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DIGITAL COMPUTER PROGRAM FOR THE
ANALYSIS OF CRACK PROPAGATION IN
CYCLIC LOADED STRUCTURES

R. G. FORMAN
J. P. HUDSON

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Force Flight Dynamics Laboratory (FDTR), Wright-Patterson Air Force Base,
Ohio 45433.
FOREWORD

This report was prepared by the Directorate of Computation, Systems Engineering Group, Wright-Patterson Air Force Base (WPAFB), Ohio and the Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio. The work was conducted under Project 1467, "Structural Analysis Methods", Task 146704, "Structural Fatigue Analysis", with Mr. Robert M. Bader acting as Project Engineer.

Mr. Royce G. Forman, Air Force Flight Dynamics Laboratory, prepared the theoretical part of this report. Mr. J. P. Hudson, Systems Engineering Group, performed the programming of the analysis and assisted in writing the description of the computer program.

The use of the computer program described herein can be obtained by contacting AFFDL (FDTR/Mr. R. G. Forman), Wright-Patterson AFB, Ohio 45433.

The manuscript was released by the authors in December 1966 for publication as an RTD Technical Report.

This technical report has been reviewed and is approved.

FRANCIS J. JANIK, JR.
Chief, Theoretical Mechanics Branch
Structures Division
Air Force Flight Dynamics Laboratory
This report presents a detailed description of a computer program for analyzing crack propagation in cyclic loaded structures. The program calculates crack growth, both for uniform and non-uniform cyclic loading and also calculates the number of load cycles to cause instability of crack growth. Instructions for use of the program and two illustrative analysis problems are presented.
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>SECTION</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>I     INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II    DESCRIPTION OF COMPUTER PROGRAM</td>
<td>2</td>
</tr>
<tr>
<td>III   CARD SEQUENCE</td>
<td>4</td>
</tr>
<tr>
<td>IV    GENERAL INPUT INSTRUCTIONS</td>
<td>5</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>7</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>9</td>
</tr>
<tr>
<td>FIGURE</td>
<td>DESCRIPTION</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Griffith Crack in a Finite Width Plate</td>
</tr>
<tr>
<td>2</td>
<td>Crack Emanating from a Circular Hole in a Sheet</td>
</tr>
<tr>
<td>3</td>
<td>Description of Cyclic Loads for a Sample Problem</td>
</tr>
</tbody>
</table>
TABLES

<table>
<thead>
<tr>
<th>TABLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Listing of Input Cards</td>
</tr>
<tr>
<td>2</td>
<td>Sample Problem of Griffith Crack in a Finite Width Plate, Listing of Data Input</td>
</tr>
<tr>
<td>3</td>
<td>Sample Problem of Griffith Crack in a Finite Width Plate, Output of Results</td>
</tr>
<tr>
<td>4</td>
<td>Sample Problem of Crack Emanating from a Circular Hole, Listing of Data Input</td>
</tr>
<tr>
<td>5</td>
<td>Sample Problem of Crack Emanating from a Circular Hole, Output of Results</td>
</tr>
</tbody>
</table>
LIST OF SYMBOLS

A        crack length dimension
AI       initial crack length dimension
B        a geometrical dimension of the problem; e.g. plate half width or hole radius
C        material constant for crack propagation
K        A/B, ratio of crack length to plate width
DK       stress intensity factor range in a load cycle
KC       fracture toughness parameter
P        applied load (or stress) on a plate
DP       range of applied stress in a given cycle; e.g. maximum stress - minimum stress
R        minimum applied stress/maximum applied stress
T        cycle number
TI       initial cycle number
TF       final cycle number in a block load
SN       power of DK
DTI      printout interval for T
f(        a function of
\frac{dA}{dT}    crack extension per cycle
\beta      plate width correction factor
SECTION I

INTRODUCTION

The computer program presented in this report was developed to support in-house research efforts by the AF Flight Dynamics Laboratory in crack propagation analysis of cyclic loaded structures. The program was specifically written to take into account complex crack geometries and cyclic loads of nonuniform character. The generality of the program and the simplicity of input data were achieved by writing and running the program under the digital simulation program MIMIC. The program in its present form was found very useful in solving numerous problems occurring in aircraft type structures, such as fatigue crack propagation and crack growth emanating from projectile impact damage.
SECTION II

DESCRIPTION OF COMPUTER PROGRAM

This program calculates the crack propagation behavior of cyclic loaded structures by means of the theory described in Reference 1. The theory states that the crack growth rate is governed by the following first order linear differential equation:

\[
\frac{dA}{dT} = \frac{C(DK)^{SN}}{(1-R)KC-DK} \quad (1)
\]

For problems of cyclic load of uniform character, e.g. the load range, DP, and the load ratio, R, constant, equation (1) has the form

\[
\frac{dA}{dT} = f(A) \quad (2)
\]

Given an initial crack size at an initial value of T, such as T = 0, the computer program calculates the crack length after a given number of cycles. The program also calculates the number of cycles required for crack growth instability, or the point when the denominator in equation (1) first becomes negative.

The program was written in MIMIC, a Digital Simulation Program developed at Wright-Patterson AFB, and was run on an IBM 7094/7044 DCS Computer with a Fortran IV IBSYS monitor. Thus, this program may be run at any installation which has the capability of processing MIMIC programs. The MIMIC program is available on request (see reference 2) and has been written for a number of computers.

Input to the crack propagation program includes the following parameters for all problems to be analyzed:

- **AI**: Initial value of A
- **C**: Material constant
- **SN**: Power of DK
- **KC**: Fracture toughness parameter
- **DTI**: Printout interval for T
- **TI**: Initial cycle number

Other parameters, such as the plate width, B, are usually required, but they will depend on the particular problem to be solved.

In addition, the function representing the stress intensity factor range, DK, must be defined. The function can be expressed analytically, or it can be listed as point values in tabular form.
For example, many solutions for DK can be expressed as follows:

\[ DK = DP \sqrt{\pi A} / FX \]  

(3)

where DP is the loading parameter and FX is a correction factor. For the solution of equation (1), DP and R must always be given in tabular listings as functions of the variable T. The correction factor FX can either be given as an analytic function of the crack length A, or listed as point data in tabular form. If tabular form is needed, the MIMIC Program has the capability of generating functions of either one or two variables, such as

\[ FX = f(\alpha) \]

or

\[ FX = f(\alpha, \beta) \]

where

\[ \alpha = \alpha(A), \beta = \beta(A) \]

A general description of the MIMIC Program with operating instructions is given in Reference 2. The card sequence for crack propagation analysis is given in Section III. General input instructions are given in Section IV.
SECTION III

CARD SEQUENCE

The input to the computer program consists of three sets of cards. They are the (1) MIMIC system control cards, (2) function cards and (3) input data cards. These are described in sequence as follows:

1. MIMIC System Control Cards - The set of cards from $SETUP thru $DELETE.

2. Function Cards - These are the program cards and include the following:
   a. Program Name Comment Card
   b. Constant Name Cards
   c. Tabulated Function Definition Cards*
   d. Parameter Name Card - Defines the step functions DP and R
   e. DK Definition Cards
   f. Differential Equation Cards
   g. Program Stop Cards
   h. Header and Output Cards
   i. END Card

3. Input Data Cards - This set of cards immediately follows the program END Card.
   a. Constant Cards
   b. Tabulated Data Cards for Function Generators*
   c. Tabulated Data Cards for Loading Parameters

A complete listing of the program input for two different problems is presented in the Appendix.

* Use only if required.
SECTION IV
GENERAL INPUT INSTRUCTIONS

1. MIMIC SYSTEM CONTROL CARDS

The MIMIC program here at WPAFB is maintained on a tape (called MIMIC). The control cards call for the mounting of this tape ($SETUP) and for the calling forth from this tape of the program subroutines ($IBLDR). The subroutine MM02 was modified for this program to change the standard output format. This change requires insertion of the modified Fortran source or binary deck surrounded by $IEDIT control cards in place of the $IBLDR MM02 card in the normal MIMIC system control cards.

The control cards end with a $DATA card to signal the beginning of the function cards and a $DELETE card to delete the MIMIC compiled listing. A complete listing of the cards is shown in TABLE I.

2. FUNCTION CARDS

a. Comment Cards: Any symbol placed in column 1 results in the entire card being treated as a comment card. The use of these cards is optional in the program.

b. Constant Name Cards: The name of a constant is defined by entering it on a CON card, and its numerical value is given in the data section of the program. As many as six constants may be named on one CON card and as many CON cards as necessary may be used in the program. The format for the Constant Name Cards is as follows:

<table>
<thead>
<tr>
<th>10</th>
<th>19</th>
<th>73</th>
</tr>
</thead>
<tbody>
<tr>
<td>CON(AI, C, SN, KC, *, *)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CON(*, *, *, *, *, *)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CON(TI, DT1, STOP1)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The asterisks designate additional constants which may be required for particular problems, such as the plate width B, or an angle α. All specific constants shown are required for every problem.

c. Tabulated Function Definition Cards: Functions generated from tabular data are specified by a CFN (constant function) card. The name of the function (e.g., F) and the number of pairs or triples of points, n, are entered on the CFN cards as follows:

<table>
<thead>
<tr>
<th>10</th>
<th>19</th>
<th>73</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>CFN(n,)</td>
<td></td>
</tr>
</tbody>
</table>

The numerical data for the function is given in the data section of the program. The function is used in the program by specifying the array name and the independent variable on a FUN card (See examples in Tables IV).

d. Parameter Name Card: This card defines the load parameters for the program. The parameters are named on a PAR card and their numerical values entered on data cards using the same format as for constants (See examples in Tables II and IV). The basic parameters required for every problem are TF, P, and R. Additional parameters can be specified for
solving problems of combined loading, or for problems where constants such as C, SN, and KC change due to environmental conditions.

e. DK Definition Cards: These cards define the expression for DK for the particular problem to be solved. One card should be used to define the expression for DK and additional cards should be used to define the constants and functions in the expression. The format for these cards is shown in the following example from Table IV:

<table>
<thead>
<tr>
<th>10 Result</th>
<th>19 Expression</th>
</tr>
</thead>
<tbody>
<tr>
<td>PI</td>
<td>3.14159</td>
</tr>
<tr>
<td>K</td>
<td>(A/B)*(A/B)</td>
</tr>
<tr>
<td>FX</td>
<td>FUN(F, A/B)</td>
</tr>
<tr>
<td>DK</td>
<td>DP<em>SQR(PI</em>A<em>FX</em>FX)</td>
</tr>
</tbody>
</table>

f. Differential Equation Cards:

g. Program Stop Cards:

h. Header and Output Cards:

i. END Card:

3. INPUT DATA CARDS

Input format for these cards is given in Reference 2. Examples for two different problems are shown in Tables II and IV. As the examples indicate, the input requirements for these cards are that numerical values must be entered in the same order as the constants or parameters on the CON, CF, or PAR cards. The first number must be entered in columns 1-12, the second in columns 13-24, the third in columns 25-36, the fourth in columns 37-48, the fifth in columns 49-60, and the sixth in columns 61-72. Finally, the numbers must be written in floating point form, that is, a number of digits with a decimal point somewhere in the number.
REFERENCES


2. MIMIC - A Digital Simulator Program, SESCA Internal Memo 65-12, Wright-Patterson Air Force Base, Ohio, May 1965.

APPENDIX

1. Sample Problem of Griffith Crack in a Finite Width Plate
   a. Problem Description: See Figure 1.
   b. Load Spectrum: See Figure 3.
   c. Listing of Data Input: See Table II.
   d. Output of Results: See Table III.

2. Sample Problem of Crack Emanating from a Circular Hole
   a. Problem Description: See Figure 2.
   b. Load Spectrum: See Figure 3.
   c. Listing of Data Input: See Table IV.
   d. Output of Results: See Table V.
DK = DP \sqrt{\pi A \beta^2} \quad \text{(from Reference 1)}

where

\beta^2 = 1 + 1.18968K^2 + 1.30162K^4 + 1.36502K^6 + 1.37394K^8 + 1.47638K^{10}

and

K = A/B

Figure 1. Griffith Crack in a Finite Width Plate
DK = DP\sqrt{\pi A} \quad FX \quad (From \ Reference \ 3)

where point values of FX are as follows:

<table>
<thead>
<tr>
<th>A/B</th>
<th>FX</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>3.39</td>
</tr>
<tr>
<td>0.10</td>
<td>2.73</td>
</tr>
<tr>
<td>0.20</td>
<td>2.30</td>
</tr>
<tr>
<td>0.30</td>
<td>2.04</td>
</tr>
<tr>
<td>0.40</td>
<td>1.86</td>
</tr>
<tr>
<td>0.50</td>
<td>1.73</td>
</tr>
<tr>
<td>0.60</td>
<td>1.64</td>
</tr>
<tr>
<td>0.80</td>
<td>1.47</td>
</tr>
<tr>
<td>1.0</td>
<td>1.37</td>
</tr>
<tr>
<td>1.5</td>
<td>1.18</td>
</tr>
<tr>
<td>2.0</td>
<td>1.06</td>
</tr>
<tr>
<td>3.0</td>
<td>0.94</td>
</tr>
<tr>
<td>5.0</td>
<td>0.81</td>
</tr>
<tr>
<td>10.0</td>
<td>0.75</td>
</tr>
<tr>
<td>\infty</td>
<td>0.707</td>
</tr>
</tbody>
</table>

Figure 2. Crack Emanating from a Circular Hole in a Sheet
Figure 3. Description of Cyclic Loads for a Sample Problem
TABLE I
LISTING OF INPUT CARDS

$SETUP LB4
$ASSIGN SYSLB4
$IBJOB MIMIC FIOCS
$EDIT SYSLB4, SCHF1
$IBLDR MMC1
$EDIT MMC2 XR7

SUBROUTINE MIMEX

C
C***** EXECUTION PROGRAM
C
DIMENSION P(95), R(250C), S(250C), BCD(1C, 900), FF(9100C)
COMMON P, R, S, FF, IOUT, IPAR, INOUT, IHDR, IFIN, IEND, NPAR,
C       DUMMY(3), IPC, IS, DUMMY1
NRUN=0
INOUT=99
CALL MIMIO(A, B, C, D, E, G)

C
C***** PROGRAM EXECUTION CONTROL SWITCHES
C
C   IEND=0 NOT END OF RUN
C       =1 END OF RUN
C   IPAR=0 DO NOT READ PARAMETERS
C       =1 READ PARAMETERS
C   IOUT=0 DO NOT WRITE OUTPUT
C       =1 WRITE OUTPUT
C   IFIN=0 DO NOT TEST FINISH STATEMENTS
C       =1 TEST FINISH STATEMENTS
C   IHDR=0 DO NOT WRITE HEADERS
C       =1 WRITE HEADERS
C   NPAR=0 NO PARAMETERS (ONE RUN)
C       =1 PARAMETERS (ONE OR MORE RUNS)
C
C***** SET FOR READING INPUT DATA
C
100 NRUN=NRUN+1
   IPAR=1
   PRINT 1, NRUN
   IEND=0
   IOUT=0
   IFIN=0
   IHDR=0
   R(i)=0.
C   WRITE(6, 2)
   CALL F
   IPAR=0
   CALL F
C***** SET FOR HEADING, OUTPUT, TESTING END OF RUN
TABLE I (Continued)

LISTING OF INPUT CARDS

IHDR=1
200 IFIN=1
IOUT=1
CALL F
IHDR=0
IFIN=0
IOUT=0

C**** TEST FOR END OF RUN
IF(IEND.NE.0) GO TO 300

C**** INTEGRATE
CALL MIMIN
GO TO 200

C**** TEST FOR FURTHER RUNS

300 IF(IPC.EQ.1) CALL MIMLT
IF(NPAR.NE.C) GO TO 100
RETURN
1 FORMAT(1H BEGIN RUN , I4)
2 FORMAT(1H1)
END

$EDIT SYSLB4, SCHF1
$EDIT MM03
$EDIT MM04
$EDIT MM05
$EDIT MM06
$EDIT MM07
$EDIT MM08
$EDIT MM09
$EDIT MM10
$EDIT MM11
$EDIT MM12
$EDIT MM13
$EDIT MM14
$EDIT MM15
$EDIT MM16
$EDIT MM17
$EDIT MM18
$EDIT MM19
$EDIT MM95
$EDIT MM96
$EDIT MM97
$EDIT MM98
$EDIT MM99

$EDIT $DATA

Data Input (See Tables II and IV)

$EOF
TABLE II

SAMPLE PROBLEM OF GRIFFITH CRACK IN A FINITE WIDTH PLATE, LISTING OF DATA INPUT

$DATA
C GRIFFITH CRACK IN FINITE WIDTH PLATE
$DELETE

CON(AI,C,SN,KC,B)
CON(TI,DT1,STOP1)
C STOP1 IS A CONTROL CONSTANT WHICH WILL STOP THE PROGRAM AFTER C DENOM HAS BECOME NEGATIVE.
PAR(TF,DP,R)
PI 3.14159
DTMIN 1.0
K (A/B)*(A/B)
BETA1 1.0+1.18968*K+1.30162*K*K
BETA2 K*K*(1.36502+1.37394*K+1.47638*K*K)
B2 BETA1 + BETA2
DK DP*SQR(PI*ABS(A)*B2)
NUMER EXP(SN,DK*EXP(1./SN,C))
DENOM (1.-R)*KC-DK

IDA NUMER/DENOM
A INT(IDA,AI)
DT FSW(TI+T+DT1-TF,DT1,DT1,TF-TI-T)
STOP STOP1 FSW(DENOM,-1.0,-1.0,STOP1)
STOP IOR(FIN(TI+T,TF),FIN(0.0,STOP1),FIN(0.0,DENOM))
STOP AI A
STOP TI TF
LCV FSW(STOP1,FALSE,FALSE,TRUE)
LCV HDR(T,A,R,DP,DENOM)
LCV OUT(TI+T,A,R,DP,DENOM)
END

1.25 5.E-13 3.0 68000. 10.
0.0 1000. 1.0
1.0 6000.0 0.0
1000.0 2000.0 0.666
1001.0 4000.0 0.500
8000.0 4000.0 0.333
$EOF
TABLE III
SAMPLE PROBLEM OF GRIFFITH CRACK IN A FINITE WIDTH PLATE, OUTPUT OF RESULTS

***MIMIC SOURCE-LANGUAGE PROGRAM***

C GRIFFITH CRACK IN FINITE WIDTH PLATE
$DELETE
CON(AI,C,SN,KG,B)
CON(TI,D1,STOP1)
C STOP1 IS A CONTROL CONSTANT WHICH WILL STOP THE PROGRAM AFTER
C DENOM HAS BECOME NEGATIVE.
PI 3.14159
DTMIN 1.0
K (A/B)*(A/B)
BETA1 1.0+1.18968*K+1.3C162*K*K
BETA2 K*K*K*(1.365C2+1.37394*K+1.47638*K*K)
B2 BETA1 + BETA2
DK DP*SQK(P1*ABS(A)*B2)
NUMER EXP(SN,DK*EXP(1./SN,C))
DENOM (1.-R)*KC-DK
IDA NUMER/DENOM
A INT(IDA,AL)
DT FSW(TI+T+DT1-TF,D1,DT1,TF-TI-T)
STOP STOP1 FSW(DENOM,-1.0,-1.0,STOP1)
STOP IOR(FIN(TI+T,TF),FIN(0.0,STOP1),FIN(0.0,DENOM))
STOP A
STOP TI TF
LCV FSW(STOP1,FALSE,FALSE,TRUE)
LCV HDR(T,A,R,DP,DENOM)
LCV OUT(TI+T,A,R,DP,DENOM)
END

<table>
<thead>
<tr>
<th>AI</th>
<th>SN</th>
<th>KC</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25000E 00</td>
<td>5.00000E-13</td>
<td>3.00000E 00</td>
<td>6.80000E 04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TI</th>
<th>DT1</th>
<th>STOP1</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.</td>
<td>1.00000E 03</td>
<td>1.00000E 00</td>
</tr>
</tbody>
</table>
TABLE III (Continued)

SAMPLE PROBLEM OF GRIFFITH CRACK IN A FINITE WIDTH PLATE, OUTPUT OF RESULTS

***EXECUTION***

<table>
<thead>
<tr>
<th>TF</th>
<th>DP</th>
<th>R</th>
<th>DP</th>
<th>DENOM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00E00</td>
<td>6.00E00</td>
<td>0.00E00</td>
<td>6.00E00</td>
<td>5.5998E+04</td>
</tr>
<tr>
<td>T</td>
<td>A</td>
<td>R</td>
<td>DP</td>
<td>DENOM</td>
</tr>
<tr>
<td>0.00E00</td>
<td>1.250E00</td>
<td>6.66E-01</td>
<td>2.00E00</td>
<td>1.8711E+04</td>
</tr>
<tr>
<td>1.00E00</td>
<td>1.250E00</td>
<td>6.66E-01</td>
<td>2.00E00</td>
<td>1.8708E+04</td>
</tr>
<tr>
<td>TF</td>
<td>DP</td>
<td>R</td>
<td>DP</td>
<td>DENOM</td>
</tr>
<tr>
<td>1.00E00</td>
<td>1.25173E00</td>
<td>5.00E-01</td>
<td>4.00E00</td>
<td>2.5993E+04</td>
</tr>
<tr>
<td>T</td>
<td>A</td>
<td>R</td>
<td>DP</td>
<td>DENOM</td>
</tr>
<tr>
<td>1.00E00</td>
<td>1.25174E00</td>
<td>5.00E-01</td>
<td>4.00E00</td>
<td>2.5993E+04</td>
</tr>
<tr>
<td>5.00E00</td>
<td>1.27974E00</td>
<td>3.33E-01</td>
<td>4.00E00</td>
<td>3.7185E+04</td>
</tr>
<tr>
<td>6.00E00</td>
<td>1.28696E00</td>
<td>3.33E-01</td>
<td>4.00E00</td>
<td>3.7233E+04</td>
</tr>
<tr>
<td>7.00E00</td>
<td>1.29413E00</td>
<td>3.33E-01</td>
<td>4.00E00</td>
<td>3.7209E+04</td>
</tr>
</tbody>
</table>
### TABLE IV

**SAMPLE PROBLEM OF CRACK EMANATING FROM A CIRCULAR HOLE, LISTING OF DATA INPUT**

```plaintext
$DATA
C CRACK EMANATING FROM A CIRCULAR HOLE.
$DELETE
   CON(AI,C,SN,KC,B)
   CON(TI,DT1,STOP1)
C STOP1 IS A CONTROL CONSTANT WHICH WILL STOP THE PROGRAM AFTER
C DENOM HAS BECOME NEGATIVE.
   F       CFN(15.
C F IS GIVEN IN TABULAR FORM.
   PI       3.14159
   DTMIN    1.0
   K       (A/B)*(A/B)
   FX       FUN(F,A/B)
   DK       DP*SQR(P1*A*FX*FX)
   NUMER    EXP(SN,DK*EXP(1./SN,C))
   DENOM    (1.-R)*KC-DK
   IDA      NUMER/DENOM
   A       INT(IDA,AI)
   DT       FSW(TI+T+DT1-TF,DT1,TF-TI-T)
   STOP     FSW(DENOM,-1.0,-1.0,STOP1)
   STOP     IOR(FIN(TI+T,TF),FIN(0.0,STOP1),FIN(0.0,DENOM))
   STOP     AI       A
   STOP     TI       TF
   LCV      FSW(ST0P1,TRUE,TRUE,TRUE)
   LCV      HDR(T,A,R,DP,DENOM)
   LCV      OUT(TI+T,A,R,DP,DENOM)
END
```

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$EOF
### TABLE V

**SAMPLE PROBLEM OF CRACK EMANATING FROM A CIRCULAR HOLE, OUTPUT OF RESULTS**

#### ***MIMIC SOURCE-LANGUAGE PROGRAM***

**C CRACK EMANATING FROM A CIRCULAR HOLE.**

```c
$DELETE
CON(AI,C,SN,KC,B)
CON(TI,DT1,STOP1)
C STOP1 IS A CONTROL CONSTANT WHICH WILL STOP THE PROGRAM AFTER
C DENOM HAS BECOME NEGATIVE.
F CFN(15)
C F IS GIVEN IN TABULAR FORM.
PAR(TF,DP,R)
  PI  3.14159
  DTMIN 1.0
  K  (A/B)*(A/B)
  FX  FUN(F,A/B)
  DK  DP*SOR(PI*A*FX*FX)
  NUMER  EXP(SN,DK*EXP(1./SN,C))
  DENOM  (1.-R)*KC-DK
  IDA  NUMER/DENOM
  A  INT(IDA,AI)
  DT  FSW(TI+DT1-TF,DT1,DT1,TF-TI-T)
  STCP1  FSW(DENOM,-1.0,-1.0,STOP1)
  STCP  IOR(FIN(TI+TF),FIN(0.0,STOP1),FIN(0.0,DENOM))
  STOP  AI  A
  STOP  TI  TF
  LCV  FSW(STOP1,FALSE,FALSE,TRUE)
  LCV  HDR(T,A,R,DP,DENOM)
  LCV  OUT(TI+T,A,R,DP,DENOM)
END
```
## TABLE V (Continued)

SAMPLE PROBLEM OF A CRACK EXAMINATING FROM A CIRCULAR HOLE, OUTPUT OF RESULTS

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TABLE V (Continued)

SAMPLE PROBLEM OF CRACK EMANATING FROM A CIRCULAR HOLE, OUTPUT OF RESULTS

***EXECUTION***

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This report presents a detailed description of a computer program for the crack propagation analysis of cyclic loaded structures. The computer program calculates crack growth for both uniform and non-uniform cyclic loading and also calculates the number of load cycles to cause crack growth instability. Instructions for use of the program and two illustrative analysis problems are presented.
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