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Automated Beta Curve Development using Parametric FEA

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Abstract

Exact solutions for stress intensity factors (SIFs) are generally not available for cracks in the presence of complex geometric features. Beta factors developed to account for these features are often expressed as the superposition of the SIFs of several simpler cases, and beta curves are then compiled as a function of crack length to perform crack growth studies. An alternative to the superposition approach is the development of proper formulated models solved by the finite element (FE) method, combined with an automated approach which selects the proper model for each stage of the crack growth. This presentation will address the modeling strategy and the automation process used to compute the complete beta curve across eight phases of crack growth at the CW-1 location of the wing skin of the C-130 aircraft using the commercial FE analysis software StressCheck. This location has significant geometric features in close proximity to the crack, including a beam cap, hat stringers, and four fastener holes along the crack path. Additionally, corner cracks from loaded holes were accounted for by the models, and due to variability in manufacturing and repairs in this wing region, parametric geometric features were also incorporated to support sensitivity studies.

To automate the process, a driver program was developed using Microsoft Excel to run a series of models through the Component Object Model Application Programming Interface (COM API) of StressCheck. For the eight phases of crack growth a series of finite element meshes optimized for various ranges of crack length were created and the COM driver automatically selects the best mesh for each phase. The COM driver also updates the model based on user input, and manages all communication with StressCheck to obtain the SIFs which are then converted to beta factors to output the complete beta curve across eight phases of crack growth. To satisfy the requirements of verification, that is to control the error of approximation in the computation of the SIFs, a sequence of finite element solutions with an increasing number of degrees of freedom is obtained for each beta factor in the curve.

This approach has several advantages over both traditional beta factor superposition and standalone handbook FE analysis. First, the models are more reliable because fewer simplifying assumptions are needed and no superposition is required; second, effects such as traction-loaded vs. pin-loaded holes can be easily accounted for; and third, no expertise in FE analysis is needed to create beta curves with a high degree of accuracy and to perform sensitivity studies of the influence of parameters in the results. Other advantages such as validation of input parameters and automatic convergence feedback are provided by this approach as well.

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The approach demonstrated how accurate beta curves may be computed across multiple phases of crack growth with a high degree of automation and without user expertise in finite element analysis. This work was performed in support of the C-130 Service Life Assessment Program (SLAP) for the Naval Air System Command (NAVAIR) Aircraft Structures Division.