EXPERIMENTAL AND NUMERICAL SIMULATION OF MATERIAL AND DAMAGE BEHAVIOUR OF 3D PRINTED POLYMERS IN COMPARISON TO METALS

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1. Motivation

This paper describes the material and damage behaviour of new materials. In the recent years the new materials become more and more interesting in the field of construction materials. One of the main task in this field is the characterisation of these materials due to influence of manufacturing processes. In this sector, rapid prototyping is becoming increasingly important. Products can be produced faster and more cost-effectively using 3D printing. However, the innovative production methods also pose challenges. The new materials must withstand complex loadings, as metals have done so far. In this research project, material and damage behaviour of 3D printed polymers are investigate and compared to metals. For the description of the material behaviour, the viscoplastic model of Chaboche was used, which is already adapted for metals under thermomechanical loading. The Gurson model that is commonly used for cast-iron and steel, was selected to consider the damage behaviour of 3D printed polymers.

2. Material Model

The investigations carried out for 3D printed Polyamid12 (PA12). Specimens were produces by selective laser sintering and manufactured in accordance to DIN EN ISO 527-2 [1]. The material behaviour was characterized according to Haupt [2] with complex experiments. Viscoplastic material behaviour was identified. In this respect, the Chaboche model [3] selected for numerical simulation.

(1)

$$\dot{\boldsymbol{\sigma}} = \boldsymbol{E}(\dot{\boldsymbol{\varepsilon}}^{tot} - \dot{\boldsymbol{\varepsilon}}^{vp})$$

(2)

$$\dot{\boldsymbol{\varepsilon}}^{vp} = \sqrt{\frac{3}{2}} \left\langle \frac{\sqrt{\frac{3}{2}} \left\| \boldsymbol{\sigma}' - \sum_{j=1}^{n_{aa}} \alpha_j \right\| - (y_0 + \sigma^M)}{K} \right\rangle^n \frac{\boldsymbol{\sigma}' - \sum_{j=1}^{n_{aa}} \alpha_j}{\left\| \boldsymbol{\sigma}' - \sum_{j=1}^{n_{aa}} \alpha_j \right\|}$$

This model contains parameters that are determined by different experiments (Eq. 1 and 2). Started with static tensile and relaxation test, followed by dynamic cyclic load tests. After determination of material behaviour and parameters, a microscopic analysis was carried out. Based on the detection of voids caused by the production process of 3D printing, a damage model was investigated.

3. Damage Model

A well-known ductile damage continuum model is the Gurson Tvergaard Needleman (GTN) model [4], [5] which is based on the concept of void nucleation, growth, and coalescence as being the mechanism responsible for damage and failure in ductile metals. Physically motivated by void induced failure process, the GTN model has been widely used to predict load deformation and fracture resistance behaviour of a range of ductile metallic materials such as steel, cast iron, copper, and aluminium. Numerical implementation of the GTN model to polymers is limited primarily because the void nucleation, growth, and coalescence process is not present in most polymers in the same way it is in metals. However, the GTN model (Eq. 3) is a continuum softening and failure model, so an appropriate selection of parameters could make the model applicable to failure of polymers like PA12.

(3)

$$\Phi = \left(\frac{\sigma_e}{\sigma_0}\right)^2 + 2q_1 f^* \cosh\left(q_2 \frac{3\sigma_m}{2\sigma_0}\right) - (1 + q_3 f^{*2}) = 0$$

Although generally good agreements have been reported between numerical and experimental results in the above-mentioned studies of polymers, there is no specific framework on how GTN [6] model parameters can be consistently determined from experiments on polymeric materials, or how a link between experiment and numerical analysis.

The papers presents the application of the GTN model for sheer test for polymeric materials. The study of the polymer material was compared to the results obtained from the study of basic materials such as aluminium. The material parameters for the GTN model were also estimated.

4. Conclusion

This research project has successfully addressed two main topics. On the one hand, it has been shown that the Chaboche model, which has so far been used for metals at high temperatures, can also be used for 3D printed polymers at room temperature and under complex loads. On the other hand, the numerical simulation of the damage behaviour using the GTN model under static loading has shown the same phenomena as in the experiment and revealed good similarities. In the continuing research, the influence of the damage under dynamic loads and a coupling of the material and damage model of Chaboche and GTN are investigated.

References

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