Identification of singular features of polymeric membranes on an example polivinylebutyrale

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Abstract. Laminated car's windshields are constructed of two outer layers of glass and an inner layer of Polyvinyl butyral resin (PVB). The general aim of dealing with these issues is to assess the level of damage of the laminated glass on impact. The research of PVB material is the basic step to understand the behavior of the material as a component of laminated windshield. Quasi-static tensile tests were carried out of PVB samples for strain rate. The resulting curves show that, depending on the strain rate, the material deformed diferently, the level of damage and strength varied. A return to original shape and length of the material was observed after the deformation. It has been proven that PVB is a hypelastic material with strongly non-linear properties. Obtained curves were used to validate the model material in a virtual environment. The same tensile test was made in the FEM system. PVB layer damage simulation was made using the criterion of maximum true strain.

PVB TENSILE TEST

The object of the study was a sample of Polyvinyl butyral material made according to PN-EN ISO 527:1988 standard. The thickness of the sample was equal to 0.76 mm because of the fact, that the majority of automotive laminated glass has an inner layer of PVB exactly this thick. Dimension L = 80 mm is the initial distance between the grips and the L_0=25 mm is the measurement length. The total length of the sample L_3=175 mm has been selected to avoid problems with pulling it out from grips. Execution of the tensile test, required the creation of a complex test system. The test system contained a universal testing machine (LaborTech), force sensor with a measuring range from 0 to 200 N, a digital measuring system Spider 8 (HBM), climatic chamber ESPEC SH-242, grips unit made for the purpose of the test and photo camera with a high resolution.

Quasi-static tensile tests were made with feed rate 5, 25, 50 and 100 mm/min. The force was recorded every 0,1 s with the accuracy of 0,1 N. Displacement measure between the measuring markers of the sample, carried out by periodic photos allowed the accuracy equal to 0,05 mm. After the first trials, due to the very large deformation to rupture, it was decided to use the sample in the scale of 1:2. Comparison of the results for both samples used, gave the same results. Smaller sample allowed faster execution of the test and the results will be a direct reference in the comparison with the second stage of research in the climate chamber.

TENSILE TEST RESULTS

Analysis of the results of a series of tests, allowed the preparation of the characteristics of stress relative to strain of the Polyvinyl butyral material for different strain rates. The maximum strain to the fracture point for the strain

rate 0.0066 [1/s] reached ε=279 %, whereas true stress reached value of σ=92 MPa. Curve in the range of deformation (0÷30 %) it is close linear elasticity, in remainder range (30÷292 %) it is nonlinear elasticity close to the second order polynomial. It can be observed that with increase of the strain rate, stress grows faster for the same strain. Fracture occurs for smaller deformations, but stress during the fracture reaches similar values.

MATERIAL MODEL VALIDATION IN FEM

Tensile simulations were performed for the PVB samples. Curve, true stress - true strain, obtained from the simulation was compared with the input curve, until convergence was obtained. They allowed the selection of the appropriate material model and selecting the appropriate description of the material curve. The final fit obtained for Ogden 2-order material model, using cubic element with eight points of integration and the size of the edge approx. 0.25 mm. Close curves analogy provided only double precision calculation algorithm Implicit.

Summary

Quasi-static tensile test of Polivinyl Butyral material allowed to determine the mechanical properties of the resin. It has been found that Polivinyl Butyral is characterized by hyperelastic properties. Analyzed material was characterized by large strains to fracture, reached 292% at a strain rate equal to 0.0066 [1/s]. The strength of material grows with the increase of the strain rate. Material which was used as an inner supporting layer in laminated windshield, can successfully prevent the process of losing cohesion of the windshield structure despise cracking of the glass.

The results of the material research were used to validate PVB material model in FEM system. It was found that solid elements, cubic with 8 points of integration, give best results of correlation PVB real tensile test with simulation test. Finally, PVB material was described by Ogden 2-order model. The developed method of modeling was used to simulate ball impact to Polivinyl Butyral layer.

REFERENCES

1. P. Kosiński, “Laminated windshield breakage modeling in the context of headform impact homologation test” in *Int. J. of Applied Mechanics and Engineering, vol. 20, no.1*, (2015), pp.87-96.
2. PN-EN ISO 527:1988, *Plastics - Determination of mechanical properties at static tension - Test conditions for films and plater*, (1988).
3. Regulation (EC) No. 631/2009.
4. Regulation (EC) No. 781/2009.
5. M. Timmel, “A finite element model for impact simulation with laminated glass” in *International Journal of Impact Engineering, 34*, (2007).
6. P. Kosiński, P. Żach, „Experimental tests of automotive sandwich Glass” in *XXVII Sympozion PKM*, Conference Proceedings, (2015).
7. P. Kosiński, P. Żach, „Sprzężone zespoły szyb w pojazdach” in *Autobusy bezpieczeństwo i ekologia: Autobusy: Technika, Eksploatacja, Systemy), R. 18 nr 12*, (2017), pp. 257-259.
1. A. Bąkowski, J. Ciosmak, A. Izwoski, T. Orzechowski, L. Radziszewski, Z. Skrobacki, P. Suliga, J. Wydrych, P. Żach, „Selected problems from signal analysis” in *Monographs of the Department of Automation and Processes*, (Katedra Automatyzacji Procesów AGH w Krakowie 2016).
8. P. Żach, “Description of phenomena vibration in hyperdeform polymers materials” in *International Journal of Dynamics and Control, vol. 3, issue 1*, (2015) , pp. 36-40.
9. P. Żach, „The use of composite hyper-deformable materials to damp vibrations at low temperatures” in *Chemical industry, 93 (8)*, (2014), pp. 1296-1300.