36th Danubia-Adria Symposium on Advances in Experimental Mechanics
24-27 September 2019, Plzen, Czech Republic

Poster ID
37

Validation method for thickness variation of thermoplastic microcellular foams using punch tests

Szabolcs Berezvai*, Attila Kossa, Adam K Kiss

Department of Applied Mechanics, Budapest University of Technology and Economics, Budapest, Hungary

Abstract

In the industry there is significant need for the proper characterization of thermoplastic materials for developing accurate finite element (FE) simulations of thermoforming in order to predict and accelerate the production process. One of the key factors that characterize final shape of the part is thickness variation. However, the material characterization process is usually based on uniaxial measurements including creep, relaxation and cyclic tests performed at several temperatures. In this contribution we present a punch-test based on validation procedure via the case study of a thermoplastic microcellular polyethylene-terephthalate (MC-PET) foam material. In the proposed method the thickness variation is investigated both experimentally and numerically, by means of laser scanning method and FE simulations, respectively.

1. Material behavior and constitutive modelling

Material: Microcellular polyethylene-terephthalate (MC-PET)

Model: Two-layer viscoplastic model (TLVP), with…

- nonlinear viscoelastic branch with strain and time hardening creep law
- linear, isotropic hardening with Mises-yield criterion

Fitting: Inverse parameter fitting algorithm using FE simulations

- Uniaxial cyclic test
- Temperatures: 21, 60, 75, 83, 90, 97, 106, 120, 160, 210 °C

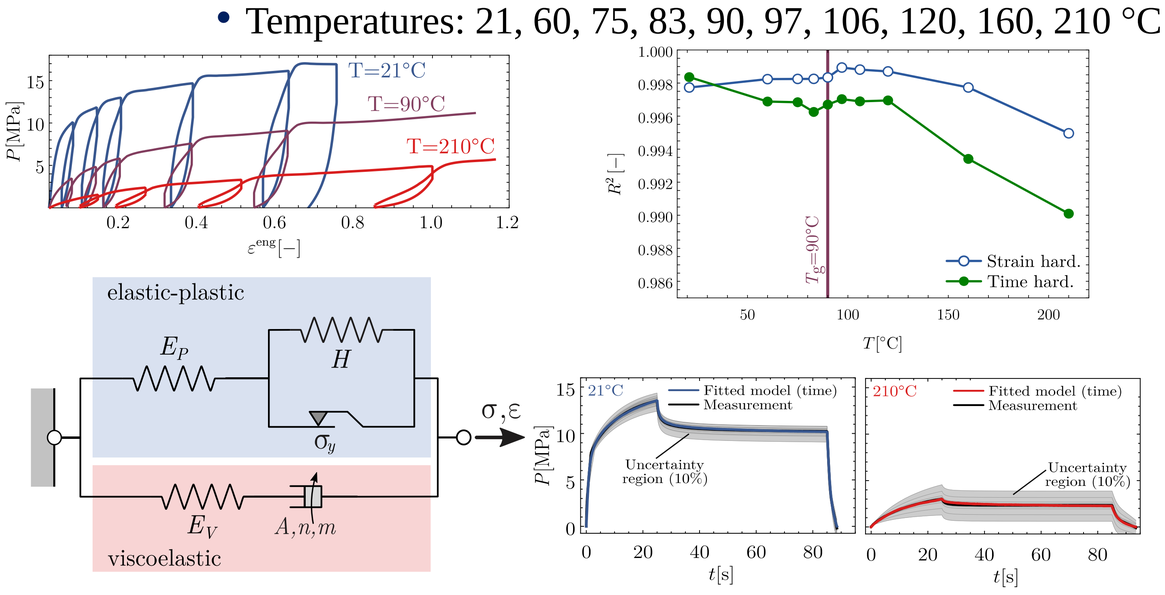

Fig. 1. The mechanical properties of the investigated MC-PET material, the applied TLVP model and the results of the parameter fitting based on uniaxial extension

2. Validation algorithm

Goal: Validate the applicability of the fitted model by means of evaluation of thickness variation under biaxial load case.

Algorithm: **1)** Experimental punch tests with spherical head

2) 3D surface laser scanning of top and bottom surfaces

3) Thickness variation compared with FE results

Punch test: uploading with 500 mm/min, relaxation for 30 s and unloading with 100 mm/min.

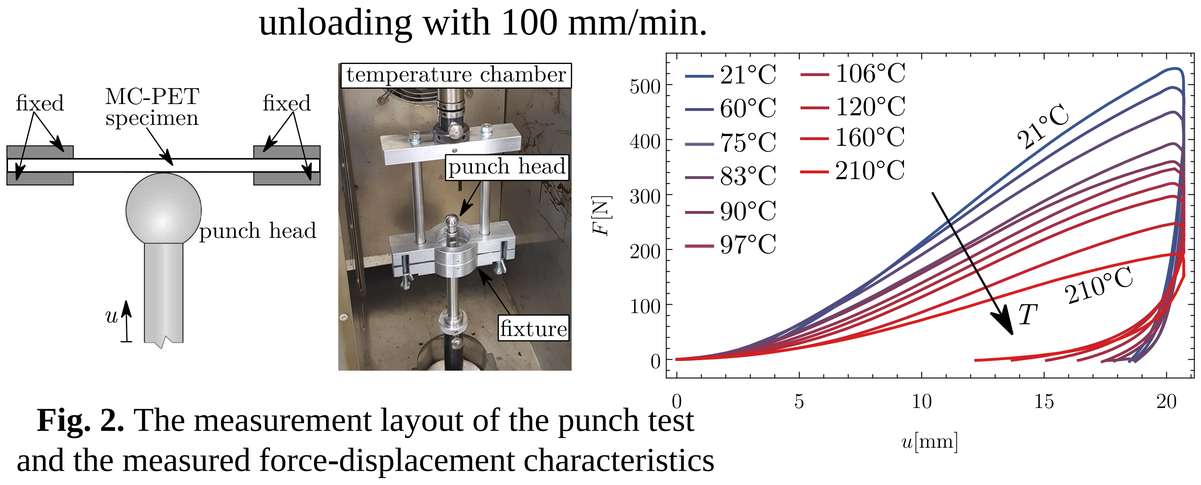

Fig. 2. The measurement layout of the punch test and the measured force-displacement characteristics

Scanning: KEYENCE IL-030 laser differentiation displacement sensor using a predefined zig-zag path performed with high-precision positioning using NCT EmR-610Ms CNC milling machine

Post-process: Synchronization of the time signal of the distance variation recorded by the laser sensor and the position data provided by the CNC machine.

The point clouds corresponding to both top and bottom surfaces of the deformed shape were obtained

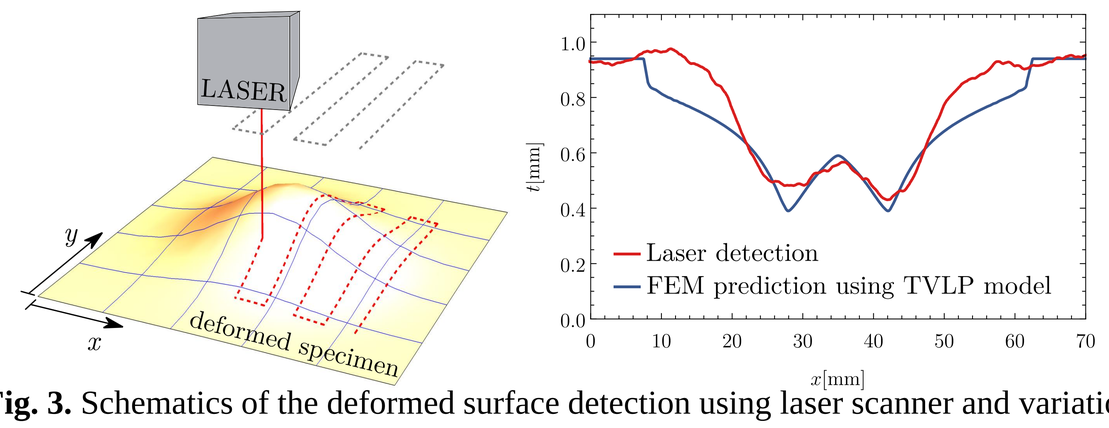

Fig. 3. Schematics of the deformed surface detection using laser scanner and variation of the thickness obtained by FE prediction and laser measurement a T=60°C

3. Results and conclusions

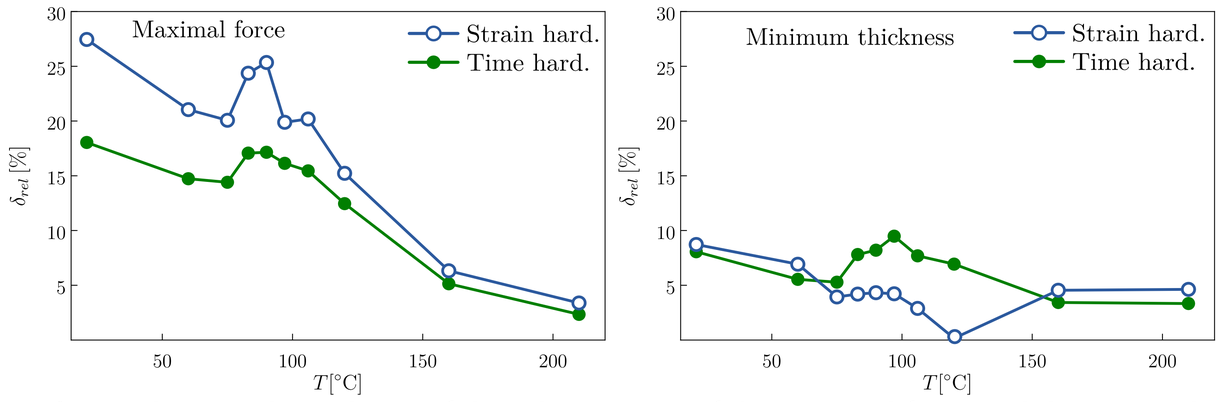

Fig. 4. The time dependence of the relative error of the maximal force and the minimal thickness obtained by punch tests measurements and the FE simulations

We can conclude that:

- an experimental validation method is proposed for thickness variation of thermoplastic materials using punch-tests and laser scanning technique.
- the comparison of the thickness variation obtained by FE prediction and the laser scanning method are in good agreement close to the punch head.
- the relative error of the maximal force varies between 5-30% and significantly decreases at high temperatures, while the error of the minimal thickness is always less than 10%.
- the TLVP model can characterize the material behaviour in biaxial stress-state with adequate accuracy.
- The prediction of the time hardening power law model for the viscous behaviour is more accurate than the strain hardening.

Acknowledgements

This research was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences. The MC-PET foam specimens were provided by Furukawa Electric Institute of Technology Ltd., Hungary. These supports are gratefully acknowledged.

References

[1] Klein, P. W. *Fundamentals of Plastics Thermoforming*; Morgan & Claypool: Boca Raton, 2009.
[2] Berezvai, S., Kossa, A. *Characterization of a thermoplastic foam material with the two-layer viscoplastic model*. **Mater Today-Proc**, 2017, 4(5), 5749-5754.
[3] Bergström, J. Mechanics of Solid Polymers, William Andrew, 2015
[4] Kiss, K. A, Bachrathy, D., Stepan, G. *Laser scanned patterns of machined surfaces*. **Proc CIRP**, 2018, 77, 355-358.

Budapest University of Technology and Economics
Department of Applied Mechanics

*Corresponding author: Szabolcs Berezvai, PhD Candiate, *e-mail*: berezvai@mm.bme.hu