CREEP BEHAVIOR OF PARTICLE FILLED EPOXY COMPOSITES

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1. INTRODUCTION

Polymer composites used in engineering applications are often subjected to stress for a long time and at high temperatures. Creep is very important end-use property for material applications requiring long term durability and reliability. Addition of nano/micro fillers to polymers has shown improvements in the strength and stiffness of the resulting composites, however, research shows that these fillers tend to plasticize the composites [1]. The objective of the present study is to investigate the incorporation of different organic (agave, cornhusk, jute) and inorganic (fly ash, carbon, basalt and glass) particulate filler on the creep behavior of epoxy composites.

2. MATERIAL AND METHODS

Three different cellulosic fibers were used (i.e. Agave Americana, cornhusk and jute). The glass, carbon and basalt fibers were selected for preparation of inorganic particles. The fly ash particles were received from the city of Plzeň located in the Czech Republic. Epoxy LH385 and Hardener H538 were procured from HAVEL Composites, CZ s.r.o. Svèsedlice.

2.1 Pulverization

Milling of all fibrous wastes as well as fly ash was carried out for 30 min using a high-energy planetary ball mill of Fritsch pulverisette 7 in a sintered corundum container with zirconia balls of 10 mm diameter. The ball mill was loaded with ball to material ratio of 5:1. The rotation speed of the planet carrier was kept 850 rpm.

2.2 Composite fabrication

The composites were fabricated by hand lay method (see Figure 1). As per resin manufacturer's guidelines, resin to hardener ratio was kept to 100:35. In this resin mixture, 3 wt% fillers were added. The curing of composites was done at *50*⍰ for 180 minutes in oven.

2.3 Dynamic mechanical analysis

Dynamic mechanical properties of the composites were tested on DMA DX04T RMI instrument, Czech Republic. The test was performed in three-point bending mode with gauge length and sample width of 50 mm and 10 mm respectively. The samples were subjected to an oscillating frequency of 1 Hz, 5 Hz and 10 Hz at 100 % oscillating amplitude in the temperature ranges of *30*⍰ to *150*⍰ at the heating rate of *3*⍰/⍰⍰⍰.

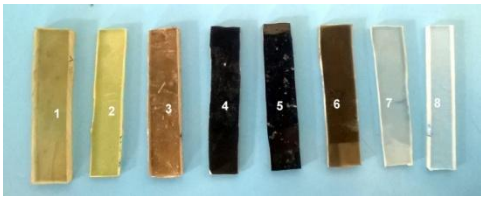

Figure 1. Micro/Nano particulate filled composites: 1. Agave Americana, 2. Cornhusk, 3. Jute, 4. Fly Ash, 5. Carbon, 6. Basalt, 7. Glass, 8. Neat Epoxy

2.4 Creep testing

Short-term creep tests were performed in three point bending mode at temperatures 40◦C using Q800 Dynamic mechanical thermal analysis instrument of TA instruments (New Castle DL, USA). The static stress of 1.0 MPa was applied for 30 min after equilibrating at the desired temperature and creep strain was measured as a function of time.

3. RESULTS AND DISCUSSIONS

3.1 Dynamic mechanical analysis

Damping factor. Figure 2 shows the effect of temperature, frequency and filler on damping factor of epoxy composites. It can be inferred that as temperature increased, there was increase in damping behavior of composite. Further, damping was found to reduce with increase in frequency of oscillation. It was also observed that damping behavior changed with the type of filler incorporated. This is mainly due to shear stress concentrations at the filler in association with the additional viscoelastic energy dissipation in the matrix material [2]. Improvement in interfacial bonding in composites occurs by lowering tan δ values. Therefore, higher values of damping at the interfaces showed poor characteristics of the interface adhesion. Amongst organic fillers, lowest damping factor was observed with Agave Americana particles, this means that Agave Americana fibers particles has better interface adhesion with epoxy resin. Basalt, fly ash and glass particles have almost similar damping factors confirming better interface adhesion with epoxy.

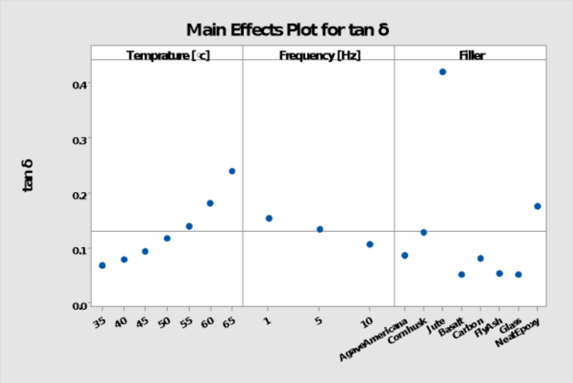

Figure 2. Main effects plot for damping factor

Storage modulus. Figure 3 shows effect of temperature, frequency of oscillation and filler on the dynamic modulus of the epoxy composite. It can be clearly seen that as temperature increases there is reduction in the storage modulus of composites. The lowering of the modulus values occurred due to increased segmental mobility of polymer chains at higher temperature [3]. Increase of frequency has been found to increase the modulus values. Frequency has a direct impact on the dynamic modulus. If a material is subjected to a constant stress, its elastic modulus will decrease over a period of time. This is due to the fact that the material undergoes molecular rearrangement in an attempt to minimize the localized stresses. Modulus measurements performed over a short time (high frequency) result in higher values whereas measurements taken over long times (low frequency) result in lower values. There is significant effect of filler on the storage modulus of composites. It was observed that addition of filler increases the storage modulus of epoxy resin. Decrease in the storage modulus was observed in case of Agave Americana fillers. This is due to poor dispersion of micro/nano particles and agglomeration. All inorganic fillers showed comparatively higher storage modulus than organic fillers.

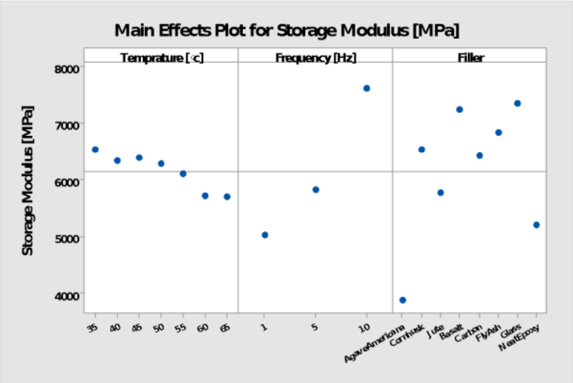

Figure 3. Main effects plot for storage modulus

3.2 Creep testing

Figure 4 shows the creep strains for various particle filled composites as a function of time at 40 °C. The particle filled composites exhibited less creep deformation than the neat composites due to decrease in frictional slippage of matrix polymer chains at the fiber/matrix interface [1]. Further, it was observed that the composites filled with inorganic particles have low creep strain due to higher stiffness of inorganic fillers over organic fillers. Among organic fillers, the creep strain of corn husk particle filled composites was affected most. On the other hand, the creep behavior of composites filled with inorganic fillers almost showed similar behavior without distinct difference between inorganic particles. The least creep strain was found in case of fly ash particles due to their better adhesion with epoxy resin.

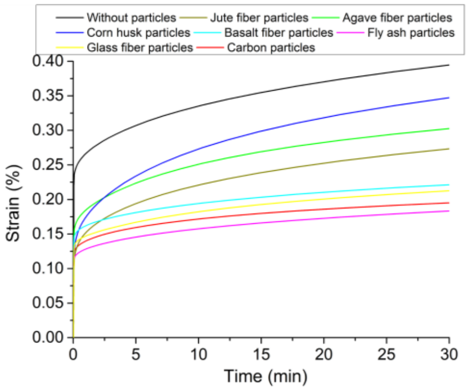

Figure 4. Creep behavior of particle filled composites

4. CONCLUSIONS

In this study, creep behavior of epoxy composites incorporated with 3 wt% of different organic and inorganic fillers (obtained from waste materials) was presented. The creep resistance of composites was found to improve significantly with the incorporation of inorganic fillers than the organic fillers.

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