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Influence of Temperature and Immersion on the Behavior of a Polymer Composite

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Abstract : This study presents an experimental and theoretical work conducted on a PolyPhenylene Sulfide reinforced with 40%wt of short glass fibers (PPS GF40) and its matrix. Thermoplastics are widely used in the automotive industry to lightweight automotive parts. The replacement of metallic parts by thermoplastics is reaching under-the-hood parts, near the engine. In this area, the parts are subjected to high temperatures and are immersed in cooling liquid. This liquid is composed of water and glycol and can affect the mechanical properties of the composite. The aim of this work was thus to quantify the evolution of mechanical properties of the thermoplastic composite, as a function of temperature and liquid aging effects, in order to develop a reliable design of parts. An experimental campaign in the tensile mode was carried out at different temperatures and for various glycol proportions in the cooling liquid, for monotonic and cyclic loadings on a neat and a reinforced PPS. The results of these tests allowed to highlight some of the main physical phenomena occurring during these solicitations under tough hydro-thermal conditions. Indeed, the performed tests showed that temperature and liquid cooling aging can affect the mechanical behavior of the material in several ways. The more the cooling liquid contains water, the more the mechanical behavior is affected. It was observed that PPS showed a higher sensitivity to absorption than to chemical aggressiveness of the cooling liquid, explaining this dominant sensitivity. Two kinds of behaviors were noted: an elasto-plastic type under the glass transition temperature and a visco-pseudo-plastic one above it. It was also shown that viscosity is the leading phenomenon above the glass transition temperature for the PPS and could also be important under this temperature, mostly under cyclic conditions and when the stress rate is low. Finally, it was observed that soliciting this composite at high temperatures is decreasing the advantages of the presence of fibers. A new phenomenological model was then built to take into account these experimental observations. This new model allowed the prediction of the evolution of mechanical properties as a function of the loading environment, with a reduced number of parameters compared to precedent studies. It was also shown that the presented approach enables the description and the prediction of the mechanical response with very good accuracy (2% of average error at worst), over a wide range of hydrothermal conditions. A temperature-humidity equivalence principle was underlined for the PPS, allowing the consideration of aging effects within the proposed model. Then, a limit of improvement of the reachable accuracy was determinate for all models using this set of data by the application of an artificial intelligence-based model allowing a comparison between artificial intelligence-based models and phenomenological based ones.

Keywords : aging, analytical modeling, mechanical testing, polymer matrix composites, sequential model, thermomechanical
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