Mechanical Properties of Groove Squared Profiles Made of Carbon Composite Material with Cured Epoxy in Shape Form and by Vacuum

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Abstract. This article describes mechanical differences in behaviour of groove squared profiles, which are made of carbon composite material. Specimens were made by winding of prepreg carbon fibre filament around Rexroth profile. Afterward was epoxy of first specimen cured in shape form and the epoxy of second specimen was cured in vacuum chamber. This way was made two difference internal structures with different mechanical properties. Their properties were tested by bend test. Bend test lasted till first hearable cracking and not until complete breakage of material. By this way, we describe carbon composite material by properties before even small breakages in internal structure. Measurement data can be used for comparisons with simulation FEM analysis. This is especially important in developing new products. This work was done at University of Žilina Faculty of Mechanical engineering, Department of Design and Mechanical Elements. The tests were performed on tensile test machine LabTest 5.20ST type: KAP-S.

Keywords: Carbon · Mechanical Properties · Rectangular Shell Composite · Form Shape · Vacuum Shape

1 Introduction

The usage field of carbon fiber material is day by day wider. In the study was design specific inner structure of carbon squared profile. The reason why we need specific inner structure is that we can boost every part made of carbon fiber for specific usage and by the inner structure of different layers of different angle direction fibers we can get results with better strength properties. Before this study of groove squared profile we made study of squared profiles without slots and we get good results which we want to improve by adding the groove/slot into the shape of rectangular profile. This study is made for future purpose of all-terrain light weight vehicle; which frame will consist of these squared profiles. The results of the measurements are also designed for comparison with FEM analysis in different SW applications. Comparison of calculations and measurements are important for the development of new products [1, 2, 7, 9], and parts thereof from composite materials [3, 8, 14]. Problem of these profile is in their joining together and

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also to join other parts to them which aren't made of carbon. For this reason, is in this paper described study of three-point bend test not only of carbon profile alone, but with filled ends of profile with aluminum Rexroth profiles, which will serve for future joining of our carbon profiles together. This article describes bend test of carbon profile with pressed Rexroth profiles to both ends. It's important to mention that bend test lasted not until whole breakage of material. Test lasted till first hearable breakage of single filament because we know the strength properties of material from datasheet.

By this way, we describe kind of user-friendly properties for our vehicle to make it comfortable without any random cracking in inner structure of profiles without total deformation of material [4–6].

2 Materials and Methods

For purpose of study was used tensile test machine LabTest 5.20ST type: KAP-S. This laboratory device allows us to make bend test. The bend test was made on groove squared profiles made of carbon fibre roving. For study intentions were selected 3K carbon filament. It means, that filament consists from 3 thousand nanofibers [4, 10–13]. Both specimens are groove squared profile made by winding the filament on Rexroth profile 30 x 30. On the profile was wounded 5 layers by different angle direction. From bottom layer to top surface the layers are wound up at an angles 25°, 75°, 33°, and 45°. Wall thickness is 1 mm so every layer measures 0.2 mm (see Fig. 1).

The differences between specimens was in their post process of hardening the epoxy [10, 13, 14]. First specimen has epoxy hardened in shape form and the form had special shape that turn the planar profile to groove squared profile with 2 slots in opposite side along the whole length of profile (see Fig. 2). These slots will have positive impact to strength of profile. Then was profile in form put into the furnace with 60 °C for better and steadier hardening of epoxy.

Second specimen was the same layers of angle direction but difference was in the post process of hardening the epoxy not in the furnace but in the vacuum chamber without shape form. The shape of planar profile was changed by causing the vacuum and form the 4 slots along the profile (see Fig. 3). The bend test was made on both specimens under

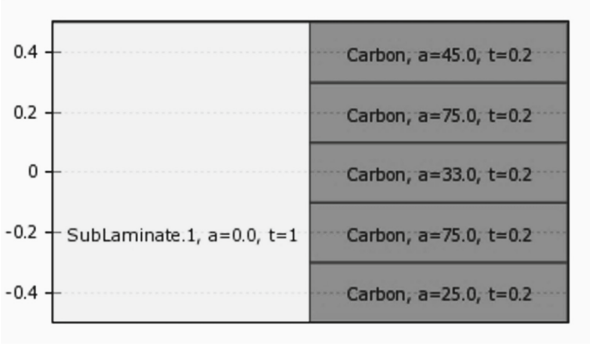

Fig. 1. Layer layout of testing profiles.

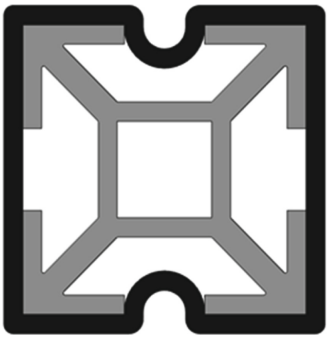

Fig. 2. Form shaped profile.

Fig. 3. Vacuum shaped profile.

the same condition. The dimensions of carbon profiles are 32 x 32 mm because Rexroth profile put in them has 30 x 30 mm. Length of carbon profiles was 250 mm and to both ends were pressed Rexroth profile of 125 mm length into the depth of 65 mm to carbon profile. This way was made the final specimen for bend test. Three-point bend was made around 2 blocks of 40 × 40 × 60 mm in the distance of 300 mm and imprint block had edge length of 15 mm (see Fig. 4). Imprint block serves also as loading element. The bending force was 100 N per 1 s.

3 Results and Discussing

At this chapter, going to be described typical test of vacuum shaped and form shaped carbon profiles (see Fig. 5). The composite profiles are designed as carbon profiles with filled ends with Rexroth profiles during three-point bend test. On every specimen was made four bend tests. That means we rotate the profile about 90° and repeat the bend test. Specimen is divided on four position where first position is base position, in second position is profile rotate by 90°, third position next 90° and fourth position is again rotate by 90° till we test every side of square profile. By this way, we get values of combined bend load and assumption that with every past bend test we get lower values of strength

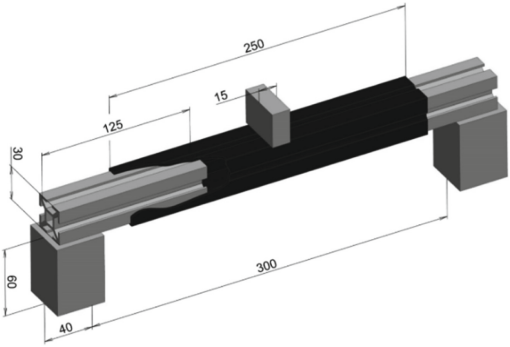

Fig. 4. Dimension of bend test.

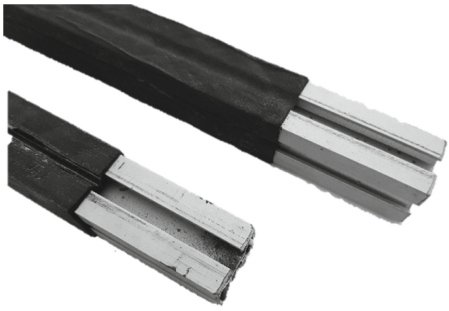

Fig. 5. Both test specimens – vacuum shaped profile (upper), form shaped profile (bottom).

properties was not in every case true. This method of repeating bend test also imitates conditions of loading our future carbon profile frame.

3.1 Form Shaped Carbon Profile

The process of bend test of form shaped carbon profile at the 1st position represents Fig. 6.

The curve in line graph (see Fig. 7) shows relation of bending force and bending deformation for 1st position. In this position was slot of carbon profile in upper position right under the imprint loading block. The graph shows linear dependence which is associated to carbon material behavior. Test was ended manually by first hearable cracking of fibers. The end occurred during maximum of 1 887 N bending load and by 3.18 mm of bending deformation.

Form shaped carbon profile at the 2nd position next bend test was rotated by 90°. The slot of profile was in the perpendicular position consider to imprint loading block. The graph (see Fig. 8) indicates linear curve, which climb with growing bending force. Cracking of carbon fiber happened on value of 2 095 N bending force. Compared to 1st position test is it more about 200 N. On this basis, we know that position of slot due to

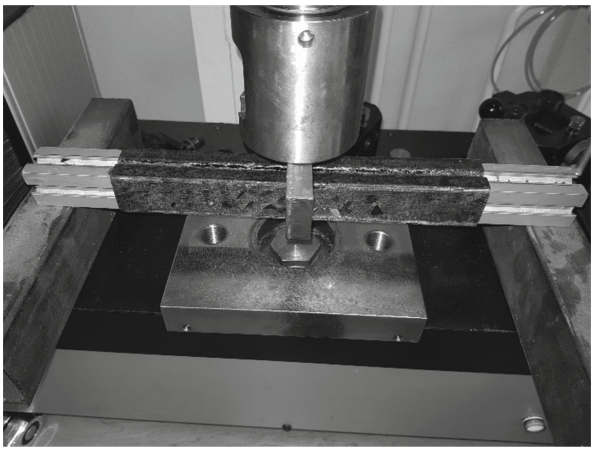

Fig. 6. Process of bend test – form shaped carbon profile.

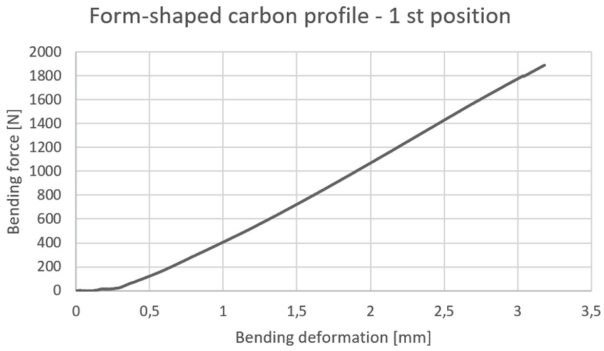

Fig. 7. Bend test result of form shaped carbon profile in 1st position.

the load has impact to profile strength. In this case the slot has elastic function and not the firming function because first cracks emerged by 3.41 mm bend deformation.

The form-shaped carbon profile at the 3rd position was rotated again and the slot is under the imprint loading block. As is possible to see from the graph (see Fig. 9) the crack of fibers was during 1 488 N of bending force and during 2.52 mm of bending deformation. It is obvious that this slot position has bad impact to material resistance. Compared to line chart at 1st position (see Fig. 7) we can see decrease of maximum load and maximum deformation.

Last bend test of form-shaped carbon profile at the 4th position is similar to bend test in 2nd position. From the graph (see Fig. 10) is clear that crack occurred by 1 992 N of bending force and 3.74 mm of bending deformation. It is clear to see decrease of material strength in comparison to 2nd position bend test. Deformation rose from 3.41 mm during 2 095 N to 3.71 mm during 1 992 N.

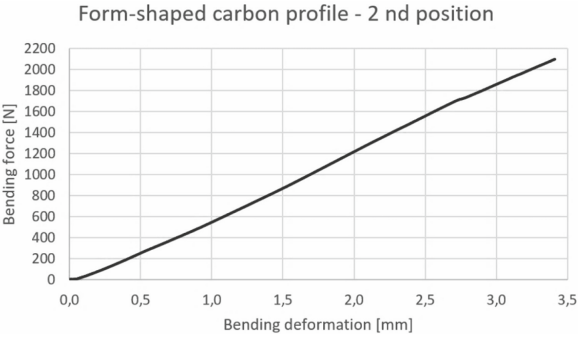

Fig. 8. Bend test result of form shaped carbon profile in 2nd position.

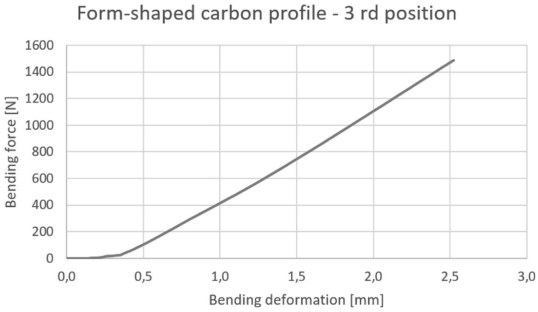

Fig. 9. Bend test result of form shaped carbon profile in 3rd position.

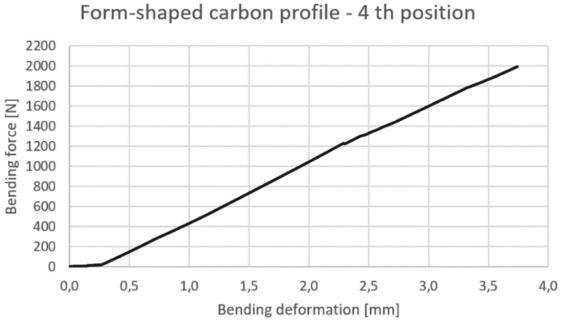

Fig. 10. Bend test result of form shaped carbon profile in 4th position.

3.2 Vacuum-Shaped Carbon Profile

The process of bend test of vacuum-shaped carbon profile at the 1st position represents Fig. 11.

The curve in line graph (see Fig. 12) shows relation of bending force and bending deformation. During every test of vacuum profile was slot of carbon profile still right

under the imprint loading block. The graph reports less linearity behavior than form-shaped profile. Test was ended manually by first hearable cracking in fiber structure. The occurred during maximum of 2 300 N bending load and by 4.28 mm of bending deformation. These results compared to form-shaped profile indicates about 300 N better resilience of bending force and also indicates better elasticity when we compare 3.18 mm of form shaped and 4.28 mm bending deformation of vacuum shaped carbon profile.

Form shaped carbon profile at the 2nd position next bend test was rotated by 90. As was mention before slot of profile is all the time right under the loading block. The graph (see Fig. 13) shows climbing curve with maximum at 1 610 N then the curve fell. Compared to 1st test of vacuum profile is evident decrease of strength properties from 2 300 N to 1 610 N resilience of bending load. Bending deformation during maximum load was 3.85 mm.

The vacuum shaped profile at the 3rd position was rotated again by another 90°. As can be seen from graph (see Fig. 14) the cracking of fibers occurred on value of 1 893 N and maximum deformation was 4.52 mm. It is interesting finding because we expect

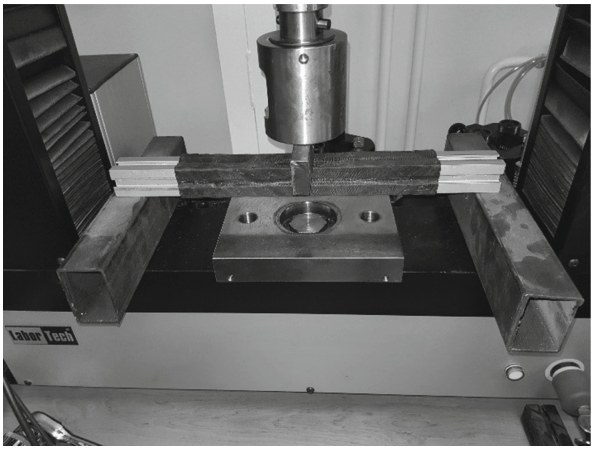

Fig. 11. Process of bend test – vacuum shaped carbon profile.

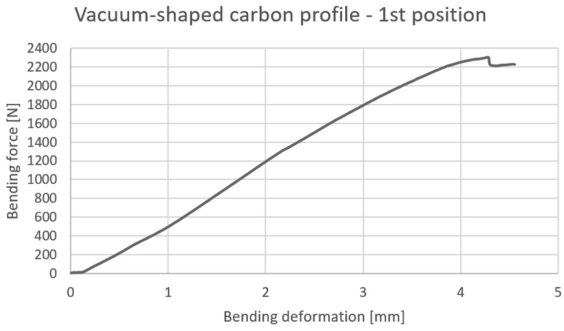

Fig. 12. Bend test result of vacuum shaped carbon profile in 1st position.

decrease of maximum load, but at this case it rose compared to 2nd test where maximum load was only 1 610 N.

The last bend test of vacuum shaped profile at the 4th position shows graph (see Fig. 15). It is clear that crack occurred by 1 533 N and cause the deformation of 4.37 mm. It is visible decrease of strength resilience against bending load, which was predicted.

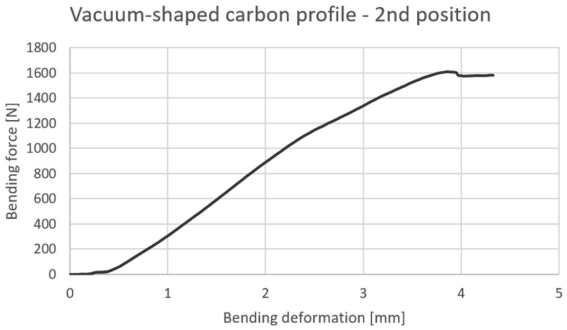

Fig. 13. Bend test result of vacuum shaped carbon profile in 2nd position.

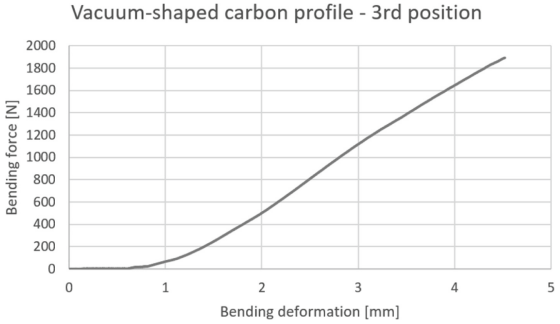

Fig. 14. Bend test result of vacuum shaped carbon profile in 3rd position.

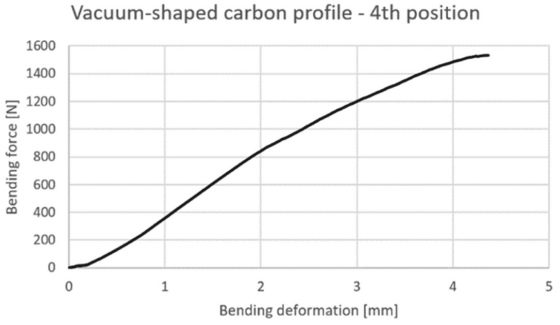

Fig. 15. Bend test result of vacuum shaped carbon profile in 4th position.

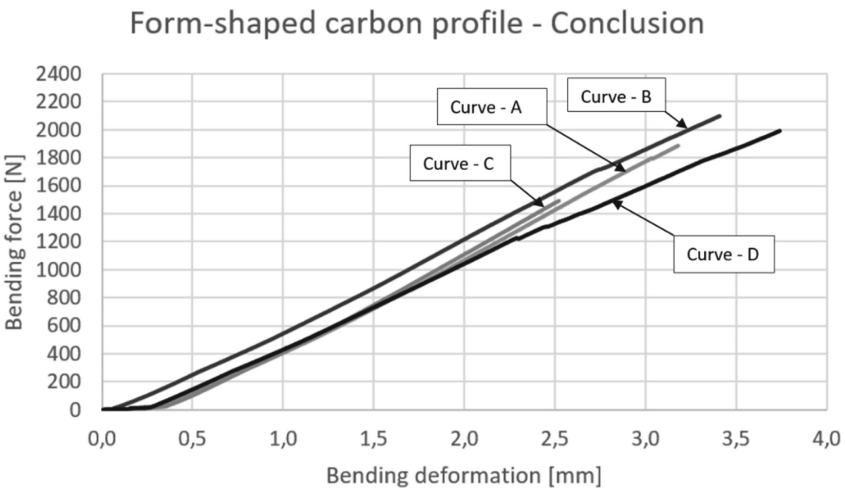

Fig. 16. Comparison of all form shaped bend test.

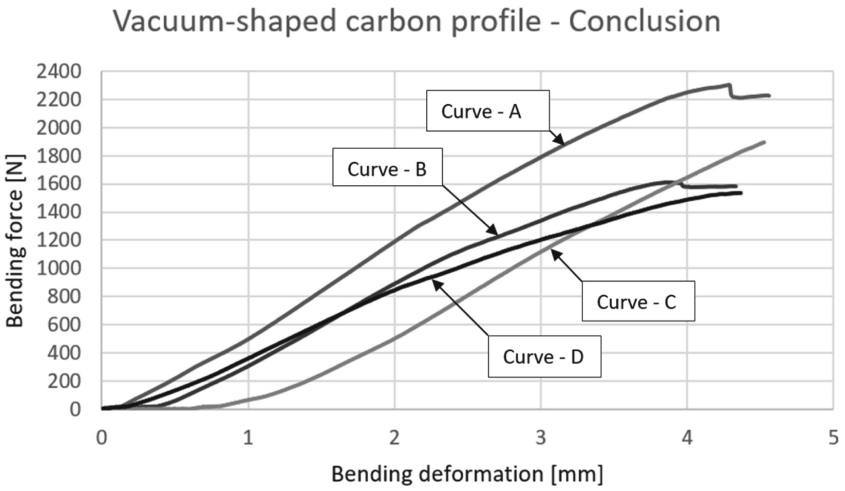

Fig. 17. Comparison of all vacuum shaped bend test results.

4 Conclusions

There are four curves in the chart (see Fig. 16). The curve - A shows the 1st position, the curve - B deals with 2nd position, the curve - C shows the 3rd position and the curve - D is the 4th position. It is visible decrease of values between curves A and C and between curves B and D. The blue and green curves show bend test with slot of profile in vertical position. Curves B and D sign bend test with slot of profile in horizontal position. In horizontal position were the slots of perpendicular position to imprint bending load block. At this position is the profile more flexible to loading force

which has perpendicular direction and so is the profile more resistant in horizontal as in the vertical position of slot.

Four curves in the chart shows all the tests shown together in on graph to compare their properties with succession of tests (see Fig. 17). The curve - A shows 1st position, the curve - B deals with 2nd position, the curve - C shows 3rd position and the curve - D is 4th position. A unique phenomenon occurred by 3rd position of testing when instead of decreasing resistance against bending load material indicates rise of strength properties. It could cause the hardening of epoxy in vacuum chamber and this side which indicates of rise of strength properties should be in bottom position in chamber and the epoxy flow there and it should strengthen this side of vacuum carbon shaped profile. The measurement results show that the mechanical properties of the form shaped carbon profiles and vacuum shaped carbon profiles are very similar. The form shaped carbon profiles have better linearity and higher modulus of elasticity as vacuum shaped carbon profiles.

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