

DOUGLASS R. RHOADS

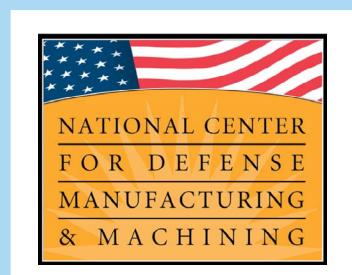
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DURABILITY OF POST-BUCKLED MACHINED FRAMES

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BACKGROUND

- Historically, rotorcraft fuselage skin and web structure have been designed to take advantage of post-buckled capability for structural weight optimization
- New military rotorcraft programs are including airframe service life design requirements, similar to fixed-wing, in order to better manage life cycle operating costs
- Damage tolerance of machined structure should be an important design driver, given that the reduced number of crack-stopping features may tend to result in larger damage sizes and associated repair costs

OBJECTIVES

- Evaluate the durability and damage tolerance of machined aluminum webs subject to repeated post-buckling loads
- Validate the use of analytical tools for crack initiation prediction and production design support
- Obtain damage tolerance data for representative rotorcraft loadings (ground-air-ground, vibratory)
- Evaluate results in light of existing existing static limit & ultimate strength design criteria for post-buckled webs

APPROACH

- Perform fully-reversed, constant amplitude tests on generic machined frames at several Buckling Ratios
- Employ periodic NDI to characterize failure modes, define crack initiation life and monitor crack growth rates
- Modify load ratio during crack growth phase to obtain crack growth rate data under high-cycle vibratory loading

Test Design

- Leverage previous static test program by using common frame configuration
- 2005 tests to verify static design methods Existing machining and test fixture
- Typical machined frame design features:
- 7050-T7451 plate Minimum gage webs (0.032)
- Anodized finish
- Fully-reversed loading at or above static design
- limit buckling loads (GAG cycle) Worst case loading scenarios
- Accelerated test to crack initiation
- Include fully-reversed (R=-1) and vibratory
- loads (R=0.5) during crack growth phase
- Low-cycle crack growth rates High-cycle threshold behavior

2005 STATIC ULTIMATE TEST



DURABILITY TEST MATRIX

LUI	Fillax (185)	
1	2,600	4.0
2	3,500	5.4
3	4,200	6.5

TYPICAL CRACK GROWTH LOADING

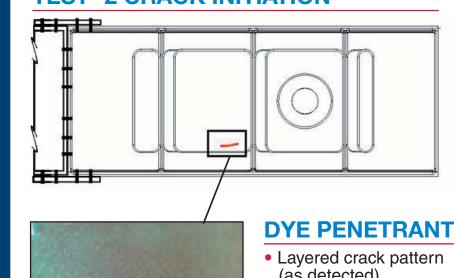
PHASE	R	Cycles	
CI (GAG)	-1.0	N	
CG (GAG)	-1.0	N/3	
CG (VIB)	0.5	100,000	

Durability Results

TEST SUMMARY (PARTIAL)

TEST	#1	#2	#3
Loading (lbs)	2,600	3,500	4,200
Crack Detection (cycles)	Run-out	285,955	44,203
Test Completion (cycles)	1,000,011	506,626	97,522

TEST #2 CRACK INITIATION



- (as detected) Combined length of
- 1.26 inches Failure location consistent with FEA



DURABILITY ANALYSIS

- Max & min principal stresses (R = min/max)
- 7050-T74 plate strain-life material properties
- Analysis does not account for crack growth Considered bare and with anodize factor
- 5,000 ■ P1-Anod ▲ P1-Bare 4.000 3,000 **2**,000

1.E+05

Cycles

1.E+06

1.E+04

TEST #2 FINAL CRACK GEOMETRY

Test Configuration LOADING & FIXTURE ASSEMBLY Cantilever beam loading & fixed reaction to generate section shear and bending Teflon-lined vertical constraint framing to resist out-of-plane deflections Load straps and supports sized for durability to prevent non-representative failures Pertical Constraints ST53883-13 2 places Stiffener "Rib" Note "Strap" is placed between this and the panel ST53883-15 (Top & Bottom) Side Play Brackets **INSTRUMENTATION** 4 Places ST53883-10 Rosette strain gages at web center Test Panel Mount used to verify buckling load and for comparison with analytical models Test Panel ST53883-12 Crack propagation gages to obtain oading Plate more accurate crack growth rates Mounting Pedestal "T" slot table Load Cell Clevis & Pin

Damage Tolerance Results

GENERAL OBSERVATIONS

- Initial cracking concentrated along the chord pad-up boundary and into the corner, following pad-up fillet tangency
- Multiple cracks occurred in a layered, fish bone pattern, then formed a more continuous jagged crack in later stages
- Significant crack spalling occurred as a result of the layered crack pattern as well as the effects of load reversal

CRACK GROWTH RATES

- Min/Max = -1 (GAG) loading:
- Growth between points A and C da/dn ~ 5.7E-06 (per crack tip)
- averaged over several intervals
- Min/Max = 0.5 (VIB) loading:
- Growth between points A and B da/dn ~ 2.4E-06 in/cyc
- Growth between points C and D da/dn ~ 4.5E-06 in/cyc

LOWER CORNER CRACK (viewed from opposite side) 506.628 505.117 503.117 503.217 501.254 - 499.017 - 4690.20 373,980 342,200 501254 Crack initiation