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Multi-Scale Damage Modelling for Microstructure Dependent Short Fiber Reinforced Composite Structure Design

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Abstract : Due to material flow during processing, short fiber reinforced composites structures obtained by injection or compression molding generally present strong spatial microstructure variation. On the other hand, quasi-static, dynamic, and fatigue behavior of these materials are highly dependent on microstructure parameters such as fiber orientation distribution. Indeed, because of complex damage mechanisms, SFRC structures design is a key challenge for safety and reliability. In this paper, we propose a micromechanical model allowing prediction of damage behavior of real structures as a function of microstructure spatial distribution. To this aim, a statistical damage criterion including strain rate and fatigue effect at the local scale is introduced into a Mori and Tanaka model. A critical local damage state is identified, allowing fatigue life prediction. Moreover, the multi-scale model is coupled with an experimental intrinsic link between damage under monotonic loading and fatigue life in order to build an abacus giving Tsai-Wu failure criterion parameters as a function of microstructure and targeted fatigue life. On the other hand, the micromechanical damage model gives access to the evolution of the anisotropic stiffness tensor of SFRC submitted to complex thermomechanical loading, including quasi-static, dynamic, and cyclic loading with temperature and amplitude variations. Then, the latter is used to fill out microstructure dependent material cards in finite element analysis for design optimization in the case of complex loading history. The proposed methodology is illustrated in the case of a real automotive component made of sheet molding compound (PSA 3008 tailgate). The obtained results emphasize how the proposed micromechanical methodology opens a new path for the automotive industry to lighten vehicle bodies and thereby save energy and reduce gas emission.

Keywords : short fiber reinforced composite, structural design, damage, micromechanical modelling, fatigue, strain rate effect
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