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# NUMERICAL ANALYSIS OF POLYMER COMPOSITE BEND TESTS MADE BY VACUUM BAGGING

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**Abstract:** *The paper presents in a very detailed way the technology of production of polymer composite by vacuum bag method. Subsequently, a three-point bending test was performed on ABAQUS. To conduct a thorough analysis of the behavior of materials in the angle of pose: 0 °, 90 °, 45 °. Models were made using Sold. Numerical analysis was carried out to obtain the initial results needed to produce a polymer composite with the specified number of layers and the amount of pavement required to achieve the best strength properties*

**Keywords: Modelling, Composite, MES (ABAQUS), Technology, Three-point bending.**

## 1. Introduction

Impact is often used to influence the objects of the outside world, used by most living beings. Instinctively or consciously they use the fact that the forces formed at the moment of impact in the bodies in contact repeatedly (sometimes even thousands of times) exceed the weight of these bodies. All this made the basic strike by destroying, destroying, and altering the shape of external objects. Hence, there is a direct link between scientific research on the effects of impact as a physical process and the mechanics of fracture (Rokach, 2005). Vacuum bag method is one of the most popular forms of polymer composite production in the world. This method is relatively cheap and allows for the production of very high quality composites. Finite element methods are numerical methods that can be applied to the exact solution of complex technical problems (Rao, 2005). Thanks to this, very accurate results of displacements and analyzes can be obtained in the whole area of the sample, and it allows to model multi-axis stretching of materials which will be the subject of subsequent articles.

## 2. Methods

Plate made of polymer composite was made by the vacuum bag method in the Laboratory of the Technical University of Świętokrzyska. Prior to the actual bending test, the FEM simulation was performed. To verify the theoretical stresses and deformations with the real ones that will appear in subsequent publications.

a) b)

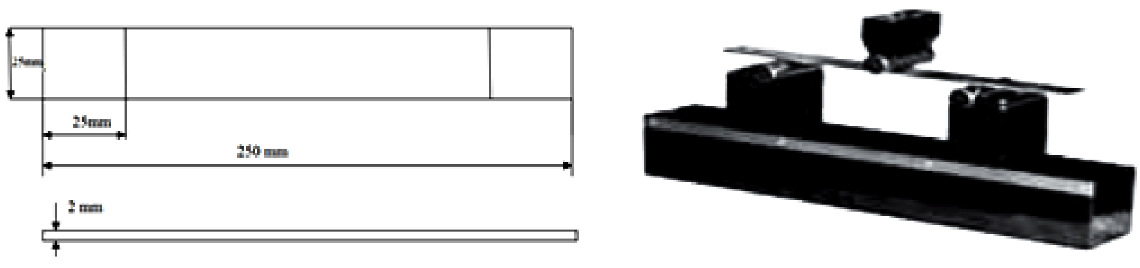


*Fig. 1: a) Geometrical dimensions of the sample; b) Device for bending laminates (Suwak, 2010).*

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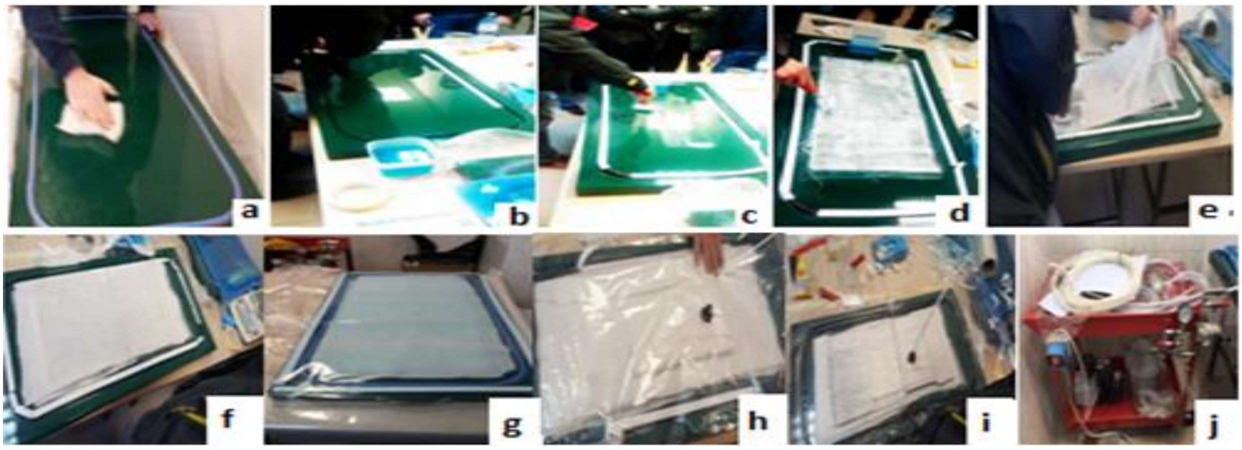
*Tab. 1: Stages of manufacture of polymer composite vacuum bag method: a - polishing mold; b - attaching the double sided tape mounting; c - the imposition of the first layer of resin; d - overlap the first layer fibreglass fabric; e - imposition of layer peel ply; f - fabric breathable perforated foil; g, h - vacuum bag attachment along with a hole with extraction; i - material subjected to pressure; j- vacuum unit.*




Prepare a three point bend test in ABAQUS according to the actual model shown in Fig. 1b. Due to the difficulty of performing composite stretching tests, three or four point bending tests (Fig. 1b) are used in a large-scale study of these materials. In ISO-EN ISO178 standard it is intended to use rectangular samples with a height-to-distance ratio of $l / h = 16$. This ensures that damage due to normal stresses σ associated with the bending moment occurs due to delamination caused by tangential stresses (Laboratory of Materials Strength).

The ABAQUS program has been modeled in three-point bending mode in the ASSEMBLLY module, 3 contact connections have been made (Fig. 2).

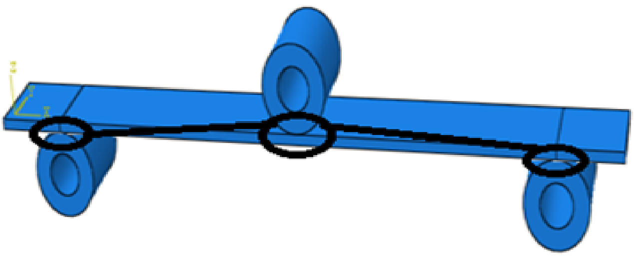


*Fig. 2: Model three-bend made in module ASSEMBLLY.*

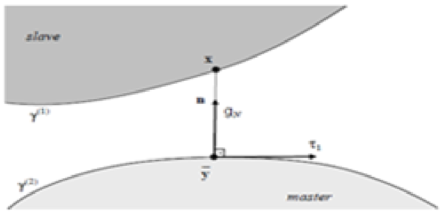



*Fig. 3: Kinematic variables in contact in the three-point bending (Supkiewicz, 2014).*

Formulation of contact conditions requires the introduction of kinematic variables determining the relative position and the relative movement of the contact surfaces (Fig. 3). A master-slave approach in which arbitrarily assigns slave and master roles, respectively, and relative motion is described with respect to the configuration associated with the master body (Lengiewicz, 2008).

*Tab. 2: Average strength of laminates (Chatys, 2015).*

| angle [°] | average $F_{max}$ [kN] | average $\sigma_{max.}$ [MPa] | average E [GPa] |
|---|---|---|---|
| 0 | 7.31 | 122.90 | 11.27 |
| 45 | 8.63 | 174.60 | 14.18 |
| 90 | 4.36 | 73.67 | 9.62 |

Very important role in the design of dynamic composite materials tests is the selection of the grid (Fig. 4) because we use contact links for two different metals of different structures (in this case steel composite).

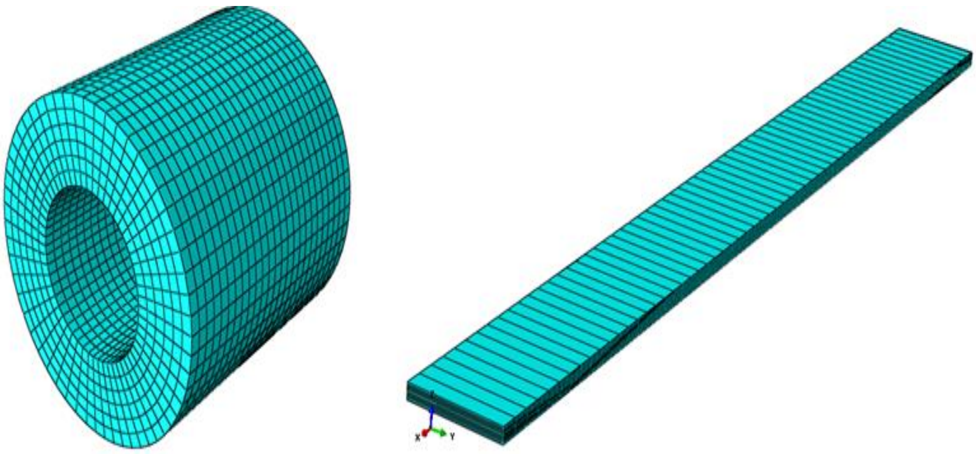


*Fig. 4: Finite element mesh selection for stamp and composite.*

### 2.1. Analysis of the results

The analytical methods for determining the strength of the polymer composites taking account of shock loads, observed a decrease in strength in research materials as a result of exceeding the threshold energy. In the literature discusses only the quality of the process of the destruction of and provides assessment of the likely size of damage by analysis (e.g., linear), as the equivalent of Tresca and Von Mizesa (Chatys, 2013). The distribution of such equivalent stresses under specified impact hypothesis Huber (Bohdar, 2004 and Rokach, 2005) for the above data contained in Tab. 2 (obtained from the five tests). Hypothesis Huber von Misses ($W_{C\text{-}T\text{-}G}$ ) very well coincide with the experimental data for elastic and according to her: work ratio bigger material at a given point of the body dictates the strain energy density, regardless of the type of stress state saved the above dependencies:

$$W_{C-T-G}=\left(\left|\frac{\sigma_1-\sigma_2}{2}\right|,\left|\frac{\sigma_1-\sigma_3}{2}\right|,\left|\frac{\sigma_2-\sigma_3}{2}\right|\right) \tag{1}$$

$$\max=\left(\left|\frac{\sigma_1-\sigma_2}{2}\right|,\left|\frac{\sigma_1-\sigma_3}{2}\right|,\left|\frac{\sigma_2-\sigma_3}{2}\right|\right)=\left|\frac{\sigma}{2}\right|\leq\frac{R_k}{2} \tag{2}$$

where: $\sigma_1$, $\sigma_2$, $\sigma_3$ - values of principal stresses.

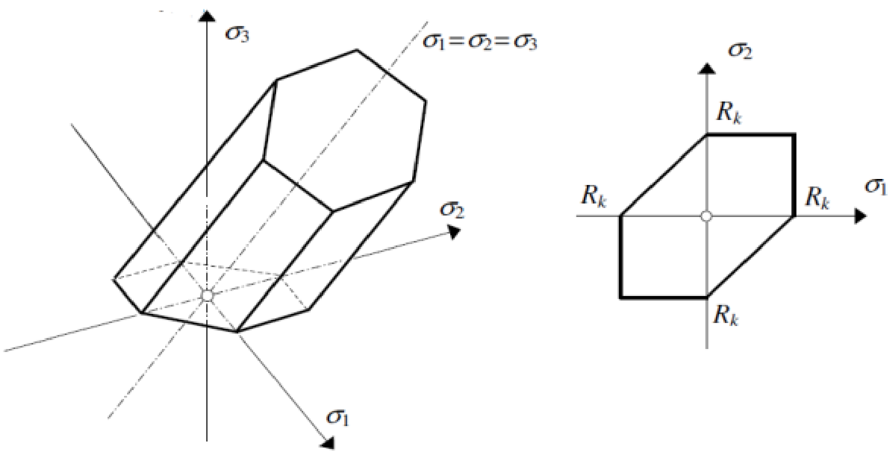



*Fig. 5: Graphical interpretation of Huber's hypothesis (Bohdar, 2004).*

In the Haigh-Becker three-dimensional space, the above condition defines the space within an infinitely long cylinder with an axis that coincides with the axis of the axes and in a two-dimensional space - an area bounded by an ellipse (Bohdar, 2004).

The graphs below (Fig. 6) can be analyzed in detail for the stress distribution of Huber von Misses. Only the stresses of the sample measurement base are taken into account.

## 3. Conclusions

During bending tests, many problems can provide a compression strength that accurately reflects the FEM analysis. Taking into account the positive and negative aspects of stretching and bending, they are used equally often. These tests are designed not only to determine the strength and elasticity modules but also the fracture behavior of the material (fig) as it is of great importance for the various types of collisions exposed to already finished composite products (e.g tram elements or car bumpers). Polymeric unidirectional characterizes high anisotropy of strength modules and elasticity.

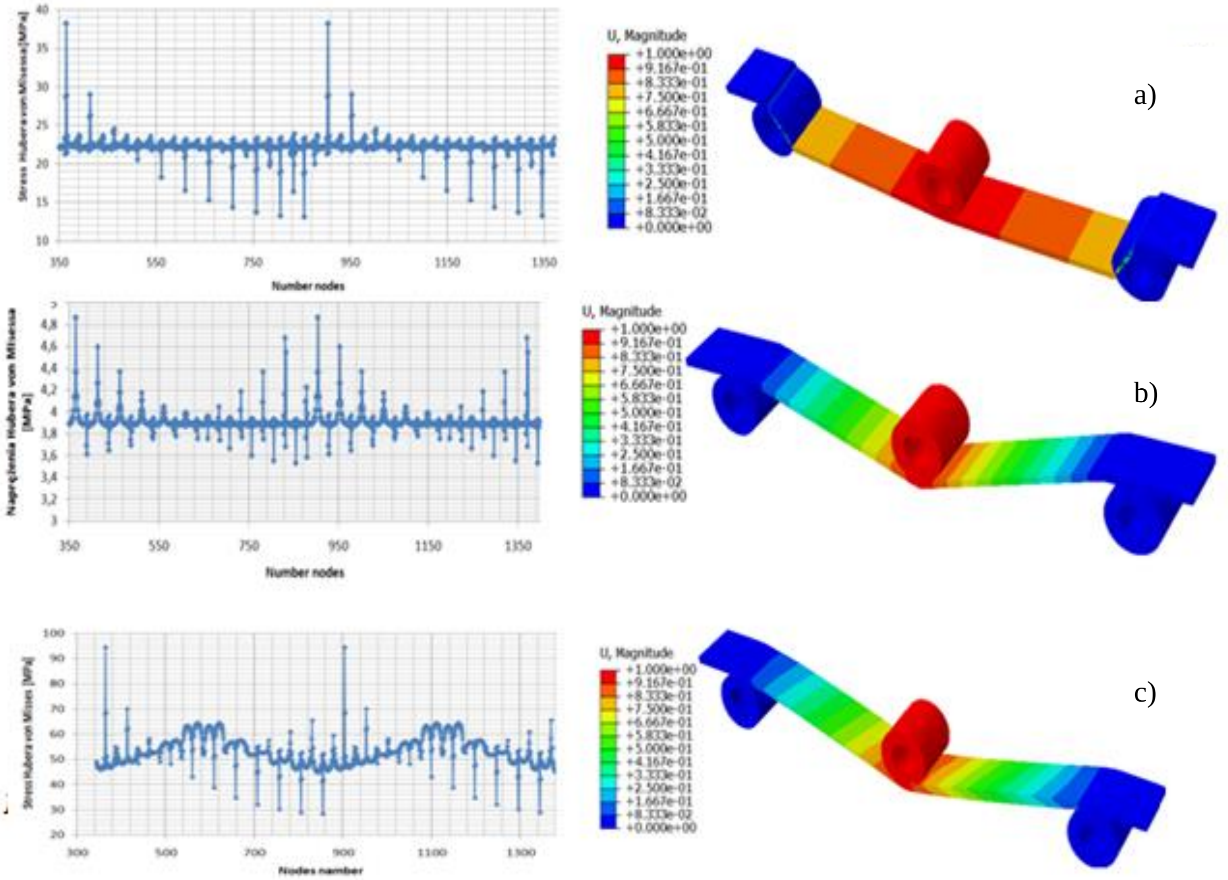



*Fig. 6:Chart Missesa von Huber stress destroying composite installation:*
*a) Destroying composite installation 0 °; b) Destroying composite installation 90 °;*
*c) Destroying composite installation 45 °.*

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