NASA Technical Memorandum

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COMPARISON OF TWO COMPUTER CODES FOR CRACK GROWTH ANALYSIS — NASCRAC VERSUS NASA/FLAGRO

PART ONE

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Science and Engineering Directorate

December 1989

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16. Abstract

This report presents results from the comparison study of two computer codes for crack growth analysis – NASCRAC and NASA/FLAGRO. The two computer codes gave compatible conservative results when the part through crack analysis solutions were analyzed versus experimental test data. Results showed good correlation between the codes for the through crack at a lug solution. For the through crack at a lug solution, NASA/FLAGRO gave the most conservative results.

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TECHNICAL MEMORANDUM

COMPARISON OF TWO COMPUTER CODES FOR CRACK GROWTH ANALYSIS — NASCRAC VERSUS NASA/FLAGRO

The structural integrity of space flight hardware is established by a combination of qualification tests and analyses which simulate actual operating conditions, including flight loads, temperatures, and corrosive environments. These structural analysis and test activities usually fall into three distinct areas. The first two areas, strength and fatigue analysis, assume the load carrying structure is unflawed. This assumption implies that no defects have been introduced during the manufacturing process of each individual part, which in reality can never be possible on an economical basis.

The existence of flaws is accounted for in the third area, fracture mechanics. This area becomes an important effort in which defects are known as a result of quality inspections, or assumed to exist in a part and an assessment is made as to their impact on the parts useful life. Fracture mechanics attempts to predict the useful service life of an initially flawed structural part by calculating crack growth and eventual part failure due to unstable crack growth.

This paper compares the service life calculations of two computer codes, NASCRAC and NASA/FLAGRO. The analysis technique is based on linear elastic fracture mechanics (LEFM), in which stresses remain below the yield strength of an elastic/plastic material. Subcritical crack growth calculations assume that in a metallic part, the extent of yielding at the crack tip is very small compared to the crack size, uncracked ligament, and the bulk of the cracked body remains elastic.

To perform service life calculations, one must have a relationship expressing incremental crack growth, DA/DN, as a function of loading, geometry, and crack size. Load, crack size, and geometry are expressed in terms of the cyclic stress intensity factor, ΔK. The crack growth rate as a function of ΔK is then determined by material tests, plotting DA/DN versus ΔK for the given material form and H.T. condition, loading condition, and environment.

Crack growth rate equations such as the Paris, Walker, and modified Forman equations are used to obtain a "best fit" curve to the laboratory DA/DN versus ΔK data. Constants in the equations which result in a "best fit" then become crack growth rate material constants for a particular set of laboratory conditions.

Two extreme values of ΔK also become material constants; ΔK_0 is the threshold stress intensity below which no crack growth occurs, K_c is the critical stress intensity at which a crack becomes unstable and complete fracture occurs. Formulations of ΔK solutions and crack growth rate equations form the basis of computer codes which numerically integrated the $DA/DN = F(\Delta K)$ relationship.

Before a computer code is used as part of the structural integrity assessment process, it should be exercised thoroughly and its numerical calculations checked to insure reasonable and accurate answers. The results presented herein compare the Safe Life calculations of two computer codes with each other, and with test data to a limited extent.

The computer program NASA/FLAGRO (commonly known as NASGRO) became available in 1986 from the NASA Johnson Space Center. The program was developed under the guidance of the NASA Fracture Control Analytical Methodology Panel and contains stress intensity factor solutions to a number of commonly used crack geometries. Service life calculations are performed with the modified Forman equation which reduces to the Walker or Paris equation depending on material constants used.

NASA/FLAGRO is menu driven and prompts the user for information in a serial manner. After selecting the type of analysis desired, such as Safe Life, the user answers a series of questions and enters data depending on the particular path taken. Generally, the program operates serially, requiring the user to follow the same path and answer a number of basic questions before each execution.

The computer program NASCRAC is being developed by Failure Analysis Associates under contract to NASA at Marshall Space Flight Center. For Safe Life analysis, NASCRAC has basically the same capabilities as NASA/FLAGRO, although implemented differently. Generally, stress intensity factors are obtained from influence function solutions to various geometries for which exact solutions do not exist. NASCRAC enables the user to select any one of several commonly used crack growth equations; including the Paris, Walker, and modified Forman equations.

NASCRAC is similar to NASA/FLAGRO in that the program is menu driven and the user answers questions and enters data in response to screen prompts. With NASCRAC, however, the user is not required to answer a series of questions before each execution. The user may randomly select only those menu items relating to the particular solution desired.

NASA/FLAGRO SAFE LIFE FEATURES

NASA/FLAGRO features which can affect Safe Life calculation:

(1) For surface cracks with constant amplitude loading, ΔK is multiplied by a crack closure factor β_R.

$$\beta_R = \begin{cases} 0.9 + 0.2\,R^2 - 0.1\,R^4 & ; \quad R > 0 \\ 0.9 & ; \quad R \leq 0 \end{cases}$$

This can increase fatigue life.

(2) ΔK_{th}, the fatigue threshold is calculated using,

$$\Delta K_{th} = (1 - C_o R)^d \, \Delta K_o$$

To be conservative, let $C_o = d = 1$ for $R \geqslant 0$

$$\Delta K_{th} = (1-R)\, \Delta K_o$$

For small cracks, $a \leqslant 0.025$ in, $\Delta K_o = 0$.

(3) Input of

K_{IC} – plane strain fracture toughness

K_{Ie} – fracture toughness for an elliptical crack

A_k, B_k – fit parameters

To calculate K_C – critical stress intensity,

a) $t_o = 2.5 \left(\dfrac{K_{IC}}{\sigma_{ys}} \right)^2$

b) $w = \left(\dfrac{A_k\, t}{t_o} \right)^2$

c) $K_C = K_{IC} \, (1 + B_k \, e^{-w})$

K_C is incorporated into the modified Forman equation to accelerate DA/DN as K_c is approached.

NASCRAC SAFE LIFE FEATURES

(1) Crack growth equations

a) Modified Forman — Analytical Comparison

b) Walker — Comparison to test data on both codes

(2) Piecewise Linear Approximation method used.

(3) K-solutions are based on influence functions with the default order of accuracy.

ANALYSIS NOTES

Surface Flaws

NASCRAC — Uses K_{Ic} value to accelerate DA/DN per the Forman equation and defines failure when $\Delta K > K_{Ic}$, where K_{Ic} is manually input.

NASA/FLAGRO — Uses K_c value calculated from K_{Ic} and other variables to accelerate DA/DN per the Forman equation when $\Delta K > K_{Ie}$, where K_{Ie} is a material constant for surface flaws.

Growth Rate Equations

NASCRAC — Uses the following growth equations: Paris, Modified Forman, Walker, Collipriest, and Hop Rau.

NASA/FLAGRO — Primarily uses the Modified Forman Equation but the Paris and Walker equations could be used.

K_c Values

NASCRAC — K_c is used in the Modified Forman equation but K is the controlling cutoff value.

NASA/FLAGRO — For $B_k \neq 0$, NASA/FLAGRO uses a K_{Ic} larger than K_{Ic} for thin material (Reference 8)

$$K_c/K_{Ic} = 1 - B_k e^{-w}$$

when $B_k = 0$, $K_c = K_{Ic}$, where $w = (A_k\ t/t_o)^2$.

COMPARISON ANALYSIS CHART

Type of Geometry	Parameters	Type of Run	NASGRO	NASCRAC
Through Center Crack	$W = 10.0$ $t = 0.25$ 4130 Steel $a_i = 0.05$	*R = 0 Tension Only	X	X
		*R = –1 Tension Only		
		Closure	X	X
	σ_t = 50 Ksi	No Closure	X	X
Through Edge Crack	$W = 10.0$ $t = 0.25$ 4130 Steel	*R = 0 Tension Only	X	X
	σ_t = 50 Ksi σ_b = 50 Ksi	*R = –1 Tension Only		
		Closure	X	X
	$a_i = 0.05$	No Closure	X	X
		*R = 0 Bending Only	X	X
		*R = – 1 Bending Only		
		Closure	X	X
		No Closure	X	X
		*R = +0.5 Tension		
		Closure	X	X
		No Closure	X	X
		*R = – 0.5 Tension		
		Closure	X	X
		No Closure	X	X
		R = +0.5 Bending		
		Closure	X	X
		No Closure	X	X
		R = –0.5 Bending		
		Closure	X	X
		No Closure	X	X
	$a = 0.25$	R = 0 Tension	X	X
		R = –1 Tension		
		Closure	X	X
		No Closure	X	X

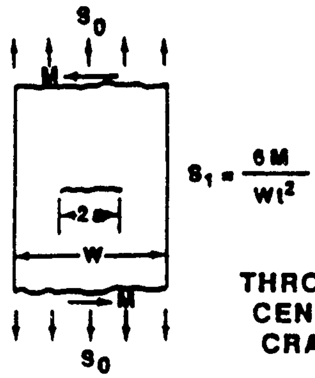
*See analysis results.

Type of Geometry	Parameters	Type of Run	NASGRO	NASCRAC
Through Crack at Pin Loaded Hole	W = 1.75 t = 0.44 D = 0.375 B = 0.83 4340 Steel σ_t = 59 Ksi σ_b = 37 Ksi a = 0.25	*R = 0 Tension + Bearing	X	X
Through Crack at Pin Loaded Lug	W = 5.0 t = 0.25 D = 0.5 σ_t = 150 Ksi 4130 Steel			
	a_i = 0.05	R = 0	X	X
	a_i = 0.10	R = 0	X	X
	a_i = 0.25	*R = 0	X	X
Surface Flaw Center Crack Specimen	Test Spec. No. 62* W = 4 t = 0.50 σ_t = 84 Ksi a_i = 0.06 $a_i/2c_i$ = 1/2 Ti = 6AL-4V	R = +0.05	X	X
	Test Spec. No. 5576* W = 4 t = 0.50 σ_t = 57 Ksi a_i = 0.06 $a_i/2c_i$ = 1/2 Ph-13-8M_o	R = +0.05	X	X

*See analysis results.

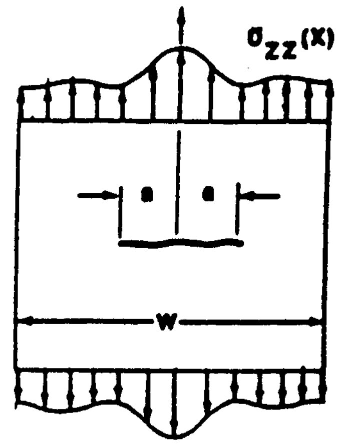
GEOMETRY MODELS

NASGRO | **NASCRAC**



TC01

THROUGH CENTER CRACK



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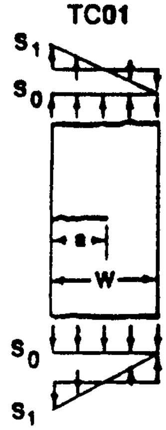
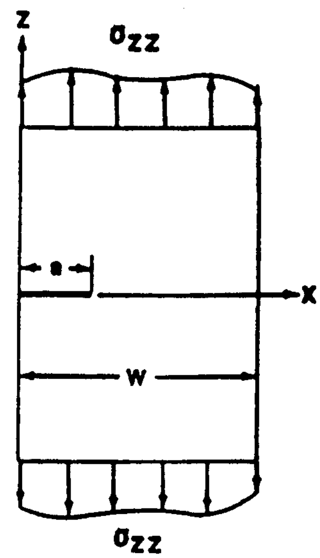


TC02

THROUGH EDGE CRACK



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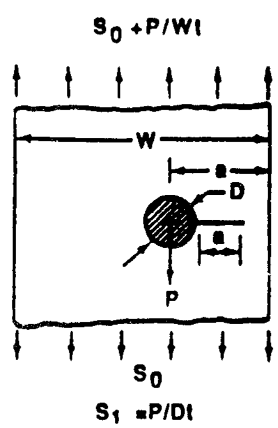
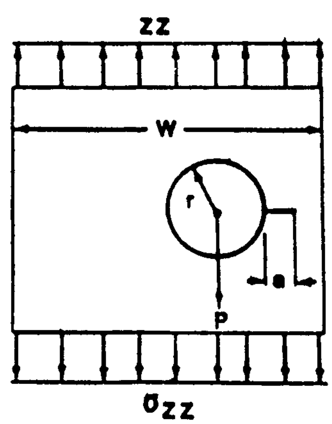


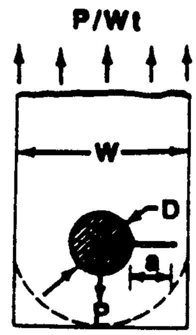
TC03

THROUGH CRACK AT HOLE PIN LOADED



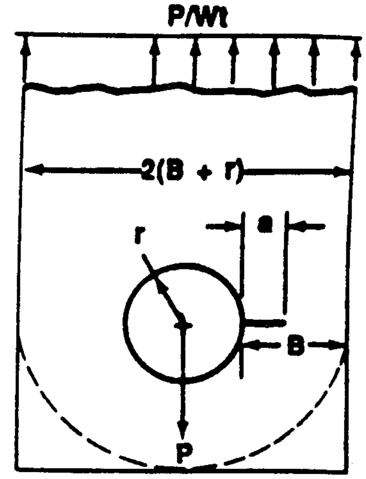
208

NASGRO | **NASCRAC**



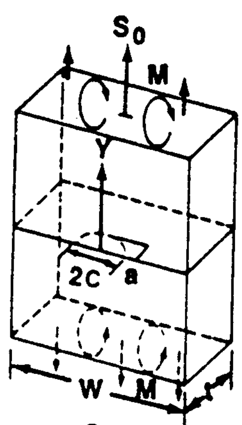
$S_0 = P/Dt$

TC04



209

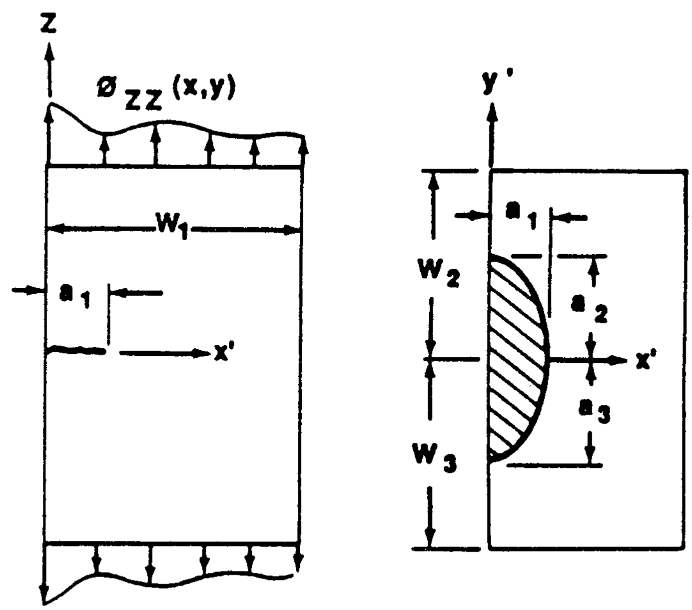
THROUGH CRACK
AT LUG



S_0

$S_1 = \frac{6M}{Wt^2}$

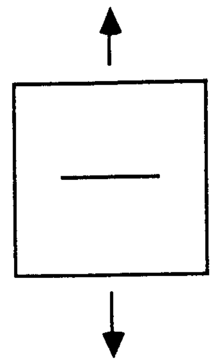
SC01



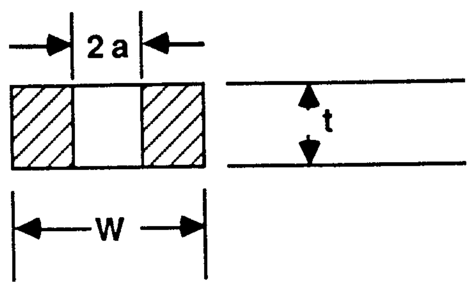
702

SURFACE CRACK
(CENTER)

ANALYSIS RESULTS THROUGH CENTER CRACK



w = 10"
t = 0.25"
2_{ai} = 0.05"
4130 STEEL
σ = 50KSI
1) R = 0
2) R = 1



NASGRO MODEL TYPE TC01   NASCRAC MODEL TYPE 202

FIRST CASE   R=O

NASGRO

K_{MAX}=80.10 KSI$\sqrt{IN}$ @ 20,173 CYCLES   2a=1.584"

NASCRAC

K_{MAX}=80 KSI$\sqrt{IN}$ @ 20,176 CYCLES   2a=1.60"

SECOND CASE   R=–1

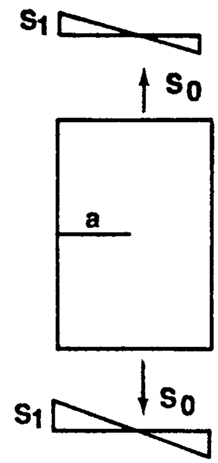
NASGRO

CLOSURE: K_{MAX}=80.12 KSI $\sqrt{IN}$ @ 16,401 CYCLES   2a=1.584"
NO CLOSURE: K_{MAX}=80.04 KSI $\sqrt{IN}$ @ 4,459 CYCLES   2a=1.58"

NASCRAC

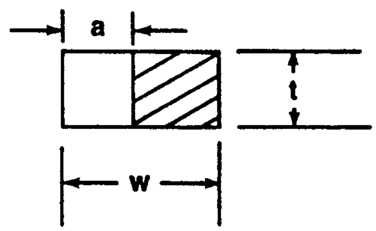
CLOSURE: K_{MAX}=80 KS$\sqrt{IN}$ @ 4433 CYCLES   2a=1.60"
NO CLOSURE: SAME AS CLOSURE

THROUGH EDGE CRACK



W = 10"
t = 0.25"
c_l = 0.05
4130 STEEL
σ_t = 50 KSI OR σ_b = 50 KSI

σ_t = 50 KSI	σ_b = 50 KSI
1) R = 0	1) R = 0
2) R = -1	2) R = -1
3) R = +0.5	
4) R = -0.5	



NASGRO MODEL TYPE TC02 NASCRAC MODEL TYPE 203

<u>TENSION ONLY</u>

<u>FIRST CASE R = 0</u>

NASGRO

K_{MAX} = 80 KSI $\sqrt{IN}$ @ 9674 CYCLES a_f= 0.610"

NASCRAC

K_{MAX} = 83.22 KSI $\sqrt{IN}$ @ 9616 CYCLES a_f= 0.655"

<u>SECOND CASE R = -1</u>

NASGRO

CLOSURE: K_{MAX} = 80 KSI $\sqrt{IN}$ @ 7901 CYCLES a_f = 0.61"

NO CLOSURE: K_{MAX} = 80 KSI $\sqrt{IN}$ @ 2148 CYCLES a_f = 0.61"

NASCRAC

CLOSURE: K_{MAX} = 83.20 KSI $\sqrt{IN}$ @ 4439 CYCLES a_f = 0.655

NO CLOSURE: SAME AS CLOSURE

THROUGH EDGE CRACK
TENSION CASES CONTINUED

THIRD CASE R=+0.5

NASGRO

CLOSURE K_{MAX}=80.05 KSI$\sqrt{IN}$ @ 27,485 CYCLES a=0.61"
NO CLOSURE K_{MAX}=80.05 KSI$\sqrt{IN}$ @ 43,772 CYCLES a=0.61"

NASCRAC

CLOSURE K_{MAX}=83.22 KSI$\sqrt{IN}$ @ 43,516 CYCLES a=0.655"
NO CLOSURE SAME AS CLOSURE

FOURTH CASE R=−0.5

NASGRO

CLOSURE K_{MAX}=80.00 KSI$\sqrt{IN}$ @ 8757 CYCLES a=0.61"
NO CLOSURE K_{MAX}=80.00 KSI$\sqrt{IN}$ @ 4010 CYCLES a=0.61"

NASCRAC

CLOSURE K_{MAX}=83.22 KSI$\sqrt{IN}$ @ 3985 a=0.655"
NO CLOSURE SAME AS CLOSURE

THROUGH EDGE CRACK CONTINUED
BENDING ONLY

FIRST CASE R=O

NASGRO

K_{MAX}=80.09 Ksi$\sqrt{in}$ @ 10,830 CYCLES a =0.73 in.

NASCRAC

K_{MAX}=81.363 Ksi$\sqrt{in}$ @ 10,228 CYCLEs a =0.721 in.

SECOND CASE R=-1

NASGRO

CLOSURE: K_{MAX}=80.03 Ksi$\sqrt{in}$ @ 8846 CYCLES a =0.73 in.

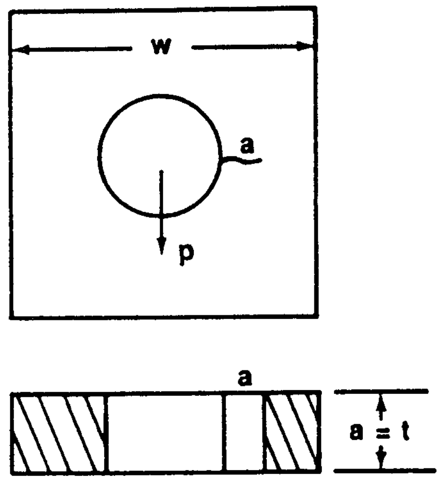
NO CLOSURE: K_{MAX}=80.03 Ksi$\sqrt{in}$ @ 2405 CYCLES a =0.73 in.

NASCRAC

CLOSURE: K_{MAX}=81.36 Ksi$\sqrt{in}$ @ 2271 CYCLES a =.721 in.

NO CLOSURE: SAME AS CLOSURE

THROUGH CRACK AT PIN LOADED HOLE



w = 1.75"
t = 0.44"
HOLE DIAMETER = 0.375"
EDGE DISTANCE = 0.83"
4340 STEEL
σ_T =59 KSI + σ_{bear} =37 KSI
CRACK LENGTH = 0.05"
R = 0

NASGRO MODEL TYPE TC03 NASCRAC MODEL TYPE 208

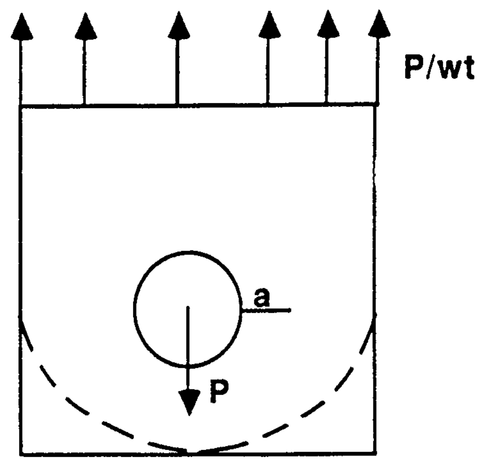
NASGRO

K_{MAX} = 90.17 KSI $\sqrt{IN}$ @ 4,334 CYCLES a_f =0.339"

NASCRAC

K_{MAX} = 90.13 KSI $\sqrt{IN}$ @ 6609 CYCLES a_f =0.492"

THROUGH CRACK AT LUG



NASGRO MODEL TYPE TC04 NASCRAC MODEL TYPE 209

WIDTH = 5.0"
THICKNESS = 0.25"
4130 STEEL
DIAMETER OF HOLE 0.5"
a_i = 0.25"
σ = 150KSI

NASGRO RESULTS

K_{MAX}=80.71 KSI$\sqrt{IN}$ @ 64,426 CYCLES a_f=1.99"

NASCRAC RESULTS

K_{MAX}=80 KSI $\sqrt{IN}$ @113,649 CYCLES a_f = 2.184"

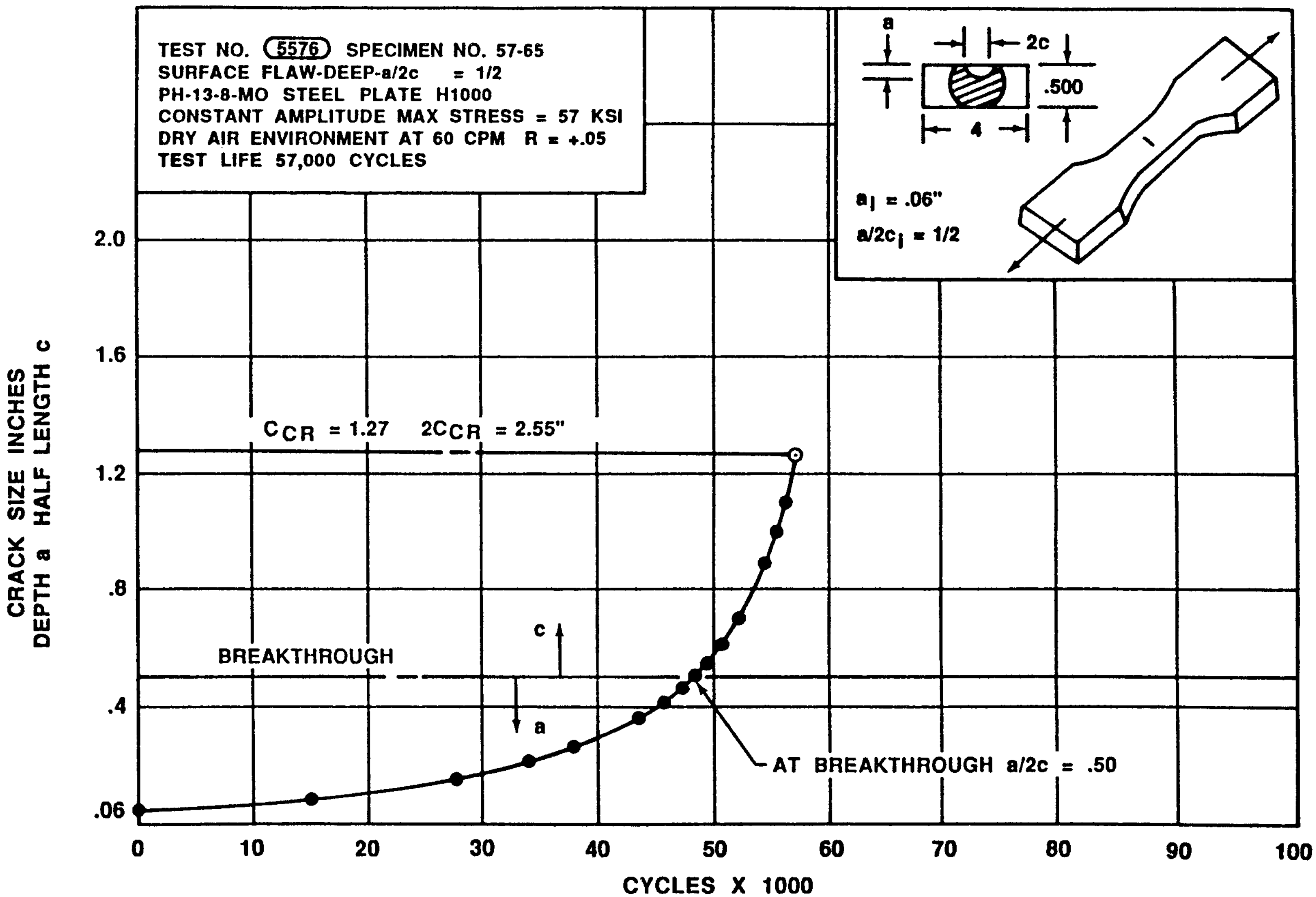
WALKER CONSTANTS FOR PART THROUGH CENTER CRACK ANALYSIS

MATERIAL: PH 13 – 8 Mo TEST CASE NO. 5576

c	7.63×10^{-11} IN/CYCLE
m	1.0
n	3.54
ΔK_{th}	8 KSI$\sqrt{\text{IN}}$
K_{Ic}	100 KSI$\sqrt{\text{IN}}$

MATERIAL: TI – 6AL – 4V TEST CASE NO. 62

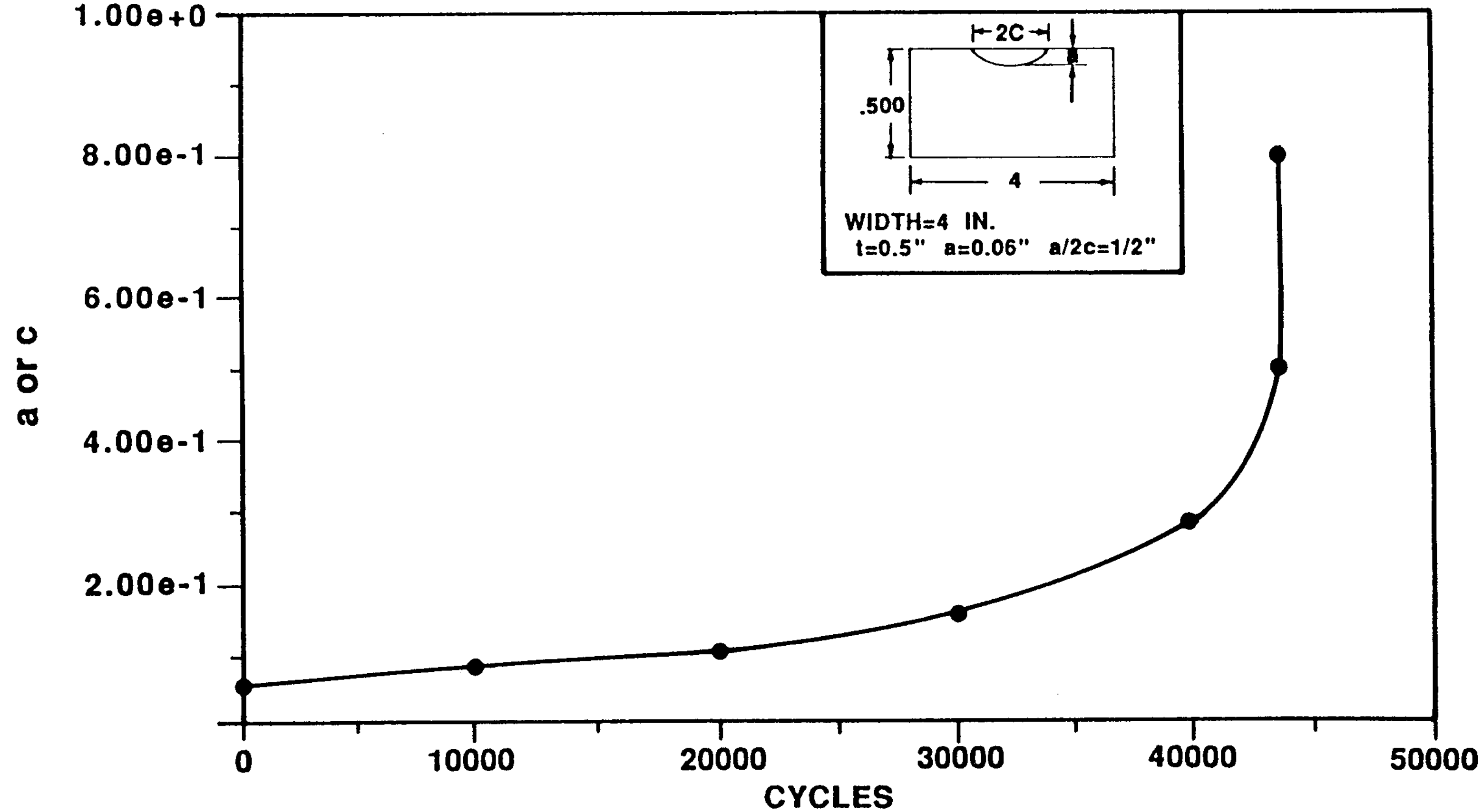
c	2.914×10^{-12} IN/CYCLE
m	0.04435
n	4.51
ΔK_{th}	4.5 KSI$\sqrt{\text{IN}}$
K_{Ic}	70 KSI$\sqrt{\text{IN}}$



TEST NO. 5576 SPECIMEN NO. 57-65
SURFACE FLAW-DEEP-a/2c = 1/2
PH-13-8-MO STEEL PLATE H1000
CONSTANT AMPLITUDE MAX STRESS = 57 KSI
DRY AIR ENVIRONMENT AT 60 CPM R = +.05
TEST LIFE 57,000 CYCLES
a
2c
.500
4
a_i = .06"
$a/2c_i$ = 1/2
C_{CR} = 1.27 $2C_{CR}$ = 2.55"
BREAKTHROUGH
c
a
AT BREAKTHROUGH a/2c = .50
CRACK SIZE INCHES
DEPTH a HALF LENGTH c
2.0
1.6
1.2
.8
.4
.06
0
10
20
30
40
50
60
70
80
90
100
CYCLES X 1000

NASA/FLAGRO PART THROUGH CRACK ANALYSIS

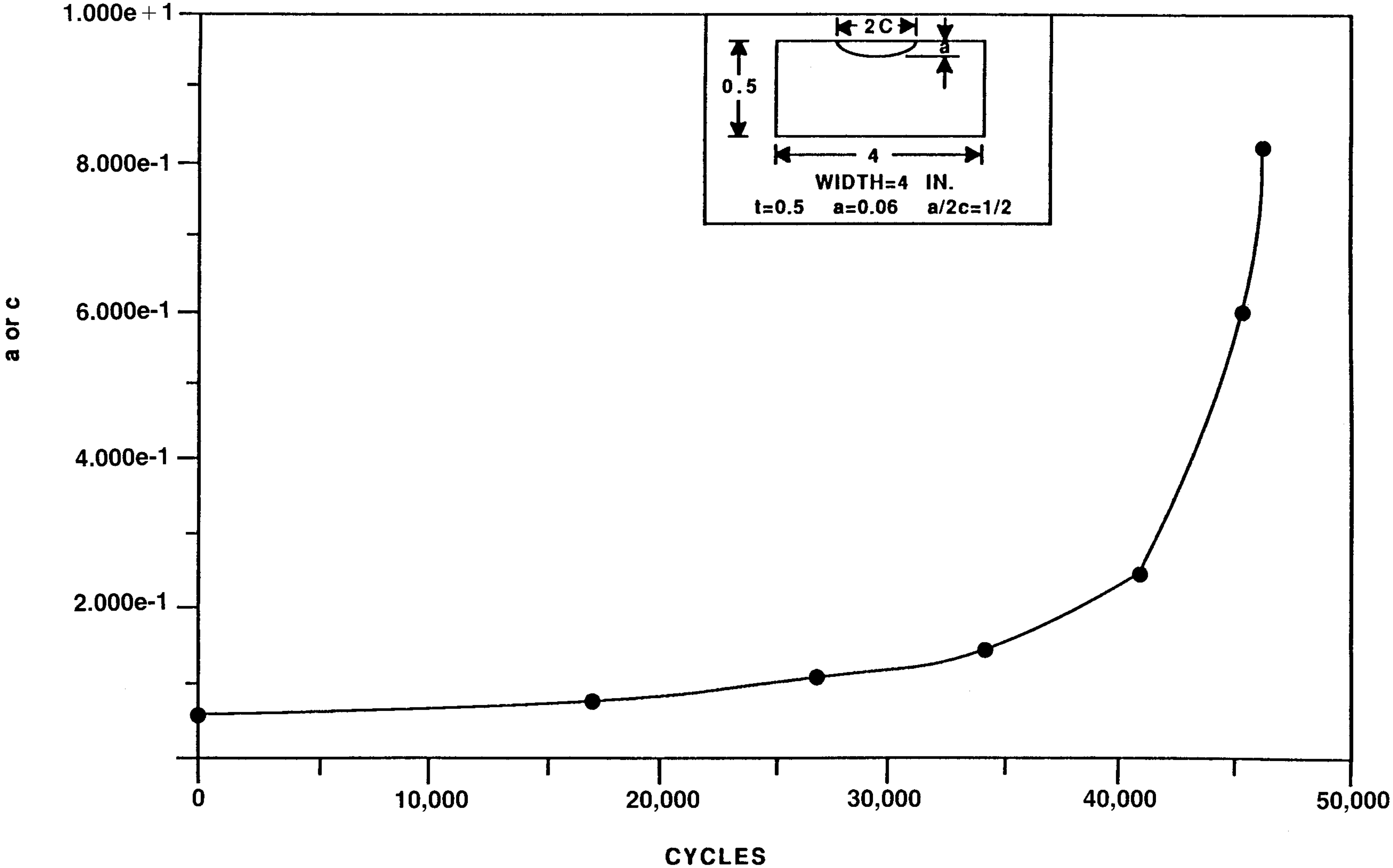
DATA FROM "NASGRO #5576"



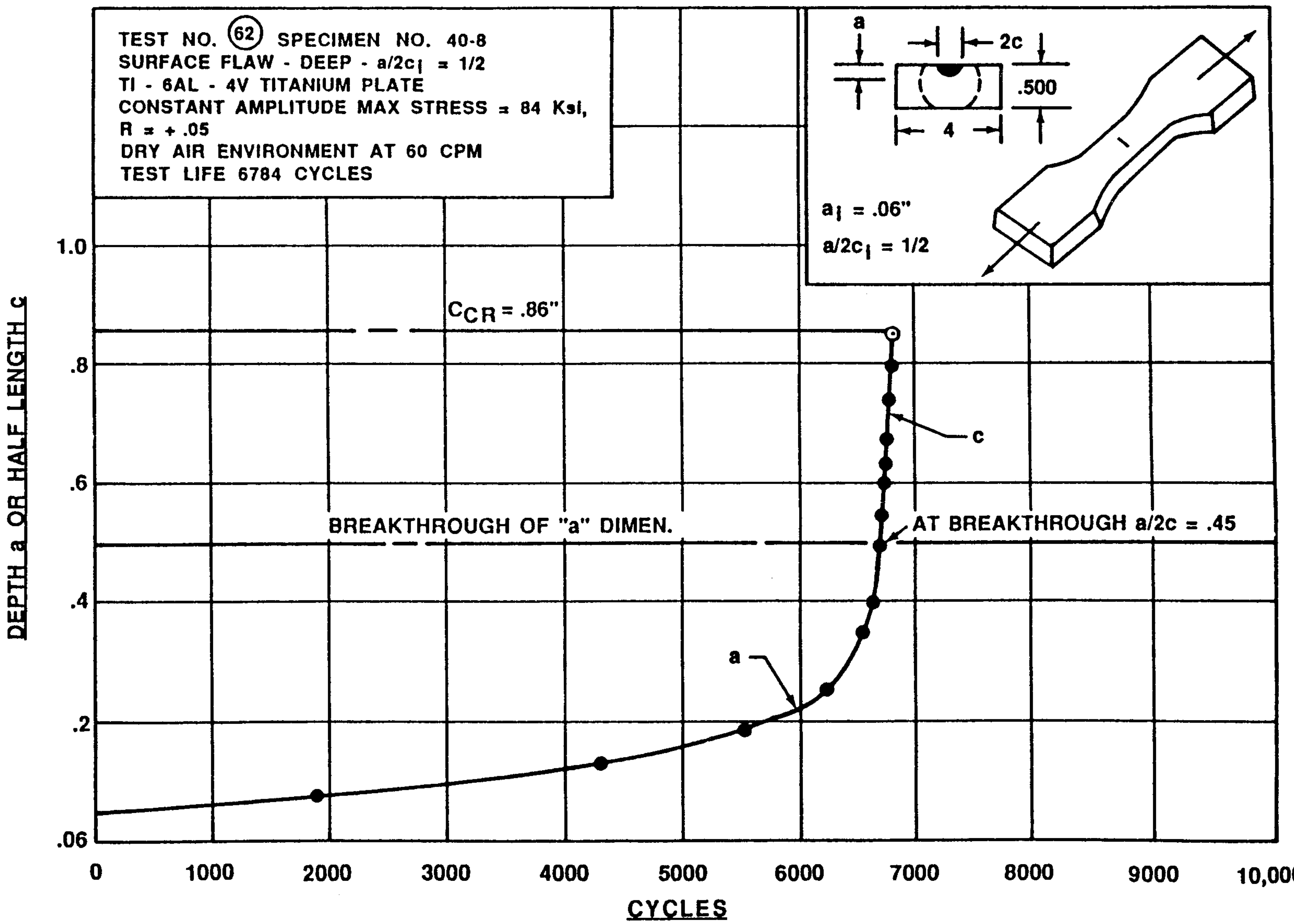
TRANSITION TO 1-D SOLUTION TC01 AT 43,531 CYCLES
a=0.5" t=0.5" c=0.62"
FAILURE OCCURED AT 43,843 CYCLES K_{max}=100.3 KSI $\sqrt{IN}$ c=0.798"

NASCRAC PART THROUGH CRACK ANALYSIS

DATA FROM "NASCRAC #5576"

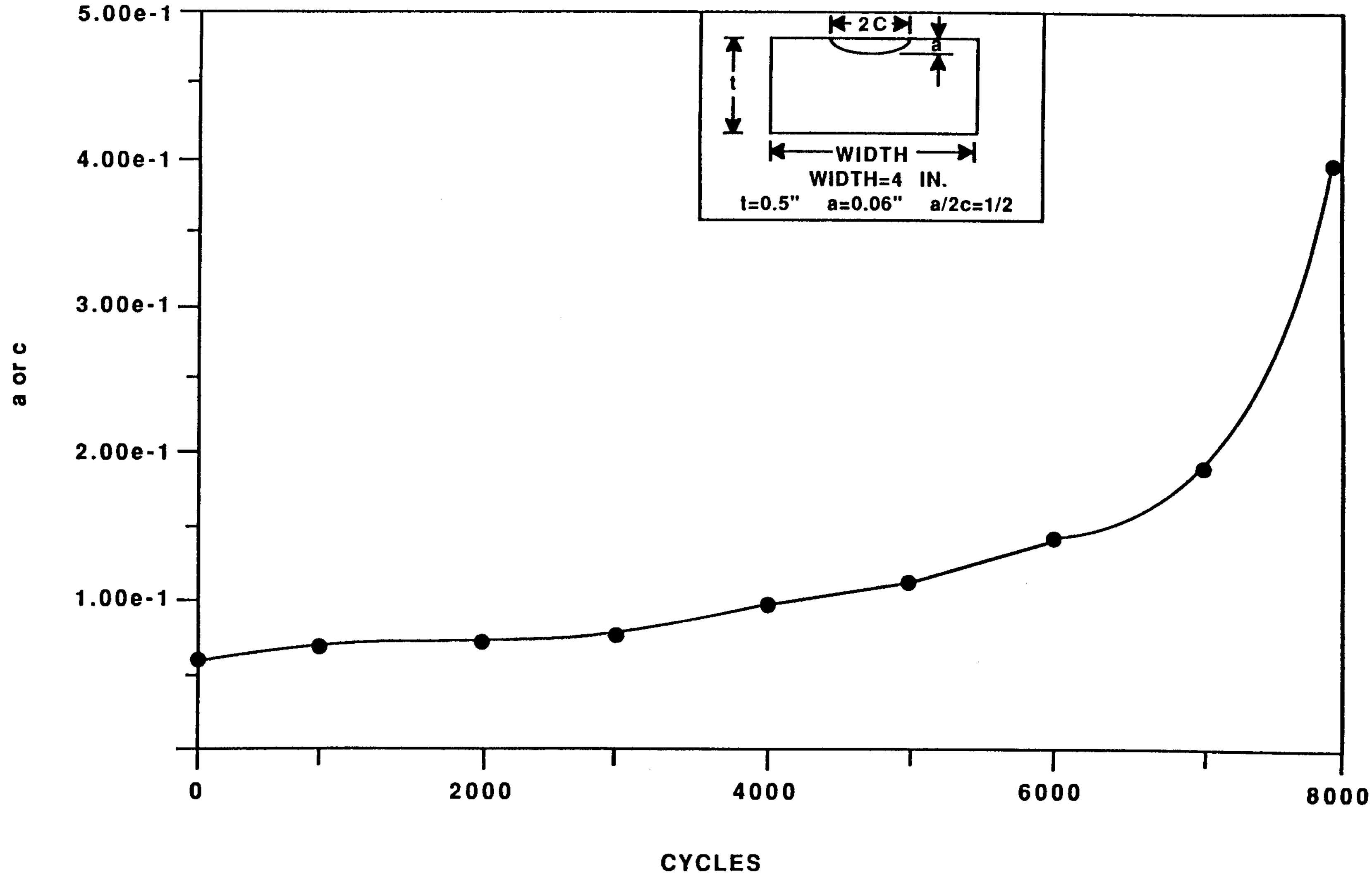


TRANSITION TO 202 MODEL AT 45,148 CYCLES
a=0.5" t=0.5" c=0.702"
FAILURE OCCURED AT 46,393 CYCLES Kmax=100 KSI $\sqrt{IN}$ c=0.827"


TEST NO. 62 SPECIMEN NO. 40-8
SURFACE FLAW - DEEP - a/2c$_i$ = 1/2
TI - 6AL - 4V TITANIUM PLATE
CONSTANT AMPLITUDE MAX STRESS = 84 Ksi,
R = + .05
DRY AIR ENVIRONMENT AT 60 CPM
TEST LIFE 6784 CYCLES
a
2c
.500
4
a$_i$ = .06"
a/2c$_i$ = 1/2
C_{CR} = .86"
c
BREAKTHROUGH OF "a" DIMEN.
AT BREAKTHROUGH a/2c = .45
a
DEPTH a OR HALF LENGTH c
1.0
.8
.6
.4
.2
.06
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10,000
CYCLES

NASA/FLAGRO PART THROUGH CRACK ANALYSIS

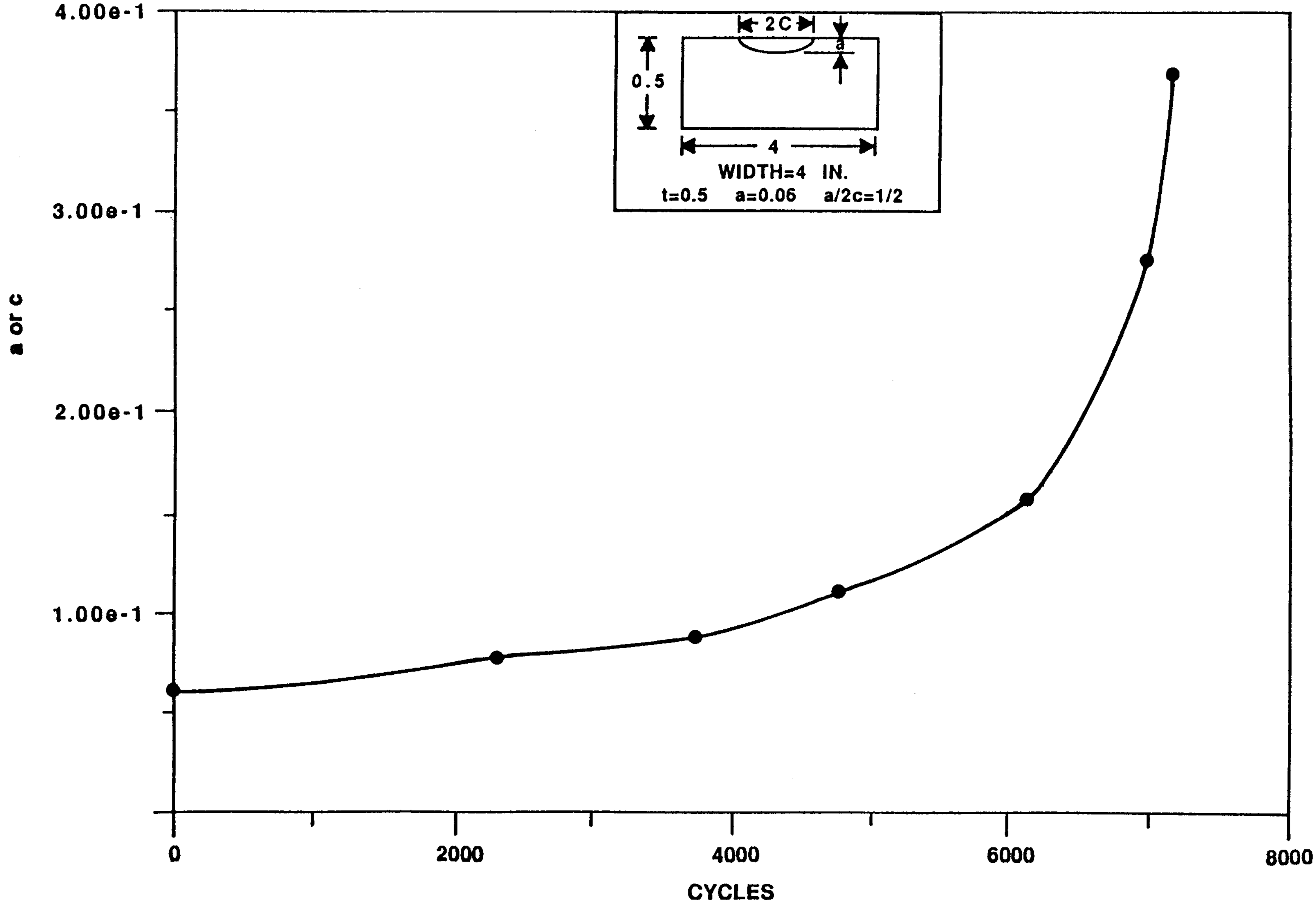
DATA FROM "NASGRO #62"



FAILURE OCCURED AT 7855 CYCLES a=0.358" c=0.4" Kmax=85.09 KSI $\sqrt{IN}$

NASCRAC PART THROUGH CRACK ANALYSIS

DATA FROM "NASCRAC TEST 62"



FAILURE OCCURRED AT 7214 CYCLES

$K_{MAX} = 71\ \mathrm{KSI}\sqrt{\mathrm{IN}} = 0.367''$

OBSERVATIONS

NASCRAC and NASA/FLAGRO are both user-friendly fracture mechanics analysis codes. Both programs offer a wide variety of crack geometries. Material property data can be read in from a resident file or from user defined input. Load spectra data for the constant amplitude loading cases were utilized easily in both programs.

For the through-crack comparison analysis the Modified Forman equation was used and for the part-through crack analysis the Walker growth rate equation was used.

For the through-crack analysis with an R ratio of zero, results showed good correlation between the two codes except for the through-crack at a lug solution. For R = –1, +0.5, –0.5, NASA/FLAGRO calculates an m value that is not readily known to the user; it must be hand calculated for use in NASCRAC. By specifying the nonclosure option, m is automatically set to zero. The nonclosure option gave the most conservative results in NASA/FLAGRO. For R = –1, +0.5, –0.5, changing the m value in NASCRAC had no effect on the results, the m value has been permanently set to some prescribed value. The NASCRAC results for the through-crack analysis for R = –1, +0.5, –0.5 were in the range of the NASA/FLAGRO results for the nonclosure option.

For the part through center crack analysis, both programs gave comparable results, particularly with specimen No. 15576 where the crack grew through before failing, but both programs showed failure before breakthrough for specimen No. 62 which was different from the results of the test.

The comparison analysis between the two programs is an on-going effort for our analysis team. Other types of solution methods and problems are scheduled to be studied in the future.

REFERENCES

1. NASA/FLAGRO — Fatigue Crack Growth Program, JSC-22267, Johnson Space Center, August 1986.

2. NASCRAC — NASA Crack Analysis Code, Version 1.02, Failure Analysis Asssociates, April 1988.

3. MSFC-HDBK-1453 — Fracture Control Program Requirements, Marshall Space Flight Center, October 1987.

4. MSFC-STD-1249 — Standard NDE Guidelines and Requirements for Fracture Control Programs, Marshall Space Flight Center, September 11, 1983.

5. NASA CR-134758 — Fracture Control Method for Composite Tanks with Load Sharing Liners, W.D. Bixter, Boeing Aerospace Co., July 1975.

6. Rocketdyne Memorandum 88 RC03594 — Part-Through Crack Growth Test Data, Dale Russell and Bob Primas, Rockwell International Corp., March 17, 1988.

7. MSFC Memorandum ED25(88-35) — Fracture Toughness Properties Used in NASA/FLAGRO, March 7, 1988.

APPROVAL

COMPARISON OF TWO COMPUTER CODES FOR CRACK GROWTH ANALYSIS — NASCRAC VERSUS NASA/FLAGRO

By R. Stallworth, C.A. Meyers, and H.C. Stinson

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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