CAD/CAE simulation of mechanical properties of tubular elements made from composite structures

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S u m m a r y . Simulation result of the wind turbine mast tubular element performed in software ANSYS Composite PrepPost and SolidWorks Simulation is given in the article. Also, there is a comparative analysis of simulation results and experimental samples. The material properties that are available in software systems are the initial data for simulation. The experimental data confirmed the results of the simulation models in CAD / CAE systems.
K e y w o r d s : fiberglass, tubular element, software complex, SolidWorks, ANSYS, model.

INTRODUCTION

Materials based on composite structures find a great application in recent years. These ones include materials having with strength and stiffness with respect to the traditional structural materials and alloys [16-18]. Therefore, the need for simulation and experimental development of structures and their components made on the basis of these structures is arising [1].

Thus, the study of polymer composite structures based on simulation and calculation in CAD / CAE systems is an actual problem [5,19].

Main aims of this paper are the following: carrying out of experimental researches to determine the mechanical properties of the polymer composite material tubular elements (TE) and performing of a comparative analysis with the simulation in the CAD / CAE systems.

OBJECTS AND PROBLEMS

A fibrous fiberglass on the basis of glass strands EC-7x30-80 and epoxy binder EDT-10 is selected to be the object of research [15]. Making of full-scale TE samples and conducting of a series of experiments were the first step. Information on samples and the obtained strength are shown in table 1.

Getting known the layer thickness and internal diameter let us deriver its area (formula 1):

$$S = \pi \cdot t \cdot \left(d_{в} + t\right), \qquad (1)$$

Where t is the layer thickness.

Known compression force lets us to deriver the stress in [0°] layer using the formula 2:

$$\sigma_{э} = \frac{P}{S}, \qquad (2)$$

where: P is the compression force.

Table 1. The strength characteristics of TE made of fiberglass

Sample No	S, mm^2	F, kN	σ, MPa	$\sigma_{averaged}$, MPa
1	18,72	15	801,28	908,12
2		19	1014,96	

The result of the destruction is shown in figure 1.

Fig. 1. TE sample in the testing adaptation and TE samples after the axial compressive loading

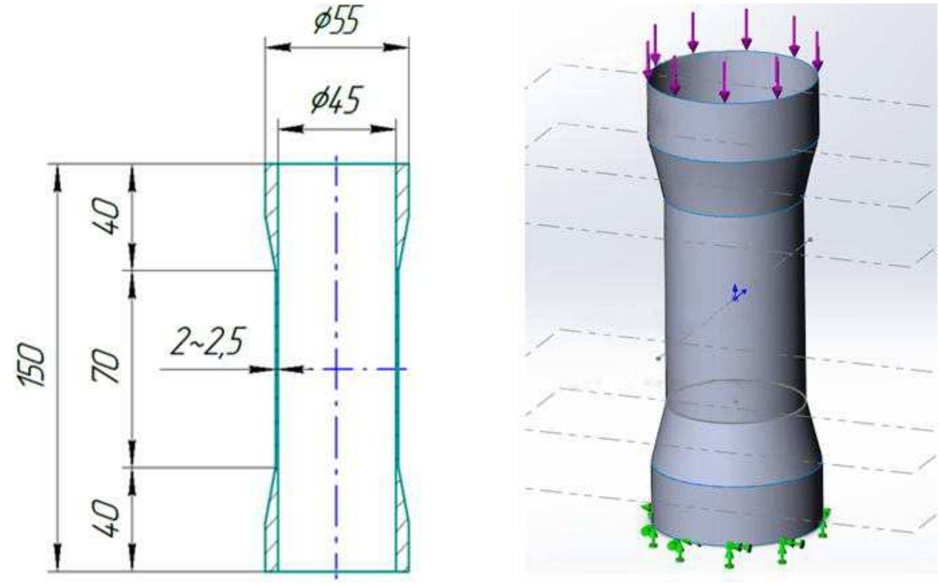

Fig. 2. The TE geometrical model and TE 3D-model

Solid Works 2012 and ANSYS 14.5 software complexes were selected for the wind turbine mast TE numerical experiments [1]. 3D-models of wind turbine mast elements made of polymer composite were constructed in software complexes according to specified parameters of a geometric model.

The next step was to simulate the process of compression loading mast element with forces up to 20 kN in a software module Simulation of the Solid Works 2012 software complex. Three-dimensional model was built according to geometrical parameters (fig. 2).

Finite element mesh is shown in figure 3. TE equivalent stresses are shown in figure 4. The maximum stress in TE are 819 MPa.

When compressed along its axis, the whole TE load is held just by the longitudinal layer (fiber lay angle is 0° relative to the axis). Transverse layer keeps circular and a minor part of the longitudinal load occurring under compression of the layer (90° relative to the axis). The simulation assumed that the whole applied axial load is applied only on the longitudinal layer.

The last step was to perform the calculation in ANSYS Workbench software.

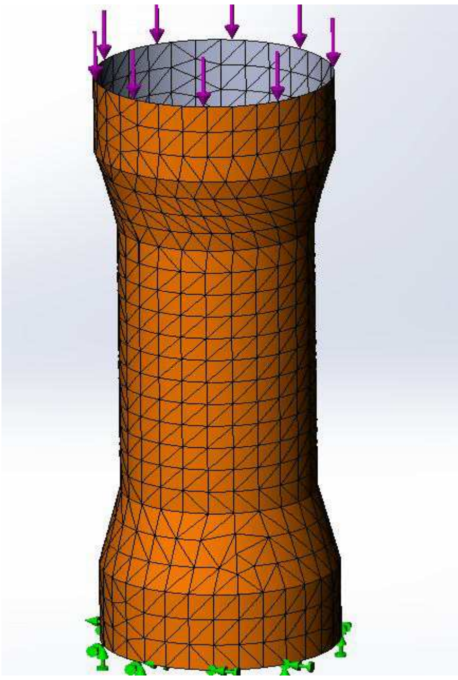

Fig. 3. Finite element model of the TE

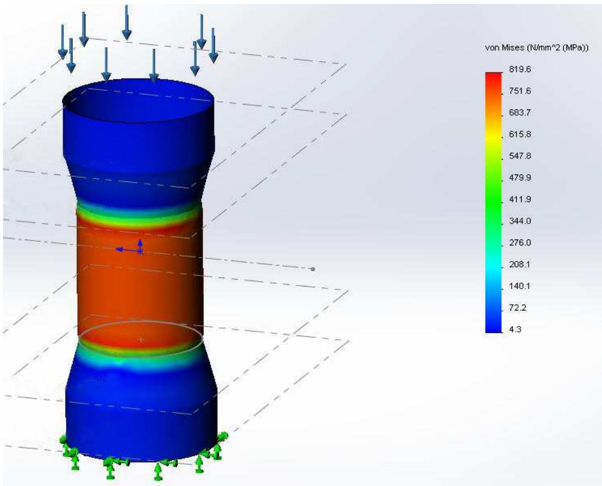

Fig. 4. Equivalent TE compressive stresses

Firstly, while calculation the elements strength in any CAD/CAE systems the material is to be selected. Epoxy EGlass material was selected in our case (E glass-based fiberglass). Table 2 represents the physical properties of material

After material application and geometry import into Workbench the ACP (Pre) (Ansys Composite PrepPost (pre-processing)) module is run. The layers thickness and packages structures are applied in it. As it was mentioned before, the tube consists of two layers [0°] and [90°] respectively of 0.3 mm thickness and has thickening at each end. There is no volume-of-the-layers displaying option in ACP, that is why we have used such function as как Section Cuts for schematic layers view. On Fig 6 the schematic layers view is represented. Scale in increased in four times for view clearness.

Table 2. Material pfysical properties

Physical quantity	Value
Elasticity modulus along fibres E_x, MPa	45000
Elasticity modulus along across E_y, E_z, MPa	10000
Poisson's ratio while loading along fibres μ_{xy}, μ_{xz}	0,3
Poisson's ratio while loading across fibres μ_{yz}	0,4
Shear modulus along fibres G_{xy}, G_{xz}, MPa	5000
Shear modulus across fibres G_{yz}, MPa	3846,2

While calculating in Composite PrepPost it is sufficient to consider that program deals with shells only without accepting the volume models. Taking this condition, the model for calculation was designed in SolidWorks and imported into Ansys. Calculation model is represented in Fig. 5.

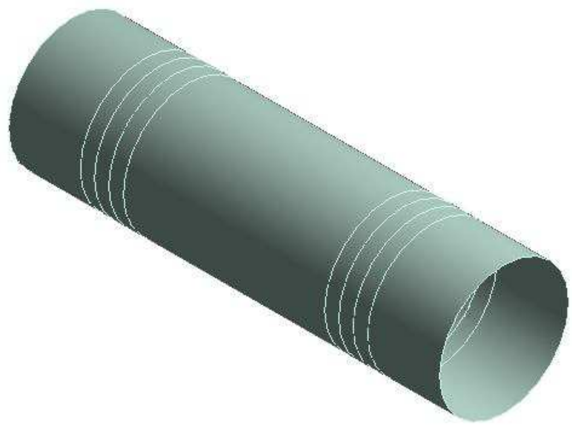

Fig. 5. Calculation tubular model

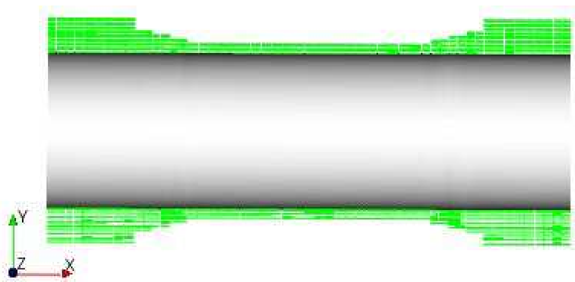

Fig. 6. Schematic layers view

The next module used in Workbench is Static Structural. We have defined the conditions of tube load in it: boundary conditions and force application. According to testing conditions the tube is to be resistance to load of 20 kN. Fig. 7 represents the design model of loading.

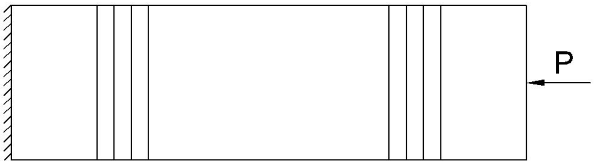

Fig. 7. Design model of loading

After loading we have reviewed the results in joined module ACP (Post) (Ansys Composite PrepPost (post-processing)). The stresses can be viewed clearly in this module. Figures 8, 9 and 10 represent the following: stresses in layers [0°] and [90°], deformation.

As you can see in fig. 6.7 stresses in TE when loading them in SolidWorks and ANSYS are arranged in the same areas.

A comparison computer simulations with experiments has shown that the method of calculating the composite TE in software ANSYS and SolidWorks gives adequate results (see table 3).

Table 3. Intensity of stresses in TE

experiment		var. coef.	simulation result	
			ANSYS	Solid-Works
σ, MPa	$\sigma_{averaged}$, MPa	%	σ, MPa	
801,28	908,12	11,76	1030	819,6
1014,96				

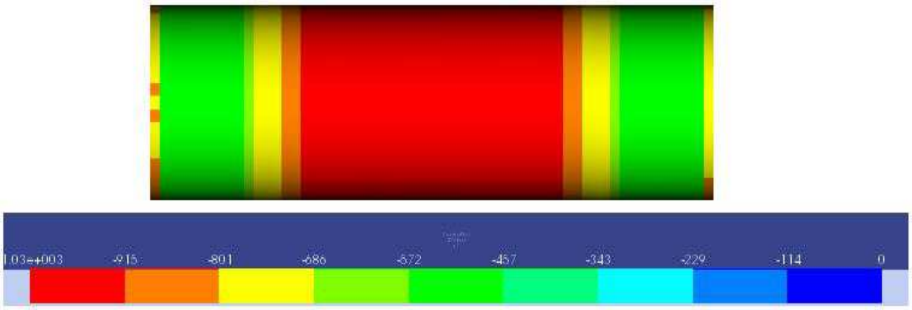

Fig. 8. Stress in layer [0°]

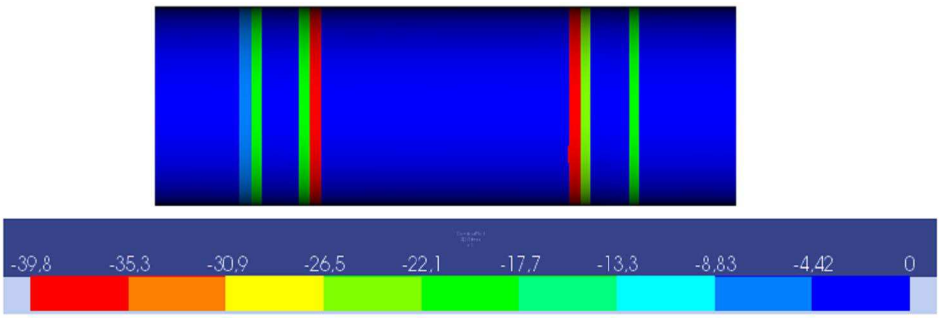

Fig. 9. Stress in layer [90°]

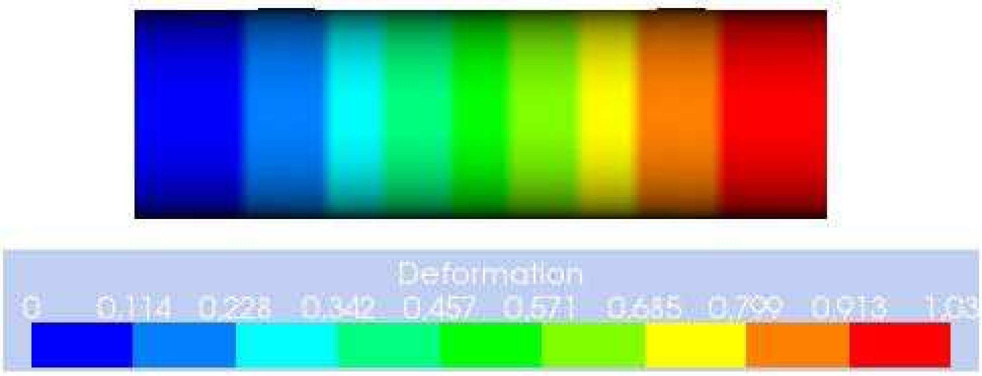

Fig. 10. Deformation

Table 2 shows that the difference in the results of calculations in software complexes is 20%. Averaged experimental data differs from computer model up to 10%. Taking into account the stresses in TE obtained during the experiment (801 and 1014 MPa), it can be argued that the numerical experiment gives close to real results with an error of up to 5%. The obtained variation coefficient is 11.76%. This meets the permissible deviation.

CONCLUSIONS

1. The experimental research on testing the mechanical properties of the polymer composite TE was conducted. The values in the range from 801.28 to 1014.96 MPa were obtained. The variation coefficient was calculated. Its value does not exceed the maximum deviation that means the adequacy of the experimental results.
2. The numerical experiment was conducted in the module Simulation of software complex SolidWorks. The deviation of the obtained result from real experiment is up to 10%.
3. The numerical experiment was conducted in the software complex ANSYS Composite PrepPost. The deviation of the obtained result from real experiment is not more than 14%.

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МОДЕЛИРОВАНИЕ МЕХАНИЧЕСКИХ СВОЙСТВ ТРУБЧАТЫХ ЭЛЕМЕНТОВ КОНСТРУКЦИЙ ИЗ КОМПОЗИЦИОННЫХ МАТЕРИАЛОВ В CAD/CAE СИСТЕМАХ

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Сергей Кашкаров, Игорь Непран

Аннотация. В статье приведен результат моделирования трубчатого элемента мачты ветроэнергетической установки, выполненного в среде ANSYS Composite PrepPost и SolidWorks Simulation, а так же сравнительный анализ результатов моделирования с экспериментальными образцами. Исходными данными для моделирования являются свойства материалов, имеющиеся в программных комплексах. Полученные экспериментальные данные образцов подтверждают результаты моделирования в CAD/CAE системах.

Ключевые слова: стеклопластик, трубчатый элемент, программный комплекс, SolidWorks, ANSYS, модель.

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