates. Aerospace Science and Technology, 5; 10(4), 2006, 327–330.
5. Ataş A, Soutis C.: Subcritical damage mechanisms of bolted joints in CFRP composite laminates. Composites Part B: Engineering, 11; 54, 2013, 20–27.
6. Klasztorny M, Nycz D.: Modelling and numerical study of blind rivet nut/bolt joints of composite shell segments. Shell Structures: Theory and Applications, Proceedings of the 10th SSTA 2013 Conference; 2014.
7. Benzarti K, Chataigner S, Quiertant M, Marty C, Aubagnac C.: Accelerated ageing behaviour of the adhesive bond between concrete specimens and CFRP overlays. Constr Build Mater. 2, 25(2), 2011, 523–538.
8. Marques AT. 7 - Fibrous materials reinforced composites production techniques. In: Fangueiro R, editor. Fibrous and Composite Materials for Civil Engineering Applications. Woodhead Publishing, 2011, 191–215.
9. Fazzolari F.A.: A refined dynamic stiffness element for free vibration analysis of cross-ply laminated composite cylindrical and spherical shallow shells. Composites Part B: Engineering, 6, 62, 2014, 143–158.