

HOST High Temperature Crack Propagation

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This program will attempt to build on the results of the Pre-HOST program I described yesterday, using the latest analytical and experimental fracture mechanics techniques. The anticipated program and its key features are summarized on the first slide. A flowchart is shown on the next slide, and I will describe the work to be done.

First we will attempt to extract additional information from the literature and from the Pre-HOST program. Specifically, nonlinear finite element (NLFE) analyses of the tubular specimens will be made using GAP ELEMENTS to calculate crack opening loads. Then, using these loads, the data will be re-analyzed to see if improved correlations result.

Various specimen configurations will be evaluated for elevated-temperature isothermal and TMF testing with tension-compression loading, with a new constraint being that now crack mouth opening displacement (CMOD) is to be measured. The most suitable specimen will be selected. Available methods for measuring CYCLIC CMOD at elevated temperatures on the selected specimen will be evaluated. Possible methods for measuring near-tip displacements are also to be identified. An "analog material" will be selected. This will be a material suitable for simulating high-temperature material behavior but at temperatures only a few hundred degrees F above ambient. The object of the analog material is to permit well-instrumented tests to be run at reasonable temperatures to ease the instrumentation and cost problems.

An experimental program similar in scope and approach to Task IV of NAS3-22550 will be run with additional instrumentation (at least CMOD) and more detailed analysis (a NLFE program with gap elements). The specimen, measurement methods, and material previously identified will be used, with both isothermal and simple (linear) TMF tests to be run. A limited series of tests using a different specimen configuration will be run to see if the resulting growth rate correlation is indeed specimen-independent.

We intend to evaluate several formulations which have been proposed for nonlinear fracture analysis in the presence of thermal gradients which result in material inhomogeneity. These will include the analyses of Blackburn et al, Ainsworth et al, Wilson & Yu, Kishimoto et al, and Atluri. Methods and strategies for performing the necessary calculations using a NLFE program will be considered. The five most promising formulations will be evaluated using the simple analytical model of an edge crack in a large plate, with a linear temperature gradient (and/or corresponding modulus variation) in the direction of crack propagation and a uniform distribution normal to the crack plane. The five formulations will be compared and two selected for further evaluation. One will be that judged to have the

most technical merit, the other the best compromise between technical merit and computational ease. Then these two formulations will be evaluated for further use by modeling the actual specimen geometry and temperature gradient to be used in later tests. Next we wish to determine whether the analytical formulations identified previously actually enable one to correlate nonlinear crack growth in the presence of thermal gradients. Specimens of the analog material will be tested under monotonic and cyclic load in the presence of a simple (nearly linear) thermal gradient.

At this point it will be NASA's option to proceed with the optional program as planned, to technically redirect the optional program by re-negotiation, or to terminate.

The optional program will consist of three main elements. We intend to extend the analytical effort to include a comparison of path-independent RATE integrals (or time derivatives of path-independent integrals), and this will be done in much the same manner as before. Then we will attempt to verify these analyses using the analog material at a somewhat higher temperature than before (into the creep range). Finally we will attempt to apply the knowledge gained using the analog material to predict and correlate crack propagation in a nickel-base alloy at temperatures typical of combustor liners.

ELASTOPLASTIC CRACK PROPAGATION AT ELEVATED TEMPERATURES

OBJECT: DEVELOP METHODS FOR CHARACTERIZING & PREDICTING CRACK GROWTH AT ELEVATED TEMPERATURES CONSIDERING NONLINEAR MATERIAL BEHAVIOR, THERMAL GRADIENTS & THERMOMECHANICAL CYCLING.

SCOPE: FOUR-YEAR TWO-PHASE CONTRACT.

FEATURES:

- * SURVEY & COMPARISON OF CURRENT PATH-INDEPENDENT INTEGRALS.
- * COMPUTER TEST OF ≥ 5 PATH-INDEPENDENT INTEGRALS USING SIMPLE PROBLEM.
- * EXTENSIVE USE OF CRACK DISPLACEMENT MEASUREMENTS FOR BETTER UNDERSTANDING.
- * ANALOG MATERIAL AT MODERATE TEMPERATURES ($\leq 500F$) FOR PHASE I: NI-BASE ALLOY AT $< 2000F$ IN PHASE II.
- * CYCLIC CRACK PROPAGATION TEST WITH TEMPERATURE GRADIENTS, THERMOMECHANICAL CYCLING & CREEP.

BASIC PROGRAM

