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Investigation on PA/PP mixture properties by means of DMTA method

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Thermal analysis of dynamic mechanical properties (DMTA) is one of the methods for evaluation of changes occurring in polymer materials within broad range of temperature and frequency of changes in load [1,2,3]. Mechanical characteristics received as a result of research done with static load, measured in room temperature are not sufficient to predict material reaction for given conditions of use and for longer periods [4]. In order to characterize PA/PP mixture properties in full and evaluate the way it is going to react in future usage conditions, it is necessary to recognize time and temperature relations of modules defined by viscoelastic functions. Because changes in viscoelastic properties, along with changing temperature, are equivalent to changes in load with time, each viscoelastic function can be expressed as temperature-time dependencies [3, 5, 6, 7, 8, 9, 10]. Load method predicted for experimental measurements, sinusoidally changing, is often similar to load patterns which occur in practical applications for polymer materials. Hence, the viscoelastic functions defined by means of reduced variables method, can be directly used for predictions of viscoelastic properties in broadly changing temperature, time and load frequency conditions and also can express influence of time or application conditions.

1. MATERIALS AND INVESTIGATION METHODOLOGY

For purpose of investigation, domestic thermoplastic materials have been used, namely: polyamide 6 with commercial name of Tarnamid T – 27 and polypropylene with commercial name of Malen PJ – 400.

As chemical coupling and compatibilizing agent, Polibond 3150 [11] has been applied. For investigations some mixtures of composition PA30%/PP70%, PA50%/PP50%, PA70%/PP30% with 2% addition of Polibond have been prepared.

Samples for investigations have been prepared by method of injection with worm injection moulding machine of KM 65 - 160 C1 type with computer control. For comparison purposes some samples made of polyamide 6(Tarnamid T – 27) and polypropylene (Malen J – 400) have been prepared.

Injection parameters have been as follows:
PA 6, mixtures of PA70%/PP30%, PA50%/PP50%: nozzle temperature – 265 ^{0}C; area I temperature - 265 ^{0}C; area II temperature - 260 ^{0}C; area III temperature - 255 ^{0}C, injection pressure - 100 MPa, cooling time - 20 s; PP, mixture of PA30%/PP70%: mouthpiece

temperature - 250 ^{0}C, area I temperature - 250 ^{0}C, area II temperature - 245 ^{0}C, area III temperature - 240 ^{0}C, injection pressure - 100 MPa, cooling time - 10 s.

Samples for dynamic properties investigations by means of DMTA have been shaped as cylinders with the dimensions of 40x10x4 mm. Measurements parameters: isothermal for 30°C, duration time 45 min., frequencies of twisting and bending: 0.01, 0.1, 1, 5, 10, 20, 50, 100 Hz, twisting angle: 0,55 mrad.

2. RESULTS OF INVESTIGATION AND DISCUSSION

In the fig. 1a, course of changes in conservative modulus E' as function of temperature with vibration frequency of 10Hz has been shown.

Within the range of elastic deformations for PA/PP mixtures it is easy to observe little influence of temperature on E' modulus. The highest concentration of PA in the mixture, the more temperature influences E'. Glass transition is the most visible for PP. For this material the largest decrease in conservative modulus as a function of temperature has been observed. For PA/PP mixtures scope of glass transition is less clear, especially with 70% concentration of PA. Within this scope the least decrease in conservative modulus has been observed for the mixture with minimal PP concentration. Within the range of entropic high-elastic deformation the strongest influence of temperature on E' modulus is visible for PP. It is caused by more intensive activity of PP macromolecules. E' modulus value within this range drops to ca. 1350 MPa, while for PA to 600 MPa. Conservative modulus changes pattern in the region of elastic transition is almost the same for all tested mixtures. The strongest declining tendency for modulus as a function of temperature has been observed for PP, while the weakest has appeared for PP.

Temperature dependency of mechanical loss angle tangent is presented in the fig. 1b. Increasing PA concentration in PA/PP mixture results in gradual decrease of $\text{tg}\,\delta(T)$ value.

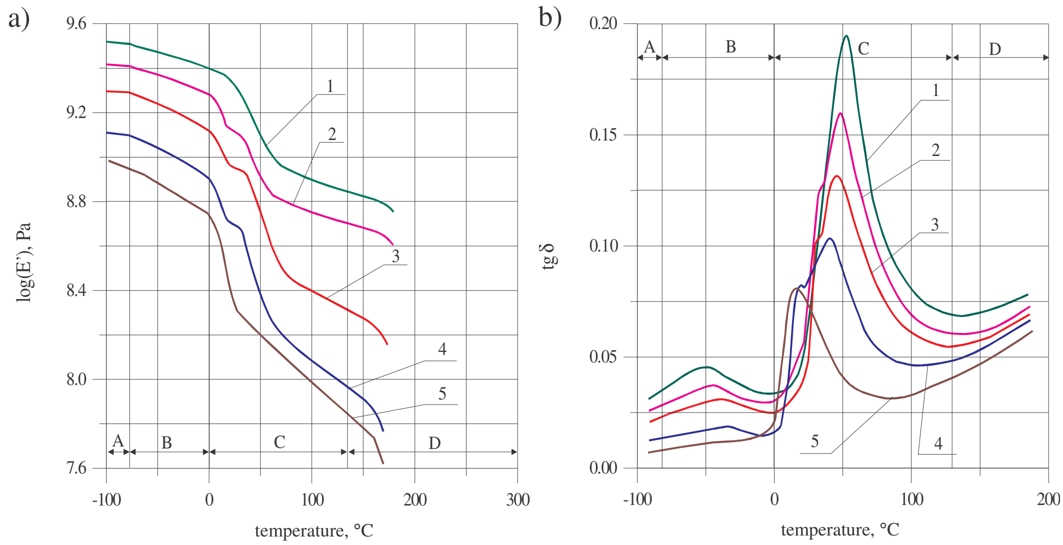

Fig. 1. Course of changes: a) for conservative modulus value, b) for mechanical loss coefficient: 1- PA, 2 – 70%PA/30%PP, 3 – 50%PA/50%PP, 4 – 30%PA/70%PP, 5 – PP; A - elastic deformation phase, B – glass transition phase, C – high-viscoelastic deformation phase, D – elastic transition phase

The highest PA concentration in PA/PP mixture the lowest value of tg δ, similar situation being with maximal values. Dynamic values measurements are universal method of investigation for material reaction under the dynamic forces which are sinusoidally changing. Increase in PA concentration in PA/PP mixture has not caused any crucial changes in pattern of dependencies of mechanical loss angle tangent complex modulus E^*. Along with the increase in PA amount in PA/PP concentration, conservative modulus value (responsible for gathering and transmitting energy during consecutive deformation cycles) increases, while modulus connected with energy dissipation (in the form of heat) value drops.

For engineering application it is assumed that material properties are evaluated basing on Young and Kirchoff modulus. In PA/PP mixtures, which are characterized by viscoelastic properties, Young and Kirchoff modulus change with the load time. Knowledge on these changes is very important for choice of optimal use of these mixtures and hence, for improving their durability. Having reduced curves for Young and Kirchoff modulus (E', E", G', G"), one can estimate the changeability of Young and Kirchoff modulus for tested PA/PP mixtures as a function of time. Between E(t) and G(t) functions and relevant E'(ω), E"(ω) as well as G'(ω), G"(ω) there are mutual dependencies:

$$E(t) = E'(\omega) - 0.4 \cdot E''(0.4 \cdot \omega) + 0.014 \cdot E''(10 \cdot \omega) \quad (1)$$

$$G(t) = G(\omega) - 0.4 \cdot G''(0.4 \cdot \omega) + 0.014 \cdot G''(10 \cdot \omega) \quad (2)$$

for $\omega = 1/t$

Immediately out of the experiment one can receive values of E'(ω), E"(ω), G'(ω) i G"(ω) in reference temperature $T_0 = 25^0$C. Some changes in Young and Kirchoff modulus as a function of time counted on the basis of equation (1) and (2) have been presented in the Fig. 2.

a) b)

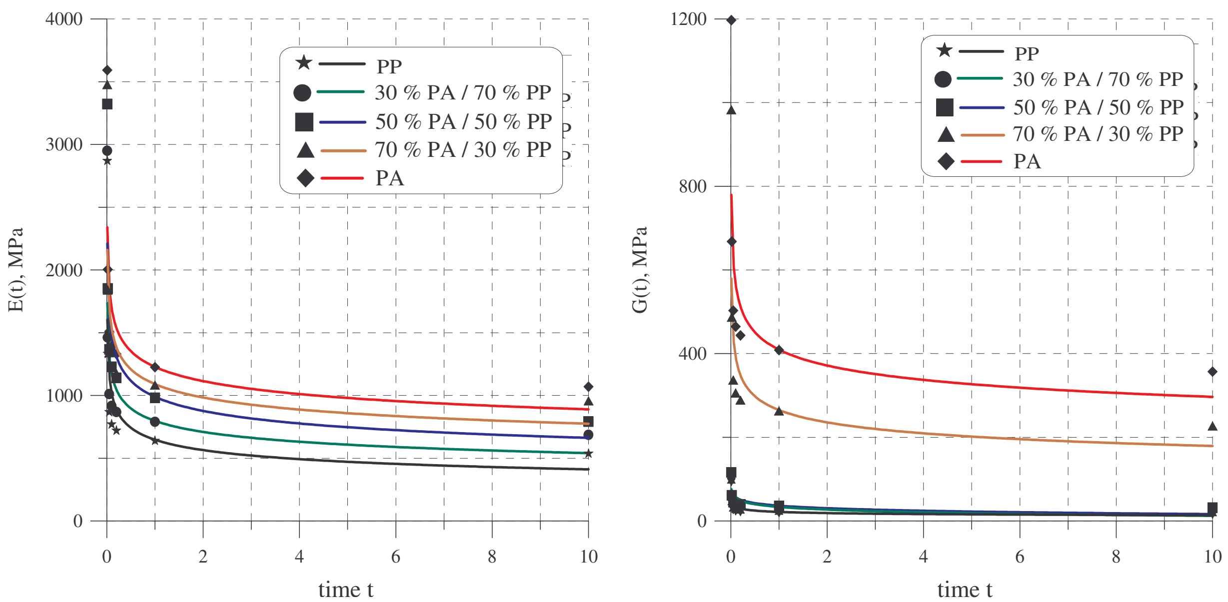

Fig. 2. Course of changes: a) for Young modulus of PA and PP and their mixtures, b) for Kirchoff modulus of PA and PP and their mixtures

3. CONCLUSIONS

By thermal analysis of dynamic mechanical properties (DMTA) some curves of viscoelastic properties changeability have been received, along with change in time and temperature. On the basis of DMTA analysis a course of Young and Kirchoff modulus changes with time calculation have been suggested. High conformity with the experiment has been achieved. For all investigated types of mixtures the highest values have been observed for PP and the lowest for PA. While increasing PP concentration in PA/PP mixture, the ratio of viscoelastic deformation to total deformation has increased.

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