Z-cracks – Industrial validation of a 3D fracture mechanics simulation software

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The development of ultra-efficient and highly optimized aircraft engines for next-generation commercial jets plays a crucial role to slash greenhouse gas emissions from aviation by 2050. Disruptive technologies and architectures as well as new materials are required to provide the foundation for an upcoming generation of more sustainable engines, thus pushing back the limits of the design processes.

Aircraft engine structures are subjected to cyclic and severe thermomechanical environments. Among the certification specifications defined by aviation regulatory authorities, the damage tolerance of engine critical parts is of particular concern regarding flight safety [1]. Aircraft engine manufacturers must ensure the structural integrity of their products assuming the presence of initial flaws in critical components. The potential for failure from material, manufacturing and service-induced anomalies within the approved lifetime must therefore be assessed to prevent any hazardous engine effects.

The prediction of fatigue crack growth is a major research topic and requires handling complex 3D problems through the development of efficient and reliable methodologies. During the last decades, predictions of crack paths and propagation kinetics have been performed using either analytical approaches, relying on libraries of stress intensity factor solutions [2], or numerical ones, taking advantage of the flexibility of computational techniques such as the finite element method [3].

The present work is dedicated to the industrial validation of Z-cracks, a state-of-the-art 3D fracture mechanics simulation software based on explicit and adaptive remeshing techniques [4, 5]. The aim is to describe how such a tool is validated in an industrial context to be further integrated in the design process of aircraft engine structures. By extending the classical definition of Technology Readiness Levels (TRLs), a maturity assessment framework consisting in three use case bases is proposed. First, a functional validation base is defined. The standard quantities of interest of fracture mechanics (*e.g.*, energy release rate, stress intensity factors, bifurcation angle) are computed for a set of elementary cases and compared to analytical solutions. Then, a technological validation base encompassing specimens representative of engine critical zones is outlined. Fatigue crack growth simulations are performed and compared to experimental data (*e.g.*, crack length, number of cycles, crack front shape) gathered on several test campaigns. Finally, industrial cases are considered and comparisons between experimental and numerical results are carried out based on lessons learnt from real engine parts. The proposed framework is thus generic and offers an efficient step-by-step approach to validate a given software by covering a wide range of applications with increasing complexity.

References

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