VALIDATION METHOD FOR THICKNESS VARIATION OF THERMOPLASTIC MICROCELLULAR FOAMS USING PUNCH TESTS

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1. Introduction

Thermoforming is a commonly applied industrial process, in which the thermoplastic polymer sheet is heated above its glass transition temperature and gets stretched [1]. In the industry, there is significant need for the proper characterization of thermoplastic materials for developing accurate finite element (FE) simulations in order to predict and accelerate the whole production process [1]. During the forming procedure the material undergoes large and nonlinear deformations which have temperature dependent viscous-elastic-plastic properties [1,3]. In the literature the available constitutive models usually consist of parallel viscoelastic and viscoplastic branches like the two-layer viscoplastic model or the models in the PolyUMod library [2,3].

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. Therefore, the applicability of the fitted model is required to be validated with measurements by means of compare the thickness variation under biaxial load case.

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.

2. Punch tests

The schematics of the axisymmetric punch-test measurement is presented in Fig. 1. A piece of a raw MC-PET material sheet with dimensions of 75×75 mm and thickness of 0.94 mm was placed in a special fixture mounted in Zwick Z010 Testing System equipped with temperature chamber. The displacement-based loading consists of three parts: uploading with crosshead speed of 500 mm/min, relaxation for 30 s and unloading with 100 mm/min. Figure 2 illustrates the experimental punch test data at 10 different temperatures between 21°C and 210°C.

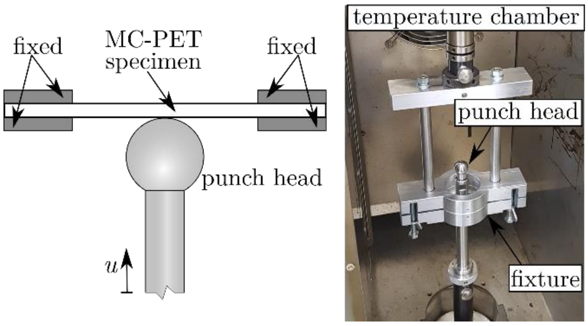

Fig. 1. Measurement layout of the punch test.

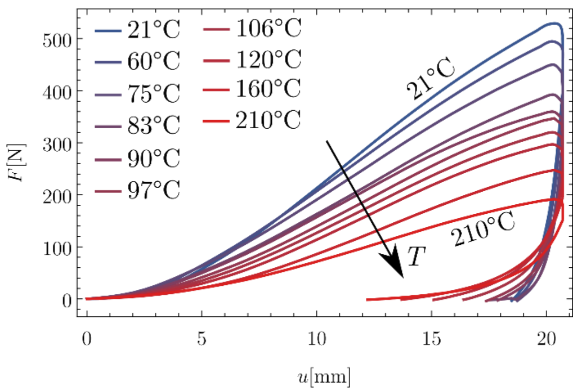

Fig. 2. The measured force-displacement characteristics in case of punch tests with spherical head.

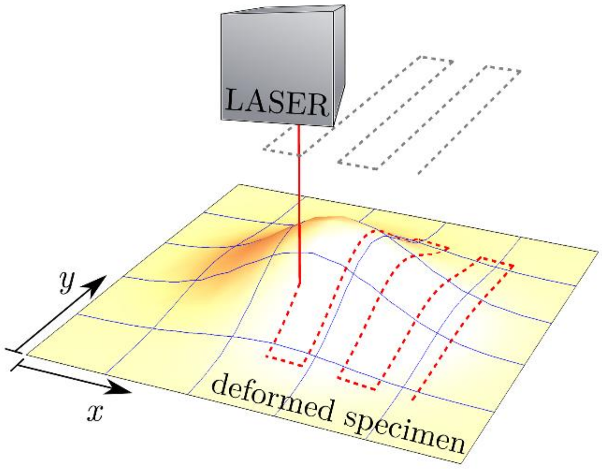

Fig. 3. Schematics of the deformed surface detection using laser scanner.

3. Surface detection

As the punch-tests were performed, the deformed specimens were placed in an NCT EmR-610Ms CNC milling machine, where the top and the bottom surfaces were scanned using a KEYENCE IL-030 Laser Differentiation Displacement Sensor using a predefined zig-zag path as shown in Fig. 3 (for further details of the laser system see [4]). After the 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. Based on the scanned surfaces the sheet thickness variation could be determined along the surface and evaluated along the symmetry axes.

4. Model prediction using FE simulation

As a next step, in order to validate the accuracy of the applied material model, the previously determined thickness variation data were compared to the FE simulation of the punch-test in the commercial software ABAQUS [5].

In this case study, the MC-PET material was characterized by the two-layer viscoplastic (TLVP) model assuming nonlinear strain-hardening creep law and linear isotropic hardening yield stress. The parameters were obtained using inverse FE-based parameter fitting procedure (see [2]) by linking ABAQUS [5] with the optimization software Isight [6]. The comparison of the measured thickness variation and the FE simulation results is presented in Fig. 4.

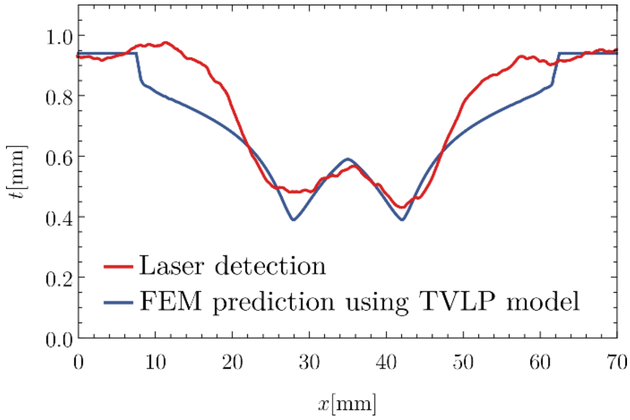

Fig. 4. Variation of the thickness obtained by FE prediction and laser measurement a T=60°C.

5. Conclusions

In this contribution an experimental validation method is proposed for thickness variation of thermoplastic materials using punch-tests and laser scanning technique. In case of the investigated MC-PET material, the comparison of the thickness variation obtained by FE prediction and the laser scanning method are in good agreement close to the punch head. A bit further, however, the discrepancy becomes more significant. Additionally, the results also revealed that the applied TLVP model is able to model the material behaviour in biaxial stress-state with adequate accuracy.

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