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Multiaxial fatigue assessment of adhesive bonded joints under proportional and non-proportional loading conditions

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Adhesive bonded joints are increasingly used in contexts where lightweight and multi-material structures are needed, including aerospace and automotive. In light of this, a proper characterization of their durability is essential to satisfy the functional and safety requirements during their application. An issue possibly correlated with this need is related to the difficulty in experimentally replicating the complexity of the real loading conditions which the joints are subjected to in their final application. In particular, a characterization based on static strength or even mono-axial fatigue strength could fail in completely describing the mechanical response of an adhesive joint subjected to multiple loading sources. A multiaxial fatigue characterization is needed to properly consider these aspects. Several studies dealing with the Multiaxial Proportional Fatigue (MPF) of adhesive joints exist in literature, while the Multiaxial Non-Proportional Fatigue (MNPF) on the same kind of joints is a relatively unexplored topic. In this work, a theoretical and experimental assessment of fatigue life of an adhesive bonded joint subjected to both MPF and MNPF loading conditions is carried out. To do this, a butt joint was selected to undergo pure axial, pure torsional and combined axial and torsional fatigue tests. The joint was designed in order to assure that peak tensile and shear stresses were localized in the same zone. The substrates were manufactured in S355 steel and using a two-component epoxy adhesive to bond them together. The study considered several fatigue-life prediction models, including stress- and strain-based uniaxial equivalent fatigue parameter, critical plane approaches (e.g.: Findley, Brown-Miller, Fatemi-Socie), and invariant-based criteria (e.g.: Drucker-Prager, Von Mises). The findings of this study will contribute to developing sound predictive models for estimating fatigue life under real loading conditions, facilitating the extrapolation of the results from simple coupon tests to full-scale structural applications and enhancing the safety and reliability of adhesively bonded structures.

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