EXPERIMENTAL INVESTIGATION OF THE DEPENDENCE OF THE VISCOELASTIC PROPERTIES OF POLYAMIDE 6 ON TEMPERATURE AND HUMIDITY

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1. Introduction

Environmental influences, like humidity and temperature, strongly affect the mechanical behaviour of polymers (see, for example, [1]). Consequently, this dependence has to be considered within the dimensioning of structural parts made of such materials. This contribution addresses the experimental investigation of the viscoelastic properties of Polyamide 6 under the influence of humidity and temperature. Besides that, first aspects of the development of an appropriate material model are presented.

2. Experimental setup

Aiming for the characterization of the viscoelastic behavior of Polyamide 6, uniaxial relaxation tests are carried out. To investigate the influence of the temperature, the applied 20kN testing machine by Zwick/Roell is extended by a temperature chamber. This temperature chamber enables the heating of the specimen due to the integrated heating elements as well as the cooling of the specimen by fluid nitrogen. Here, specimens with dimensions of 80mm x 10mm x 4mm, made from BASF Ultramid B40 (Polyamide 6) by injections molding, are utilized. To fulfill the requirements from the automotive industry, the tests are conducted in a temperature range from -20°C to 60°C. Within these relaxation tests, the temperature is measured by a thermocouple, which is mounted at the specimen. Additional to the temperature, the influence of the humidity on the mechanical behavior is analyzed. To this end, the specimens are conditioned in a water bath of 80°C. Depending on the duration of the conditioning, different moisture contents are adjusted. To measure the resulting moisture content, Karl Fischer titration is applied. Consequently, specimens with different moisture contents can be tested in the defined temperature range and the dependence of the viscoelastic behavior on temperature as well as on humidity can be investigated experimentally.

3. Experimental results

Applying the described experimental setup, the relaxation tests are conducted for four different moisture contents at seven different temperatures. Each relaxation test is repeated at least three times. Within these relaxation tests, the traverse is initially proceed about 0.75 mm with a speed of 200 mm/min. After a specific strain value has been reached, the strain ε, measured by an extensometer, is kept constant for 550s. During the whole testing, the required force F is detected by the load cell of the testing machine. Fig. 1 shows the averaged results of the relaxation tests performed with the specimens having the cross section area A. Here, the modulus

$$E(t) = \frac{T(t)}{\varepsilon(t)} = \frac{F(t)}{A\,\varepsilon(t)} \qquad (1)$$

is plotted over the time t. With respect to the shown experimental results, the influence of temperature and humidity on the viscoelastic behaviour of the investigated polymer can be identified. Generally, the polymer will be more compliant if the temperature is increased. Furthermore, the relaxation time will reduce. A similar effect can be observed for the moisture content. The lower the moisture content is, the stiffer the polymer is. Furthermore, the relaxation time will increase, if the polymer is drier.

4. Aspects of the development of an appropriate material model

To consider the characterised behaviour, for example, within a finite element simulation, an appropriate material model has to be developed. For this purpose, a concept by [2], which enables material modelling at large strains based on directly connected rheological elements, can be applied. According to this concept, a material model is derived from a rheological model. Here, a generalized Maxwell model can be utilized to

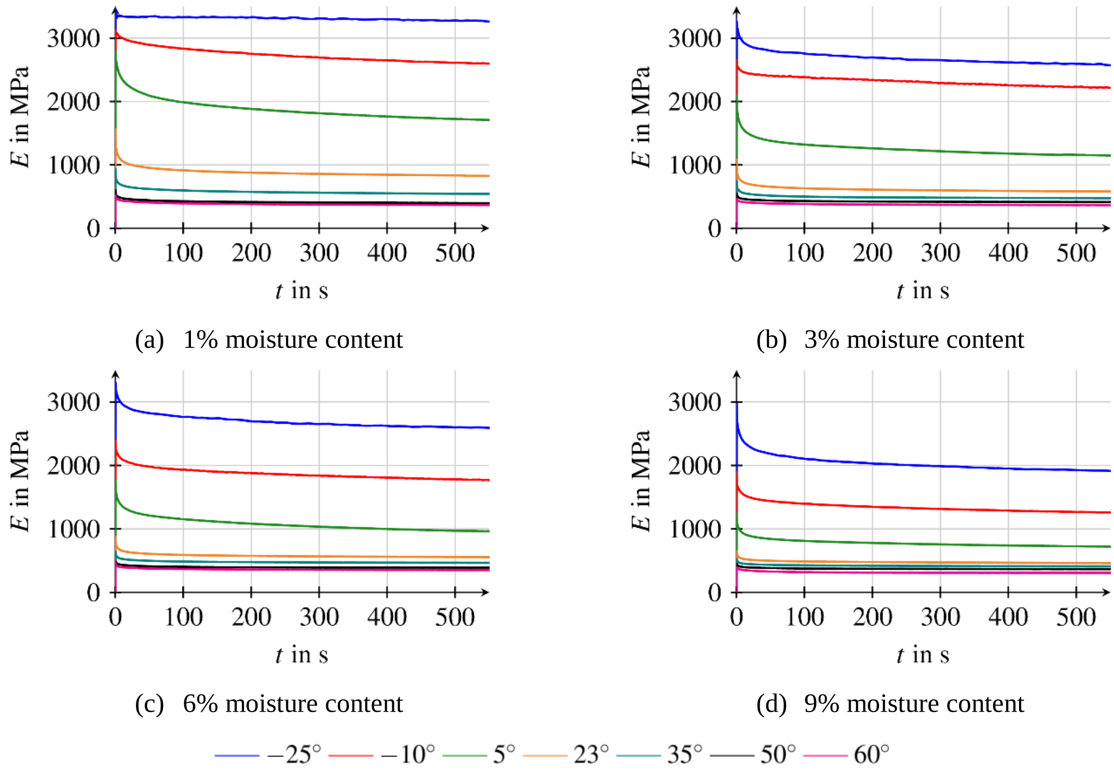

Fig. 1. Results of the performed relaxation tests.

formulate an appropriate material model. As shown in Fig. 2, a generalized Maxwell model consists of a parallel connection of an elastic element with an appropriate number of Maxwell models, i.e. series connections of an elastic element and a viscous element. With respect to this rheological model, a material model at large strains is formulated and implemented. Afterwards, a set of material parameters is identified from each relaxation test, which was carried out for a certain moisture content at a specific temperature. Based on these data, a set of material parameters for a combination of moisture content and temperature, which has not been characterized experimentally, can be determined by interpolation.

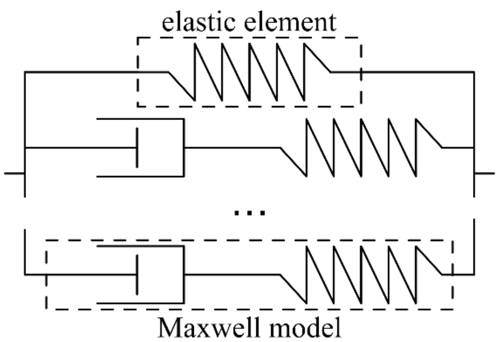

Fig. 2. Generalized Maxwell model.

5. Conclusion and prospect

Within this contribution, the influence of humidity and temperature on the viscoelasticity of Polyamide 6 was investigated experimentally. To this end, relaxation tests at specific temperatures were carried out. Thereby, specimens with different moisture contents were examined. Finally, aspects dealing with the formulation of an appropriate material model were presented.

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