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Non-Linear Incremental Fatigue Damage Calculation for Multiaxial Non-Proportional Histories

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Abstract

Most fatigue models must somehow identify and count individual load events before quantifying the damage induced by each one of them, making multiaxial fatigue damage calculations under non-proportional variable amplitude loadings a challenging and laborious task in practical applications. Moreover, to apply such models it is usually necessary to use semi-empirical methods to evaluate the non-proportionality of the load path of each event, through path-equivalent ranges obtained e.g. using a convex enclosure or the MOI (Moment Of Inertia) method. To avoid this burden, a new approach called the Incremental Fatigue Damage methodology is proposed in this work to continuously accumulate multiaxial fatigue damage under actual service loads, without requiring path-equivalent range estimators or rainflow counters. This new approach is not based on questionable Continuum Damage Mechanics concepts, or on the integration of some unrealistic scalar damage parameter based on elastoplastic work. Instead, inspired on multiaxial plasticity procedures, a framework of nested damage surfaces is introduced, allowing the calculation of fatigue damage even for general 6D multiaxial load histories. In this way, fatigue damage itself can be continuously integrated along the load path, considering damage parameters adopted by traditional fatigue models and following reliable procedures well tested in engineering practice. The proposed approach is experimentally validated by non-proportional tension-torsion tests on tubular 316L stainless steel specimens.

Keywords: Multiaxial fatigue; Variable amplitude load; Non-proportional multiaxial load; Nested fatigue damage surface; Incremental damage calculation.

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