Fatigue Final Fracture Predction Considering a Non-Local GTN Damage Model

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The fracture toughness of metallic materials is usually quantified using K_{IC}. Typically, K_{IC} [MPa.m0.5] is measured in high-strength materials, showing a linear-elastic fracture behavior. The fracture toughness of 18Ni maraging steel ranges from 60 to 120 MPa.m$^{0.5}$ depending on the finishing temperature during hot rolling, solution, and aging heat treatments [1]. There is also a sample thickness influence on these properties [2]. Valid plane-strain KIC was successfully determined for 18Ni (300) maraging steel, with a thickness of 18 mm, solution treated at 815 °C, air-cooled, and aged for 3 h at 427 °C, 482 °C, and 533 °C and 100 h at 427 °C [3]. However, aged samples with thicknesses of less than 18 mm do not meet the thickness requirement for a plane-strain state, which is required to determine a critical value according to the E399 ASTM standard [4]. Thick sections are usually needed in tooling applications, but AM stimulated the design of thin-walled parts and structures. Therefore, other alternatives to measure fracture toughness are needed. The E1820 ASTM standard [5] offers two additional parameters to measure the fracture toughness of materials with elastoplastic behavior: the J-integral and crack tip opening displacement (CTOD) methods.

An interesting alternative consists in the use of the Gurson-Tvergaard-Needleman (GTN) damage model to predict the onset of fracture in ductile materials. The research team has experience in the use of this ductile damage model to predict fatigue crack growth [6] through several crack tip parameters (cyclic plastic strain and porous damage at the crack tip, crack closure, etc.).

The objective here is to apply the GTN model to the study of final fracture of the 18Ni (300) maraging steel. A first approach to the problem of final fracture of ductile metals subjected to cyclic loads considered a 6082-T6 aluminium alloy. Accordingly, an integral regularization method was applied to define a non-local GTN model, able to deal with deformation localization and strain softening. The study has been submitted for publication, were the fatigue crack growth and final ductile fracture was successfully predicted considering a node release strategy. In fact, near the material K_{IC} the GTN model triggered successive node releases without further increase in the applied load, indicating the occurrence of final fracture in a previously defined crack path. Despite the success in the prediction of final fracture, the results shown mesh dependence. However, the case of the ductile fracture of a tensile specimen and the fatigue life predictions provided mesh independent results, with the same numeric model. Therefore, the prediction of the crack path will also be studied in order to check if the model becomes capable of predicting the final fracture regardless of the employed mesh.

References

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