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Effect of humidity on the flexural creep behavior of polyamide 6 and polyamide 6 nanocomposites

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Abstract :

Nano level reinforcement to polymer matrix shows remarkable enhancement in physical and mechanical properties. The aim of the present investigation is to understand the flexural creep behaviour of Polyamide 6 (PA6) and Polyamide 6 nanocomposite (PA6NC) at different relative humidities and at a constant temperature. Experiments were carried out in a flexural creep test rig developed in house, where the deflection of the specimen was measured as a function of time in a controlled atmosphere. Primary and secondary creep curves for both PA6 and PA6NC were obtained at 35%, 60% and 90% relative humidity. The increase in humidity shows an increase in the slope of creep curve for both PA6 and PA6NC and is due to the plasticization of PA6 and PA6NC by the water particles absorbed. It is observed that all humidity levels PA6NC shows better flexural creep resistance than PA6.

Keywords : *polymer nanocomposite, flexural creep, humidity.*

Introduction :

Polymeric materials are replacing the metallic materials in many engineering applications due to its high strength to weight ratio. The properties of the polymers can be improved by reinforcing the polymer matrix with long fibers, short fibers, micro fillers, or nano fillers [1, 2]. Polymer nanocomposites are the materials where nano fillers with high aspect ratio are used as the reinforcement. Various physical and mechanical properties are remarkably improved by addition of nanoparticles to polymer matrix [3, 4]. In engineering applications parts need to sustain short term and long term loadings that too in different environmental conditions. Some of these applications require a deep understanding about the durability and a predictability of the properties under different environmental conditions and over a long time periods. Creep and stress relaxation tests under different conditions can be considered as the useful experiments to study the behaviour of the material during its service and are useful to develop models [5, 6].

The time dependent deformation in viscoelastic material is defined by creep under constant loading. Scaffaro et al. [7] reported the effect of humidity, temperature and ultraviolet on tensile creep behavior and showed that humidity can affect the tensile creep behaviour and the crystalline characteristics polyamide 6. A viscoelastic model was developed for constant and fatigue loading conditions using creep experiments by Wang et al [8]. Zhou et al. [9] reported that nanoparticles addition to the thermoplastic polymers can improve the creep resistance. In most practical applications components are subjected to flexural loading and therefore it is necessary to investigate the flexural behaviour of newly emerging materials. This paper describes the flexural creep behaviour of polyamide 6 (PA6) and polyamide 6 nanocomposite (PA6NC) in different humidity conditions.

Test materials and experiments :

In the present study, melt intercalation technique is used to produce PA6–hectorite based layered silicate nanocomposites. Prior to processing PA6 pellets were dried at 333 K for 24 h in a hot air oven to remove the moisture. PA6 pellets and clay were mixed thoroughly in a screw mixer and fed into a Bernstoff co-rotating twin-screw extruder. The rotation of the screws was maintained at 125 rpm. Specimens were fabricated by injection molding. Prior to injection molding, PA6 and nanocomposite pellets were dried at 333 K for 4 h in a hot air oven. The characterization of the material was reported elsewhere [6].

The injection moulded samples were dried in a vacuum oven. Before starting the test, dry sample was kept in the environmental chamber for 4h. The creep tests were conducted at a flexural creep test rig developed in house at a constant load of 12 N. A non contact type displacement transducer is used to measure the tip deflection as a function of time. The set up was enclosed in an environmental chamber, in which humidity and temperature can be set to the requirement. The time and displacement data were monitored and stored using a data acquisition system and a personnel computer.

Results and discussion :

Figure 1(a) shows the instantaneous deflection at different humidity levels when the load was applied. It can be observed that the instantaneous deflection is significantly influenced by the relative humidity. Moreover the instantaneous deflection is less for PA6NC compared to PA6. The creep curves of the PA6 for a time period of 100h at 35%, 60%, 90% relative humidity is plotted in the figure 2(a). At higher humidity levels the creep resistance of PA6 is reduced. The PA6 samples at 90% humidity were deformed to the maximum limit of the displacement transducer in a time period of ~50h, so that it is reported only in that range. The flexural creep behaviour of PA6NC at different humidity levels are reported in the figure 2(b). In PA6NC rise in humidity has the similar effect as in PA6 however, the amount of deformation due to creep behaviour for the same load is less in PA6NC compared to PA6. The deflection of samples at the end of creep tests are shown in figure 1(b).

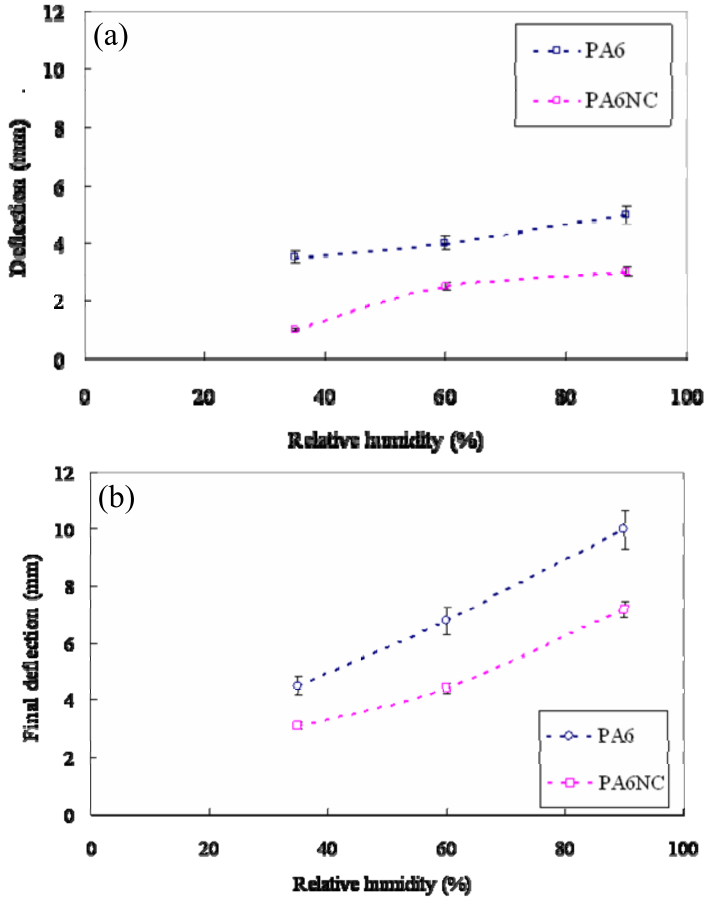

Fig. 1. Tip of deflection of PA6, PA6NC at different relative humidity (a) instantaneous and (b) final

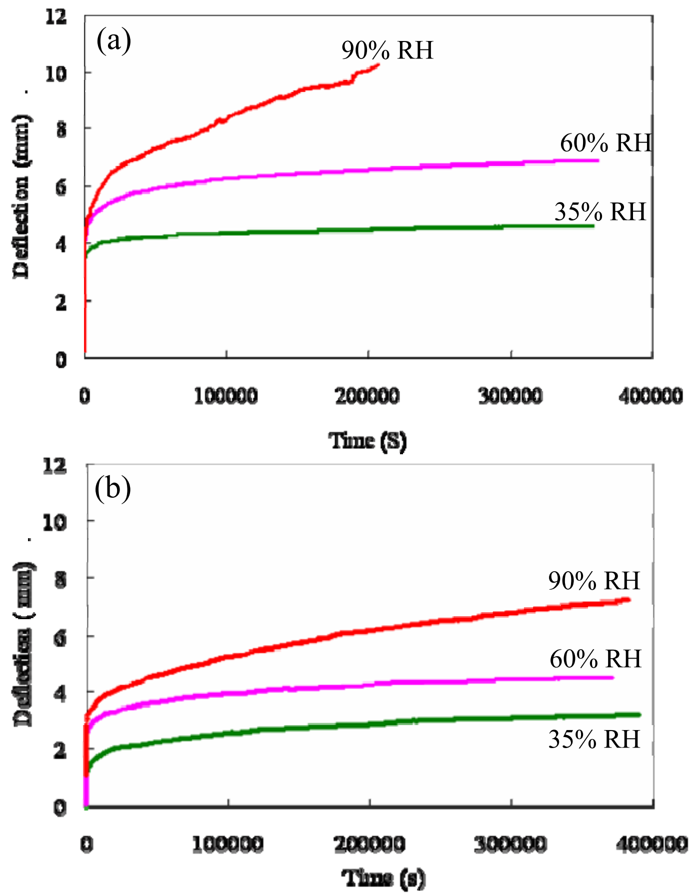

Fig. 2. Creep curves at different relative humidity (a) PA6 and (b) PA6NC

When the relative humidity increases the amorphous part of polyamide absorbs more water from the environment [7]. The water particles absorbed may act as a plasticizer in polyamide matrix [10] and consequently it will decrease the flexural modulus of the material. The outer surface of the specimen, which is exposed to the atmosphere, absorbs moisture initially. The amount of moisture absorbed and depth to which water is penetrated solely depends on the relative humidity of the surroundings for PA6 and PA6NC since all the other conditions are kept constant during the tests. The absorbed moisture at the outer surface influences the initial deflection itself since the maximum stress is experienced at the outer layer in a bending specimen. The creep behaviour in polymers at room temperature is mainly due to its viscoelastic nature [8]. It can be observed from creep data that the humidity affects the viscoelastic behaviors. In all humidities, PA6NC shows better creep resistance than PA6 it is due to improved barrier property [11] and reinforcement due to the addition of nanoclay to the PA6 matrix. PA6NC has a good barrier property and it allows less amount of water to penetrate to the sample compared to PA6 resulting in low plasticization. Due to nanolevel reinforcement, stiffness of the PA6NC is improved and hence the flexural rigidity.

Conclusion :

Based on the flexural creep studies conducted, following conclusions are drawn.

1. The creep behaviour in PA6 and PA6NC is affected by humidity of the environment.
2. Increase in humidity decreases the flexural creep resistance of both PA6 and PA6NC.
3. The instantaneous as well as the final deflection of the sample is affected by the humidity. Both elastic and viscous properties of PA6 and PA6NC are influenced by the humidity.
4. At all humidity levels PA6NC can show better flexural creep characteristics than PA6.

Reference :

(1) Bryan Harris, Engineering composite material, IOM Communications, Michigan 1999.

(2) G. Srinath, R. Gnanamoorthy. Effect of nanoclay reinforcement on tensile and tribo behaviour of Nylon 6, J of Mater Sci. 2005; 40: 2897 – 2901.

(3) G. Srinath, R. Gnanamoorthy. Two-body abrasive wear characteristics of Nylon clay nanocomposites-effect of grit size, load, and sliding velocity. Mater Sci Eng A. 2006; 435–436: 181–186.

(4) D. R. Paul, L. M. Robeson, Polymer nanotechnology: Nanocomposites. Polymer. 2008; 49 : 3187–3204.

(5) A. Ramkumar, Axial and flexural fatigue characteristics of polymer nanocomposites, MS Thesis, January 2009.

(6) Antonio Greco, Claudio Musardo, Alfonso Maffezzoli, Flexural creep behaviour of PP matrix woven composite. Compos Sci. Technol. 2007; 67: 1148–1158.

(7) R. Scaffaro, N. Tzankova Dintcheva, F.P. La Mantia. A new equipment to measure the combined effects of humidity, temperature, mechanical stress and UV exposure on the creep behaviour of polymers. Polymer Testing. 2008; 27: 49–54.

(8) Z. D.Wang, X. X. Zhao, Modeling and characterization of viscoelasticity of PI/SiO_2 nanocomposite films under constant and fatigue loading, Mat. Sci. Eng. A 2007; 486: 517-527.

(9) Tong Hui Zhou, A novel route for improving creep resistance of polymers using nanoparticles, Compos Sci Technol. 2007; 67: 2297-2302.

(10) G. W. Ehrenstein, Richard P. Theriault, Polymeric Materials, Hanser Verlag, 2001.

(11) E. Picard, A. Vermogen, J.-F. Gerard, E. Espuche, Barrier properties of nylon 6-montmorillonite nanocomposite membranes prepared by melt blending: Influence of the clay content and dispersion state Consequences on modeling, Journal of Membrane Science. 2007; 292: 133–144.