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Experimental Analysis of Deformation Behaviour of Full Scale Fiat 500L Tailgate Made From Fibre Reinforced Polyester Composite

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Abstract: A prototype of Fiat 500L tailgate made from innovative 3D functional textile – long glass fibre reinforced polyester thermoformed composite was developed as a demonstrator within 3D Light Trans project of the EU 7th Framerok Programme. The component was selected in order to demonstrate capabilities of the material for efficient manufacturing of different types of complex components. The tailgate provides an innovative high strength, low weight alternative to the nowadays customary metal parts manufactured with state-of-the-art technology. Full scale validation of the prototype was an essential part of the project implementation. The experimental method and results are described in this contribution.

Keywords: Full Scale Test; Car Tailgate; Deformation Analysis; Glass Fibre Reinforced Polyester Composite.

1 Introduction

In spite of that glass fibre reinforced plastics (GRP) have been used as a structural material already for more than fifty years, their penetration to other industries than aircrafts or wind turbines has been pursued quite slowly, rather due to conservatism of many designers on one hand and numerous characteristic differences in comparison with steels on the other hand. Nevertheless, GRP composites are characteristic by properties, which can be particularly advantageously used in transport vehicles, e.g. low density, quite high strength, internal damping or low noise conductivity [1]. Such properties have been recently desired in connection with requests to produce environmentally friendly vehicles with reduced CO_2 emission, fuel consumption, noise emission and improved dynamic properties. On the other hand, penetration of GRP to other industries than aircrafts or wind turbines has been pursued quite slowly, not only due to conservatism of some designers, who have not been familiar with numerous characteristic differences in comparison with steels, but also due to specific mechanical properties of these materials and their sensitivity to manufacturing processes [2,3]. Another problem of wide application of polymer composites in heavy loaded structures, like e.g. transport vehicles is that even quite well-know techniques as global–local approaches, which can be used for designing with good results, are not yet usually implemented in commercial codes [4].

A special, very innovative type of GRP materials is represented by 3D textile composites, which have been developed because they exhibit, thanks to the use of z-binder for the through-thickness reinforcement, better delamination properties, impact and fatigue resistance than conventional composites [5]. It was demonstrated that the developed 3D glass fibre reinforced polymer thermoformed thermosets, either polypropylene or polyester, have suitable mechanical properties, not only static tensile or flexural strength and E-modulus [6] but also important shear properties [7] A complex manufacture chain has been developed within the 7th Framework Project 3DLigtTrans in a collaboration of 18 partners from different EU countries. One of the project demonstrators was Fiat 500L tailgate manufactured fully from thermoformed polyester composite. Since some mechanical properties of the material. like stiffness, inhomogeneity or orientation sensitivity strongly differs from steel, full scale tests demonstrating acceptable properties of the component were an essential final step of the project solution. The experimental approach and results are presented and discussed in this contribution.

Tab. 1: Numbering of strain gauges bonded on the inner tailgate surface.

Tailgate area	Horizontal	45 deg	Vertical
Right upper window corner	SG1	SG2	SG3
Left upper window corner	SG4	SG5	SG6
Left bottom window corner	SG7	SG8	SG9
Right bottom window corner	SG10	SG11	SG12

2 Experimental Programme

According to requests of the project partner Fiat Research Centre (CRF) [8], the main characteristics to be verified were torsional stiffness and side flexion. In both cases, the tailgate was supported in horizontal position on three rigid supports, namely in the area of tailgate hinges with a possibility of free rotation (supports A) and in the area of tailgate lock, which freely lied on the third rigid support B – Fig. 1. Vertical force was applied at one of the bottom tailgate corner during the torsional test and horizontal side force was applied in the area of tailgate lock during side flexion test. Vertical and horizontal displacements were measured using high precision electromagnetic gauges Sangamo – Fig. 2.

Stress-strain analysis of the tailgate during both tests was performed in terms of strain measurement at critical tailgate areas, namely near the four window corners. Strain was measured using strain gauge rosettes with 14 mm long measuring grids – Figs. 3 and 4. Numbering of strain gauges and their position is shown in Tab. 1.

Actually, the support was realized using the very rigid table of SCHENCK PVQA 63 kN fatigue resonance machine. The table contains several grooves with nuts and so the component could be attached to this rigid support quite easily.

An essential part of the test plan contained reference measurements on the conventional steel Fiat 500L tailgate, where the same experimental procedure was used. The steel tailgate was equipped with the same type and dimensions of strain gauge rosettes attached in the equal positions and with the equivalent instrumentation. A new spare tailgate purchased from a certified Fiat distributor in Prague, Czech Republic was used for the reference tests.

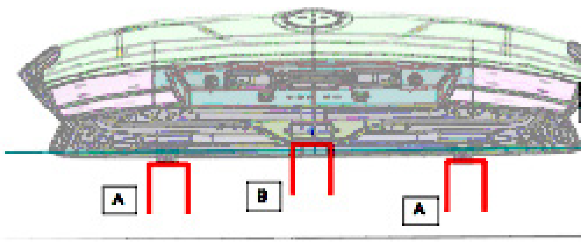

Fig. 1: Scheme of the tailgate support during the torsional and flexural tests – according to CRF request.

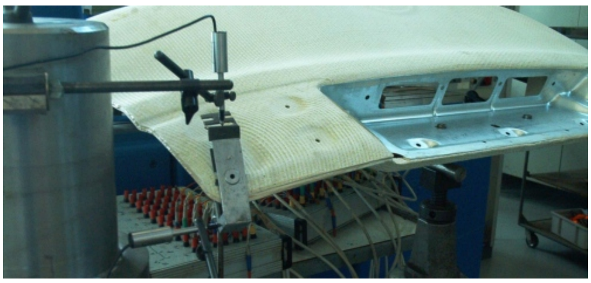

Fig. 2: Measurement of vertical and horizontal displacements at the tailgate bottom corner during torsional test.

The loading was realized using a special hanger taken from rotating bending machines used in the laboratory. The hanger was attached either to the left or to the right corner of the tailgate. The hanger is actually a rod with a hook at the upper end and a plate at the bottom, where calibrated weight can be put. The hanger was carefully weighed before the tests to know exactly the total vertical force at each loading step. All strain values measured by the strain gauge (SG) rosettes and displacement measured by the extensometers were recorded after each adding of the weight, during both loading and unloading.

3 Results and Discussion

Comparisons of displacements of 3DLT and steel tailgates during the torsional and side flexion tests are in the following diagrams – Figs. 5 and 6.

Fig. 3: Total view of the tailgate during test preparation with SGs at four near-window inner corners.

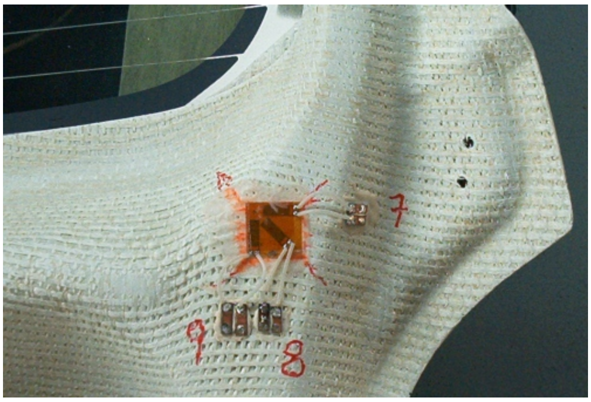

Fig. 4: Detail view of SG rosette at the inner side of the tailgate left bottom near-window corner.

It follows from the diagrams that particularly during the torsional test, the 3DLT tailgate is less rigid than the steel one – by more than factor of 2 (Fig. 5). Unlike the torsional tests, the differences between the 3DLT and steel tailgates is much less in case side flexion – just 20 – 25 % difference.

The second comment concerns the torsional test of 3DLT tailgate. Unlike the steel tailgate, there is quite significant hysteresis. But in spite of the hysteresis, the recorded values return to zero when the component is unloaded. Some hysteresis can be observed even during the 3DLT tailgate side flexion test, but is not significant.

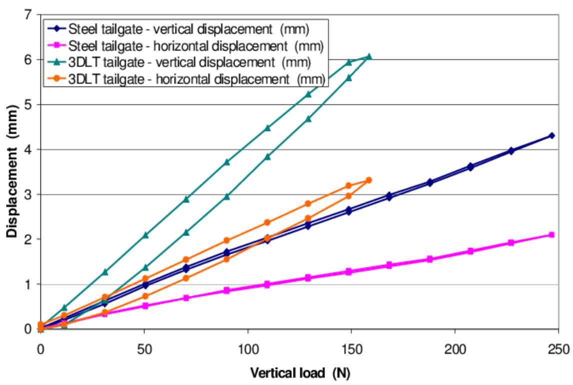

Fig. 5: Comparison of vertical and horizontal displacements during torsional tests of 3DLT and steel tailgates, respectively.

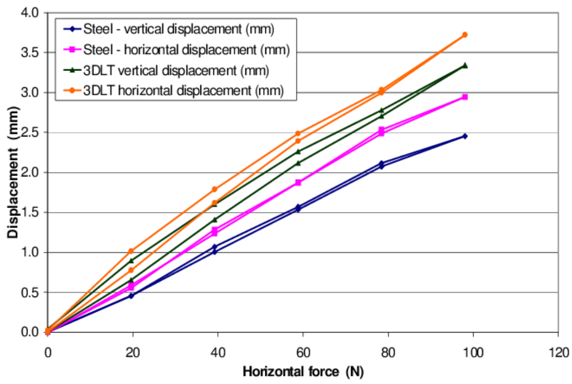

Fig. 6: Comparison of vertical and horizontal displacements during torsional tests of 3DLT and steel tailgates, respectively.

Strain values recorded during torsional stiffness tests are shown in Figs. 7 and 8 for the composite tailgate and in Figs. **??** and **??** for the reference steel tailgate. The diagrams correspond to vertical loading at the bottom left tailgate corner. Like displacement values, also SG values are lower for the steel tailgate, though the differences are quite low, mostly up to 25 %. An important result is linearity of the dependencies, though the maximum loading was quite high, much more than requested in [8]. Also in case of strain measurement some hysteresis was observed for the composite tailgate unlike the steel component.

4 Conclusion

Though the stiffness of the composite tailgate during torsional test is approximately 2-times lower in comparison with steel, the results are encouraging and still acceptable. Differences between strain values are even lower. Note that E-modulus of the composite is more that 10-times lower than that of steel. The composite tailgate stiffness was reached using special design and stiffeners. The tests demonstrated possibilities of use of the advanced 3D thermoformed composite in vehicle bodies.

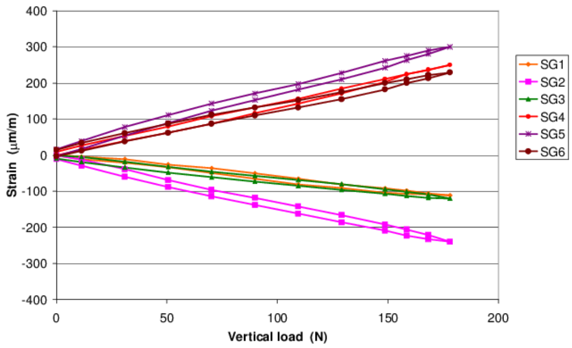

Fig. 7: Strains near upper window corners during right side vertical loading, 3DLT tailgate.

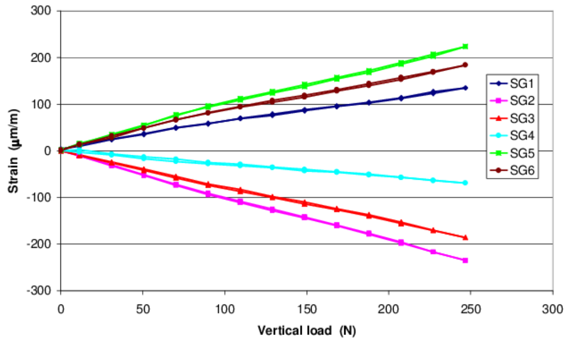

Fig. 8: Strains near upper window corners during right side vertical loading, 3DLT tailgate.

Acknowledgement

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