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Interlaminar Fatigue Elements for Crack Growth Based On Virtual Crack Closure Technique

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Interlaminar fatigue analysis has historically been a tedious analysis to perform. Fatigue growth may be predicted with a Paris law that relates Energy Release Rate (ERR) to crack growth rates. Another approach determines the onset of fatigue growth for a given number of load cycles at a given level of ERR. Both approaches assume preexisting damage in the structure and both use DCB test results to calibrate the fatigue laws. Mode mix ratios are assumed not to influence fatigue growth at load levels near the onset or growth threshold. The challenge in analysis of realistic three-dimensional composite structure is that the structure may contain multiple crack tips or crack fronts. One must also consider a nonlinear structural response when the structure is subjected to either a constant loading at a user specified load ratio, P_{min}/P_{max}, or the structure must be evaluated for flight spectrum loading. In practice, impact damage may have an irregular shape that is permitted to "round-out" in determining the life of the structure in order to satisfy a "no-growth" criterion.

The Composites Affordability Initiative (CAI) has developed an ABAQUS user element for the simulation of composite delamination onset and growth under generally nonlinear conditions. These Interface Fracture Elements (IFE) implements the Virtual Crack Closure Technique (VCCT) in a novel way where both the critical release force and the energy consumed during strain softening is calculated based on fracture mechanics criteria. The *ABAQUS*®[**] UEL (User ELement) contains separate modules to handle either 2D or 3D modeling problems. The IFE contain ERR components, nodal spatial information and a mechanism to release constrained nodes; the most important parameters and functionality necessary to perform interlaminar fatigue calculations. This paper describes modifications made to the 2D IFE for the purpose of demonstrating constant load fatigue analysis. The analysis approach is completely general, may be extended to 3D analysis and may include spectrum loading. Analysis of problems exhibiting nonlinear behavior will be possible with only slight modifications to the software.

Nomenclature

CAI	=	Composites Affordability Initiative
IFgE	=	Interlaminar Fatigue Finite Element
IFE	=	Interface Fracture Finite Element
VCCT	=	Virtual Crack Closure Technique
G_I	=	Mode I Energy Release Rate
G_{II}	=	Mode II Energy Release Rate
DCB	=	Double Cantilever Beam
ERR	=	Energy Release Rate

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[**] *ABAQUS*® is a software product from ABAQUS, Inc., Pawtucket, Rhode Island.