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LONG-TERM PERFORMANCE OF CONTINUOUS FIBER REINFORCED THERMOPLASTIC COMPOSITES

Ozan Erartsin(*), Leon E. Govaert
Chair of Production technology, University of Twente, Enschede, Netherlands
(*)*Email:* o.erartsin@utwente.nl

ABSTRACT

Pure and fiber-reinforced thermoplastic polymers are prone to failure under creep loading due to high molecular mobility they possess, which renders lifetime prediction under creep loading crucial. Pure and short fiber-reinforced composites were shown to exhibit two main stress-dependent failure mechanisms depending on the magnitude of creep stress applied: plasticity-controlled and crack growth controlled failure mechanisms, which can be identified by comparing the lifetimes in static and cyclic fatigue at equal value of maximum stress [1]. In this work, the same procedure is applied to transversely loaded unidirectional (UD) composites for identification of failure mechanisms to develop lifetime prediction models and acceleration methods based on them. Plasticity controlled failure mechanism was observed for continuous fiber-reinforced UD composites as well.

Keywords: long-term, creep, thermoplastic, composite, lifetime.

INTRODUCTION

As shown in Fig. 1, although failure mechanisms are macroscopically apparent in pure polymers, this is not the case for short fiber-reinforced polymers. The latter exhibited macroscopically brittle failure regardless of the stress level although stress vs time-to-failure graph was still bilinear. Kanters *et al*. [1] observed that, at equal value of maximum stress, cyclic fatigue resulted in longer lifetime at higher stress levels and shorter lifetime in lower stress levels, which showed failure, is still controlled by plasticity at high loads even though failure looks macroscopically brittle.

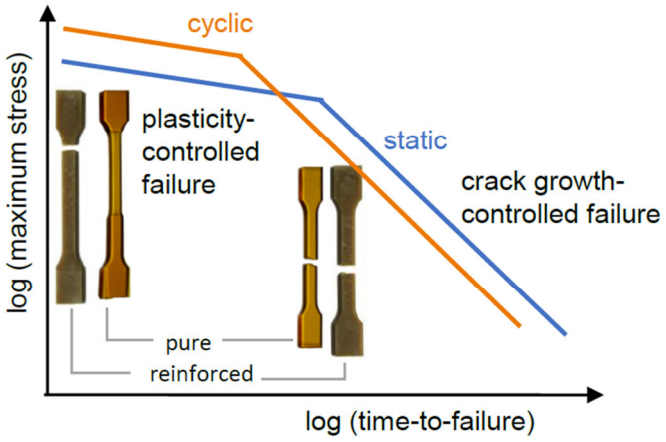

Fig. 1 - Influence of dynamic loading on plasticity-controlled and crack growth-controlled failure of pure and short fiberglass-reinforced polyethylenimine (PEI)

In this study, the aim is to determine the failure mechanisms under static and cyclic fatigue in transversely loaded UD composites and develop acceleration methods and lifetime prediction models by taking failure mechanisms into account. UD specimens are manufactured by hot pressing. Constant strain rate tensile tests and constant stress creep tests are conducted at different environmental temperatures to characterize failure kinetics of transversely loaded 90° iPP/glass UD laminates. Cyclic loading is applied to identify failure mechanisms.

RESULTS AND CONCLUSIONS

At high stresses, dependence of lifetime on creep loading and tensile strength on applied strain rate are found to be related to each other by the same slopes (but with different signs) as shown in Fig. 2, which can be used as a tool to predict the lifetime under creep loading by utilizing short term tests. At high stress levels, cyclic loading caused an increase in lifetime at high stresses, which shows that failure is plasticity controlled and negates the common belief in the literature that dynamic loading would accelerate the failure.

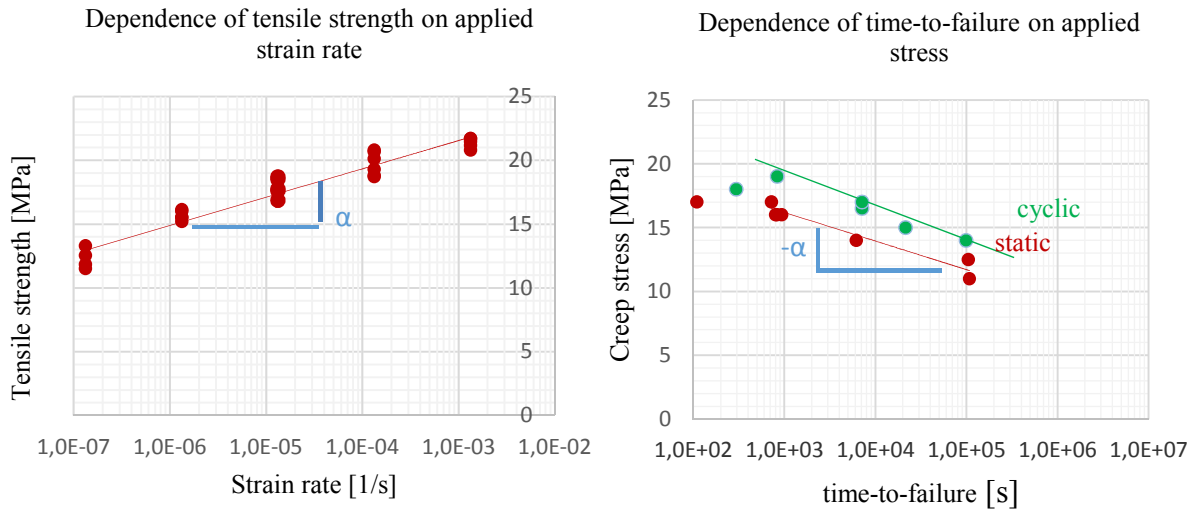

Fig. 2 - Strain rate dependence of the tensile strength and stress dependence of time-to-failure in static and cyclic loading for 90° glass/iPP specimens

Cyclic loading will be applied at lower stress levels as well to observe crack growth-controlled failure. Several other material systems such as carbon/PEEK and glass/polyamide will be studied.

REFERENCES

[1]-M. J. W. Kanters, T. Kurokawa, and L. E. Govaert, “Competition between plasticity-controlled and crack-growth controlled failure in static and cyclic fatigue of thermoplastic polymer systems,” Polym. Test., vol. 50, pp. 101-110, 2016.