Effect of both temperature and relative humidity on the viscoelastic properties of polyamide 6 determined by contact creep experiments

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The mechanical properties of semi-crystalline polymers are strongly sensitive to environmental conditions (temperature, moisture). Thus, water acts as a plasticizer in aliphatic polyamides and causes a glass transition temperature (Tg) depression. This environmental dependency will have consequences on the (visco)elasticity of the surfaces and so on their contact creep behavior. The effect of both temperature and moisture on the contact mechanics of PA6 surface was therefore investigated by indentation and contact creep experiments.

Keywords: contact creep, semi-crystalline polymers, temperature, moisture

1. Introduction

Polyamide 6 is a temperature and moisture sensitive material due to the presence of two polar groups in its monomer forming hydrogen bonds. This hydrophilic behavior leads to plasticization when PA6 is kept under a damp environment and results in a decrease of the glass transition temperature (T_g) together with a huge degradation of its mechanical properties. The aim of this work is to investigate the influence of the environmental conditions on the (visco)elastic properties of semi-crystalline polymer surface sensitive to moisture.

2. Methods

The macroscopic viscoelastic behavior of several PA6 samples stored at various relative humidity is determined by DMA experiments. In parallel, contact creep experiments were performed thanks to a spherical indenter [1] on polyamide 6 (PA6). During these experiments, the evolution of the contact area is in-situ followed along with the imprint left on the surface, depending on the indentation conditions (creep duration t_c, tip radius R, normal load F), temperature and relative humidity.

3. Results

It is well known that with the increase of temperature the mechanical properties of polymers tend to decrease (Young's modulus, yield stress …). This phenomenon is also observed during spherical indentations on a PA6 surface where the contact radius increases with the testing temperature. Moreover, as illustrated in Fig. 1, for the same indentations conditions and temperature, the contact radius also increases with the moisture content of the tested material, resulting in a decrease of the mechanical properties. The reduction of T_g with moisture could be regarded as an "apparent" increase in the room temperature in such a way that is possible to define an apparent temperature $\tilde{T}$ [2]. It is based on the hypothesis that the distance to T_g is determining in the mechanical response of polyamide.

$$\tilde{T} = T + (T_{g,dry} - T_{g,wet})$$

4. Discussion

From the contact creep experiments performed at room temperature, it was observed that the kinetics of evolution of the contact radius as a function of creep time are different depending on the moisture content of the sample. This must be rationalized with respect to the position of the glass transition in relation to the ambient temperature. Far from Tg the viscoelastic behavior is not well marked and the kinetics are slower compared to the same experiment performed on samples for which Tg is closest to room temperature.

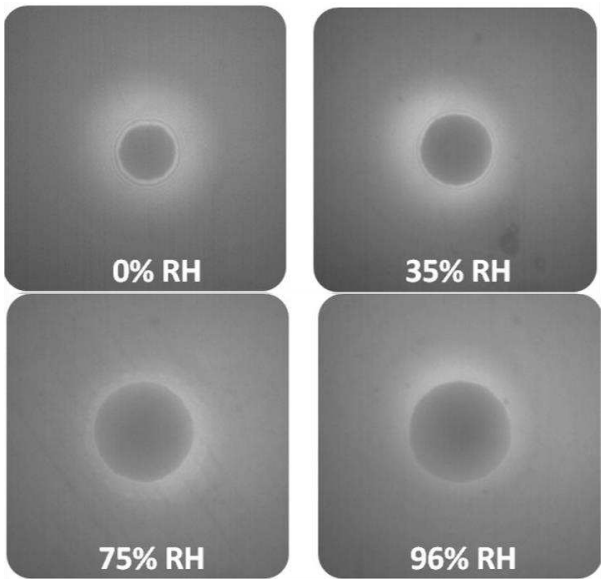

Figure 1: Contact shape between a spherical indenter (R=9.82 mm) and a PA6 surface stored at various relative humidity. Images and creep tests are at the same scale and load respectively.

5. References

[1] Rubin A. et al, "Direct observation of contact on non-transparent viscoelastic polymers surfaces: A new way to study creep and recovery", Prog. Org. Coat. 2016, 99, 134-139

[2] Parodi, E. et al., "Prediction of plasticity-controlled failure in polyamide 6: influence of temperature and relative humidity" J. Appl. Polym. Sci., 2017, 45942.

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