Stress-Strain Modeling of Polypropylene Composite

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Abstract
The strain rate dependency of the initial modulus (E_i), secant modulus at yield (E_o), and of the yield stress, (σ_y), of glass fiber reinforced polypropylene (GF-PP) were investigated and modeled along with the stress strain relationship. The GF-PP had a density of 1940 kg/cm^3. The tensile test specimens were directly machined out of the pipe insulation system. The strain rate, , of loading was varied from 0.30%/min to 35%/min. The stress strain relationship of the composite polymer in tension was elasto plastic with hardening and a stress strain model was used to predict the behavior.

1. Introduction

Glass fiber reinforced polypropylene is used in deep water pipeline insulation system to increase the thermal insulation capacity of the steel pipeline and its stability (Hunter, 2008). Glass fiber is a high strength brittle inorganic material. The densities of the ones used in composites range from approximately 2.11 to 2.72 g/cm^3. Glass fibre reinforced polypropylene is a mixture of glass fibre of variable length, 0.1mm to 50 mm and lower as 150 μm to 300 μm (Fu, Lauke, Mäder, Yue, & Hu, 2000), with polypropylene as matrix. Addition of glass fiber to polypropylene increases its stiffness but decrease its ductility (Lauke & Fu, 2013). The composite stress strain behaviour is a function of its components individual properties and proportion (Cox, 1952).The stress strain behaviour of GF-PP varied consequently with it components proportion and size.

2. Objective

The objective of this study was to develop relationships between the stress-strain model parameters and the strain rate of loading off the PP composite.

3. Testing

The tensile test specimens of the glass fiber reinforced polypropylene were machined out of the insulation layers. Direct tensile tests were performed on the dog bone specimens following ASTM D638-03 at room temperature. The tests were displacement control and the strains were recorded using extensometers. The strain rate of loading was calculated as average of the strain read from the strain gage divided by the duration of the test, and ranged from 0.3%/min to 35%/min.

4. Result and Discussion

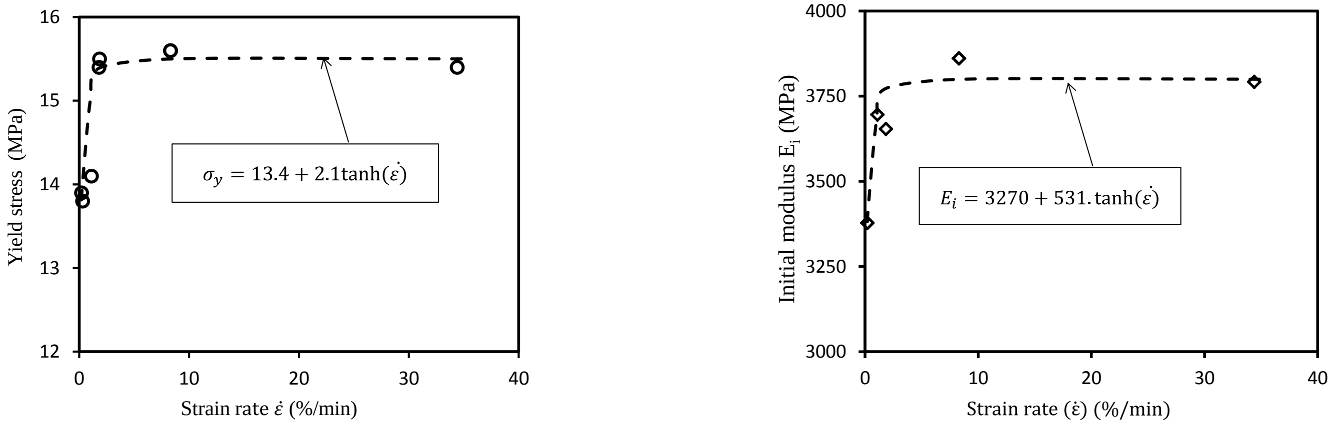
Four parameters were determined from each stress-strain curve: yield stress (σ_y), yields strain (ε_y), initial elastic modulus (E_i), and the secant modulus at yield (E_o). The initial modulus is the Young's modulus, the initial slope of the stress-strain curve. The secant modulus at yield is obtained by dividing the yield stress by the yield strain. The initial modulus, the secant modulus and the yield strength evolution with the strain rate were modeled as followed at room temperature:

; ; Eq. (1)

where *A, B, C, D, E* and *F* are material parameters.

A is the yield stress of the composite in direct tensile test at strain rate nearly 0 and *B* is the rate at which the yield stress would increase in a linear relation, see Fig. 1. According to equation (1), the plot of the yield stress vs. should give a straight line. The slope of the straight line is the value of parameter *B* and its intersection with the Y-axis is the value of parameter *A*.

To use equation (1)., an appropriate dimension of strain rate has to be selected or a reference strain rate. the evolutions of the initial modulus, E_i, and of the secant modulus at yield, E_o, were also defined



a) *b)*

Figure 1. a) Variation of the yield stress with the strain rate. b) Variation of initial modulus with strain rate.

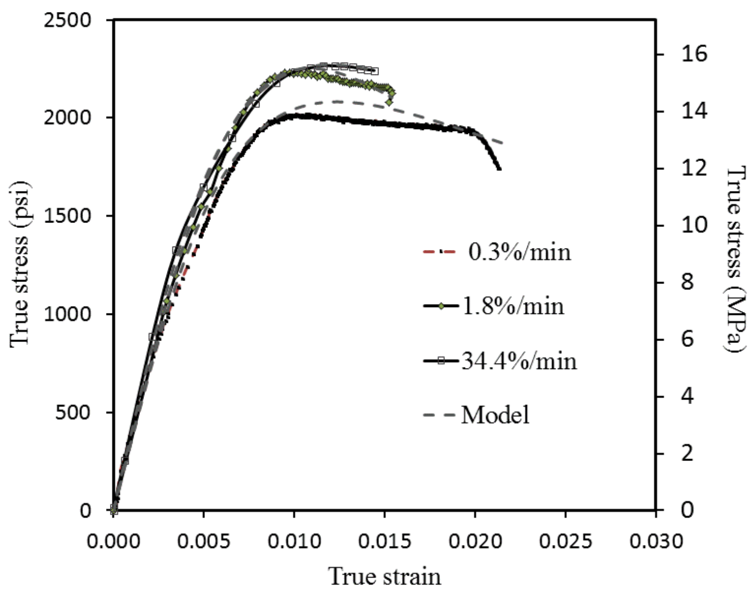


Figure 2. Stress-strain curves and the proposed model results.

5. Modeling approach

A modification of Mantrala and Vipulanandan (1995) stress strain model is introduced as follows:

………….. Eq. (2)

The parameter — and p is material parameter. The applied model results are shown in Fig. 2. The prediction was very good.

6. Conclusion

A model was proposed to capture the variation of the yield strength, initial modulus and secant modulus with strain rate of loading. A stress model was introduced.

7. Acknowledgements

This work was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT).

8. References

Cox, H. L. (1952). The elasticity and strength of paper and other fibrous materials. *British Journal of Applied Physics*, *3*(3), 72–79. doi:10.1088/0508-3443/3/3/302

Fu, S.-Y., Lauke, B., Mäder, E., Yue, C.-Y., & Hu, X. (2000). Tensile properties of short-glass-fiber- and short-carbon-fiber-reinforced polypropylene composites. *Composites Part A: Applied Science and Manufacturing*, *31*(10), 1117–1125. doi:10.1016/S1359-835X(00)00068-3

Hunter, R. (2008). Wet insulation evolves to meet subsea flowline performance demands. *Offshore (Conroe, TX)*, (October).

Lauke, B., & Fu, S.-Y. (2013). Aspects of fracture toughness modelling of particle filled polymer composites. *Composites Part B: Engineering*, *45*(1), 1569–1574. doi:10.1016/j.compositesb.2012.07.021

Mantrala, K S , Vipulanandan, C. (1995). Nondestructive Evaluation of Polyester Polymer Concrete. *ACI Materials Journal*, *92*(6), 660–68.