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Material Characteristics the CFRP for Car Seat Frame

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Abstract. Material properties such as strength, stiffness and elasticity of a given composite material depend on the type of fibers used in combination with the matrix, composition and shape of the resulting product. The article deals with the measurement and evaluation of the properties of carbon fiber composite. The tubular profile is one of the basic profiles of the carrier frame of the front passenger and driver's seat. The main criterion of substitutability is to maintain the same mechanical properties of the seat frame with maximum weight reduction [1, 2]. An integral part of the realized activities is also the design of the material model of the tested composite stack. This material model will be used in follow-up FE simulations of the upgraded design of the seat frame.

Introduction

A car seat is a complicated part of the car in terms of design. It belongs to the elements of passive vehicle safety. It evolves long-term to meet the requirements of comfort, mechanical and utility properties. The weight reduction of the seat is an objective while preserving the mechanical and vibration-isolation properties of the structure. Conventional metallic materials are gradually replaced by composite materials, particularly fiber-reinforced plastics (FRP). The orientation and type of fibrous reinforcement should be adapted to the mechanical properties requirements when loading the seat design. Carbon fibers have high strength and modulus in generally [3]. Modelling of properties and behavior of composite structures is an integral part of designing parts for industrial use. Material properties, i.e. set of elastic constants of the composite structure, are the result of a virtually modelled experiment. The results of the model experiment are then used for the actual product.

Experiment

Specimens for experiment - tubes made using pultrusion from carbon fibers and epoxy resin were used as a support structure. All filaments are oriented in only one direction. This part of the composite ensures the strength of the component. Two or four layers of carbon fibers pre-impregnated with an epoxy resin with directional orientation of ± 45 ° were added to reduce vibration and to absorb deformation energies. The tubes were cured under prescribes conditions.

The tensile test is the basic method of determining static strength of composite materials. Tube testing is difficult. Tube ends crack in jaws of the tearing machine when not specially prepared. The tensile test can be replaced by a bending test, three or four point bending test. The flexural module is calculated from measured force and deflection variables. The flexural module is recalculated to the tensile modulus. Specimens group for testing four point bending is showed Figure 1, device for four point bending is showed Figure 2 [4, 5, 6].

Fig. 1 Groups of specimens

Fig. 2 Testing device

During the test were measured this variables: the total force on the crossbar of the load medium, its displacement [mm] and the deflection in the centre of the sample w_{max} [mm]. An example of measured values of dependencies F-w_{max} is shown in Fig. 3.

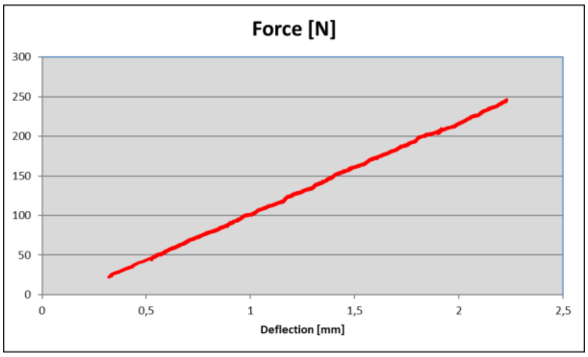

Fig. 3 Dependence F-w_{max}

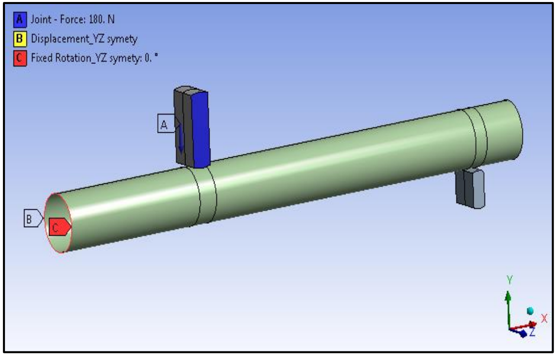

Fig. 4 Four point bending FE model

The specific stiffness of the specimens was determined from the measured values according to the equation (1).

$$Stif = \Delta F / \Delta y \qquad (1)$$

The stiffness of individual specimens and their mean values are shown in Tables 1-3.

Tab. 1 Stiffness of carbon pultruded tubes

Specimen	Stiffness [N/mm]	AVG value	standard deviation
C1	96.3	93.4	2.55
⋮	⋮		
C12	90.6		

Tab. 2 Stiffness of carbon pultruded tubes + 2Cpl

Specimen	Stiffness [N/mm]	AVG value	standard deviation
C2V1	101.3	104.1	1.89
⋮	⋮		
C2V24	107.6		

Tab. 3 Stiffness of carbon pultruded tubes + 4Cpl

Specimen	Stiffness [N/mm]	AVG value	standard deviation
C4V1	116.1	116.1	1.84
⋮	⋮		
C4V24	119.3		

The second method of finding strength modulus is based on the measurement of the velocity of the longitudinal wave propagation in a material with a defined density. The velocity of wave propagation can be measured only by the indirect method, i.e. measuring the time shift at defined distances. The time difference Δt [s] of the passage of the longitudinal wave at the tube length l [mm] was measured during the test. The statistic values of the measured values are shown in Table 4.

Tab. 4

No. specimen	AVG Δt [s]/1m	SMODCH. Δt [s]/1m
C	0.00017	0.00002
C2V	0.00086	0.00003
C4V	0.00079	0.00003

The measurement should be supplemented by measuring the shear modulus for the consistency of the knowledge about the mechanical properties of the composite material. Direct measurement of torsion is a test that gives the exact result. The method is based on the simultaneous measurement of the torque Mk [Nm] and torque angle γ [rad]. Measurements were made during the test: torque Mk [Nm] and torque angle γ [rad]. Example of measured values of Mk-φ dependence is shown in Fig. 7. Specimens group for torsion test is showed Figure 5, device for torsion test is showed Fig. 6.

Fig. 5 Specimens group for torsion test

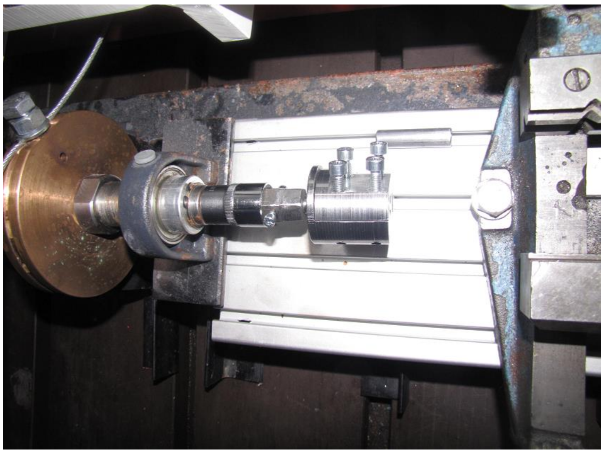

Fig. 6 Device for torsion test

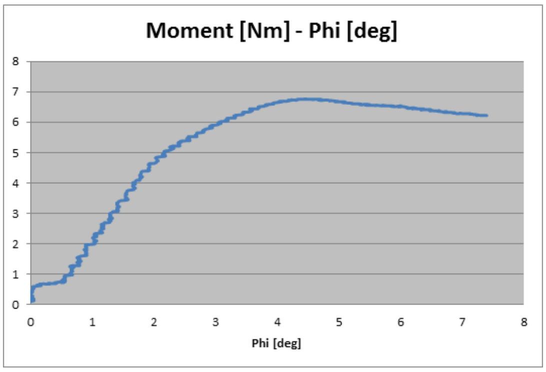

Fig.7 Dependence M_k-φ

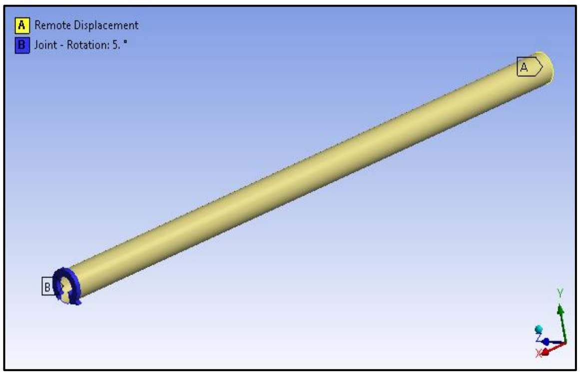

Fig. 8 Torsion FE model

The torsion stiffness was determined from the measured values according to equation (2).

$$Stif\_tor = \Delta M_k / \Delta \varphi \qquad (2)$$

The torsion stiffness of the individual specimens and their mean values are shown in Table 5.

Tab. 5 Torsion Stiffness

No. specimen	AVG Torsion Stiffness [Nm/rad]	SMODCH.
C	-	-
C2V (1 - 6)	85.37	7.10
C4V (1 - 6)	91.10	4.41

Pultruded carbon tubes was not measured by torsion test, because the specimens was destructed by low loading.

Identification of elastic properties of composite structures

The elastic material constants of the layers of the composite structure were evaluated on the basis of specific stiffness that were measured during the experiments. FE models (see Fig. 4, 8) were designed to match physical experiments. The elastic constants of the orthotropic layers of the respective composite structure were found through iterative techniques using the micromechanical theory of the Halpin-Tsai. The results are shown in Table 6.

Tab. 6 Elastic constants

E1	E22	E33	G12	G23	G13	P12	P23	P13
[MPa]	[MPa]	[MPa]	[MPa]	[MPa]	[MPa]	-	-	-
71 380	6 194	6 194	2 274	1 908	2 274	0.322	0.623	0.301

Conclusion

Based on the methodology based on the use of four point bending and torsion, together with the numerical modeling of these experiments by the finite element method and the application of one of many micromechanical theories of composite structures, the elastic constants of the tested composite compositions were determined to be used in the development of prototypes bearing frames of the seats in the means of transport.

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