Prediction of temperature-dependent properties of short fiber reinforced thermoplastic by unit cell analysis

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Introduction. The behavior of short fiber reinforced thermoplastic is viscoelastic-viscoplastic materials and depends on temperature. Viscoelastic-viscoplastic analysis is used to predict the behavior of short fiber reinforced thermoplastic⁽¹⁾. However, further development of the analysis method is needed to predict the actual behavior.

In this study, stress-strain curves of short fiber reinforced polybutylene terephthalate (PBT) are predicted by finite element method of elastoplastic (EP) analysis or viscoelastic-viscoplastic (VEVP) analysis⁽²⁾. Moreover, fiber break and interfacial debonding between the fiber and the matrix are introduced in the analysis.

Finite element modeling. Stress-strain curve is predicted by using various unit cells with respect to the fiber length distribution and the fiber orientation angle distribution according to the actual specimen. Then, a laminate analogy approach is applied to the results

obtained by unit cell analyses in order to predict macroscopic stress-strain curve. In this study, EP analysis or V EVP analysis is assumed that the matrix is elastoplastic material or viscoelastic-viscoplastic material, respectively. Those material properties are determined by the experiments for unreinforced material under various temperature.

In addition, the effect of fiber break and interfacial debonding is examined for the composite consisting of unidirectional fiber and V EVP matrix.

Results. Figure 1 shows macroscopic stress-strain curves evaluated by experiments and predicted by the EP analysis and V EVP analysis. At 40 °C, the both of EP analysis and V EVP analysis are in good agreement with the experiment in small strain. In plastic region, the stress of EP analysis is much smaller than that of the experiment. The stress of V EVP analysis is close to the experiment except large strain region. The differences in large strain region between the V EVP analysis and the experiment are thought to be lacks of damage mechanisms in the analysis. At 50 °C and 60 °C, all analysis results are smaller than experimental results because of the nonlinear viscoelasticity of the matrix.

Figure 2 presents the experiment and the analysis results including fiber break and interfacial debonding. These analyses are in good agreement with the experiment. The analysis modeled only fiber break indicates that fibers break in order of decreasing fiber length after strain of 0.02. Multiple fiber break is observed in the fibers longer than 0.4 mm, but fibers less than 0.2 mm do not break. The stress in each unit cell is smaller than 120 MPa. The analysis modeled both of fiber break and interfacial debonding shows the interfacial debonding at fiber edges and the stiffness reduction cause by the increase of the interfacial opening displacement. Fiber break is not observed in this analysis. The analysis modeled only fiber break is thought to be high reproducibility of the stress-strain curve at large strain.

Conclusions. Viscoelastic-viscoplastic analysis is suitable for prediction of the behavior of the short fiber reinforced PBT. In addition, fiber break is needed to the prediction of the behavior in large strain region.

References.

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Fig.1 Macroscopic stress-strain curves evaluated by experiments and predicted by the FE analyses.

Fig. 2 The experiment and the analysis results including fiber break and interfacial debonding.