Proceedings of the Canadian Society for Mechanical Engineering International Congress 2021
CSME Congress 2021
June 27-30, 2021, Charlottetown, PE, Canada

Actual Microstructural Voids Generation in Finite Element Analysis utilizing Computed Tomography Scan of Highly Cross-linked Epoxy

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ABSTRACT

Composite materials are widely used in several engineering fields such as automotive, aerospace and ship industries. The mechanical behavior of composites is superior to that of conventional metals regarding strength/stiffness-to-weight ratios. However, composite materials and especially fiber-reinforced polymers (FRP) usually suffer from complex failure modes. Two of which are dominated by the resin material. In the present work, computed tomography (CT) was utilized to characterize the microstructural voids content in a plain epoxy resin similar to the one used in aerospace applications. A Python script was developed and implemented within the mainstream finite element (FE) software Abaqus to generate actual microstructural FE model employing computed tomography (CT) scan of highly cross-linked epoxy. The developed script enabled modeling sophisticated microstructural features such as micro-voids based on their actual physical aspects, i.e., size/location. Specimen sized models incorporating microstructural region(s) were used to investigate the material behavior and damage initiation at microscale lengths. The framework of extended finite element method (XFEM) was utilized to investigate the effect of microstructural voids on the damage process. The proposed algorithm is capable of generating a micromechanical model in less than one-minute runtime using moderate desktop computer. Prediction results proved excellent agreement compared to experimental data from the current investigation. Microstructural voids were observed to act as stress raisers and to trigger the damage process at micro-lengths and possibly leading to the final fracture.