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Reference Manual for the LIFE2 Computer Code

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REFERENCE MANUAL FOR THE LIFE2 COMPUTER CODE*

by

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ABSTRACT

LIFE2 is a PC-compatible computer code that analyzes the service lifetime of a WECS component. The LIFE2 code is written in Fortran and has the option of using either a fatigue analysis or a linear fracture mechanics analysis. This document contains information on what the code expects as input and what can be expected as output from the code. Also included are two example problems.

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INTRODUCTION

The LIFE2 computer code (see Refs. 1, 2 and 3) is a fatigue/fracture analysis code that is specialized to the analysis of wind turbine components. The code is designed to run on a personal micro-computer (PC) or compatible machine. It is written in Fortran using a modular design to maximize its versatility and to permit modification to the code with minimum difficulty.

The LIFE2 code is written in Fortran 77. The Microsoft Fortran Optimizing Compiler (Version 4.1)[4] was used to compile the code. Plot results were obtained from the PLOT88 plotting package[5].

The code has five main computational modules (or subroutines). The modules are referred to as the Wind Resource module, the Constitutive Properties module, the Stress State module, the Operational Parameters module and the Lifetime Calculations module. In addition to the main modules there are an Executive Module that ties the main modules together and two auxiliary modules, a Plot Parameters module and a Library Functions module. The Plot Parameters module sets hardware default parameters for plotting results and the Library Functions module permits storing/retrieval of data.

This manual describes the inputs to the computational modules and gives examples of correct responses to the code's prompts. Two example problems are used to validate the output of the code.

This manual does not contain a detailed description of the mathematical formulations that the code uses. It is intended to be a user's manual. Reference 3 contains a detailed discussion of the mathematical formulations of the code.

INSTALLATION

To run the LIFE2 code on a PC computer system, the system must be equipped with a hard disk, 640M bytes of memory and a 360k or 1.2M floppy drive. If graphics are desired then the monitor must be capable of doing CGA, EGA, or Hercules graphics. This configuration will be assumed throughout this manual.

The LIFE2 code can be installed manually or can be installed using the batch file called INSTALL.BAT. The installation program creates a subdirectory called LIFE2 on the specified hard disk. This directory contains an executable file called LIFE2.EXE and a batch file called RUNLIFE.BAT. These are the only two files that are needed to run LIFE2. The installation program will also copy the Fortran source code and the batch files to compile and link the source code using the Microsoft Version 4.2 Fortran compiler. The installation program will also create a subdirectory under the LIFE2 directory called DATA. This directory will store all of the files that are created while running the LIFE2 program.

To use the installation program, put the disk labeled <u>LIFE2: Executable</u> into drive A. If the LIFE2 code is to be placed on hard disk C, then type the following at the DOS prompt:

A:INSTALL C:

If a different hard disk is desired, replace the C with the desired hard disk specifier. The installation program will copy all of the files onto the hard disk prompting for the disk labeled <u>LIFE2: Source Code</u> when it is required. If the Fortran source code is not desired, then type <control C> when the installation program requests the source code disk.

After the installation program is completed, the batch file COPYFILE.BAT is no longer needed in directory LIFE2 and may be erased if desired.

A path statement is required by the operating system before the LIFE2 code can be executed. The following statement must be executed before the LIFE2 code can be executed:

PATH C:\LIFE2

This statement may be added to the autoexec.bat file to facilitate automatic execution. The above example assumes that the code was installed on hard disk C. If the code is on a different hard disk, then replace C with the appropriate hard disk specifier. If a path statement is already in use, then the following statement may be added to the end of the current statement:

;C:\LIFE2

If the path statement is placed into the autoexec.bat file the computer will have to be rebooted in order for the statement to have any effect. Once the proper path statement is functional, the LIFE2 code is ready to run. With the hard disk containing the LIFE2 code as the active drive, at the DOS prompt, type RUNLIFE and the current directory will change to the /LIFE2/DATA subdirectory and then the code will begin executing. After exiting the code the current directory is changed back to /LIFE2.

BACKGROUND INFORMATION

Notation

In this manual, LIFE2 code prompts are written in **bold letters**. Examples of correct responses to the code's prompts are written in *italics.*

When one of the code's menus is shown, the page number corresponding to each option is printed on the right margin. This indicates the page of this manual on which the option is discussed.

If a sequence of steps is to repeated, it is indicated using three dots in a row. Both horizontal and vertical formats are used: namely, ... and

.

.

.

respectively.

Data Files

Several classes of data files are used by the LIFE2 code. These files are used to transfer data between computational modules and to archive data. Their operation is transparent to the operator.

Location of Data Files: All files that are created by the LIFE2 code are placed in the current directory. If the code was started with the batch program RUNLIFE.BAT then the current directory will be /LIFE2/DATA. It is assumed in this manual that RUNLIFE.BAT was used to start the execution of the code.

Calculational Files: The first four modules (the Wind Resource, the Constitutive Properties, the Stress States, and the Operational Parameters) will create what are called calculational files. Calculational files reflect the current data stored in memory for that particular module. For example, the Wind Resource module uses the calculational module called WND.CAL. When the Wind Resource module is executed, the data in the current WND.CAL file are read into memory. These data become the current wind data base. If the data are changed, the calculational file WND.CAL is automatically updated to reflect the change. When the Wind Resource module is exited, the file WND.CAL will contain the most recent wind data base created by the module. There are seven different calculational files which are stored in the DATA subdirectory. The Wind Resource program uses WND.CAL. The Constitutive Properties program uses two calculational files; the FAT.CAL file, used for the fatigue analysis and the FRC.CAL file, used for the fracture analysis. The Stress States program uses three calculational files called OPS.CAL for the operational stresses, STS.CAL for the start/stop stresses and BUF.CAL for the buffeting stresses. The Operational Parameters program uses the OPP.CAL file.

Calculational files contain the data to be used in the next lifetime calculation. Therefore, all of these files, except for the STS.CAL and BUF.CAL, must exist before the service lifetime of a component can be calculated. When the code is executed for the first time, the first four options must be executed before calculating the service lifetime. Thereafter, the LIFE2 code uses the last calculational file input into or calculated by the code.

Storage Files: Storage files are used to archive calculational files. The calculational files are not permanent files. They contain the data from the last calculation. If a new calculation is done or the data is changed the calculational file will contain the new data. Therefore, if data are to be recalled, they must be archived in a library file. Once archived, a calculational file may be retrieved using the code's library functions. To archive a calculational file, the code asks for a 1-6 character name to use to store the file. The code adds an extension to indicate which module produced the file. The Wind Resource files will have the extension WND. The Constitutive Properties module uses two extensions. The extension FAT is used to indicate a fatigue calculation file and the extension FRC is used to indicate a fracture calculational file. The Stress States module uses extension OPS for the operational stresses, extension STS for the start/stop stresses, and extension BUF for the buffeting stresses. Extension OPP is used for the calculational files created by the Operational Parameters module. Since each module adds its own extension, the operator may input the same name in different modules. For example, if the operator archives the constitutive description in fatigue for 300M steel to be file 300MST, he may also name the fracture description 300MST. The fatigue file will be stored on the disk as 300MST.FAT and the fracture file will be stored as 300MST.FRC.

Library List Files: Library list files store the names of the data files that have been archived. There are five library list files stored in the DATA subdirectory. The Wind Resource's list file is WNDLST.LST. The Constitutive Properties module has two list files, one for the fatigue analysis called FATLST.LST and one for the fracture analysis called FRCLST.LST. The Stress State module has three list files called OPSLST.LST for the operational stresses, STSLST.LST for the start/stop stresses and BUFLST.LST for the buffeting stresses. The Operational Parameters module has OPPLST.LST. If a particular list file does not exist in the DATA subdirectory, it is assumed that no data files have been archived for that module.

When the code lists the files that are contained in a library, only the files contained in the current module's library list file are shown. For example, if the operator is using the Wind Module and the library is written to the screen, only the files contained in WNDLST.LST are shown.

Error Handling

If an input error is recognized by the code, a bell will sound and an error message will be printed to the screen. The code will then reprint the prompt and wait for the new input.

Units

The LIFE2 code is unit insensitive. The user must assure that compatible units are used throughout the calculation. The code will ask for the units being used in the calculation so that they may be documented in the calculational files.

Blank Options

Many of the menus that appear have options labeled 'Blank'. These options are blank subroutines and are reserved for future use by the code. With the code in its original form, if an option labeled 'Blank' is selected, the code effectively stays at the current menu.

Memory Requirements

Because the code uses a large number of files in its calculations and because of its ability to archive files, the work space on computer's hard disk can fill rapidly. The quantity of memory required to complete a computation varies with the problem. For the examples cited in this manual, approximately 500 kbytes of free disk space are required (220 kbytes for the data files and 280 kbytes for the LIFE2 executable file).

GETTING STARTED

This section gives the inputs required to do a lifetime calculation based on a fatigue analysis. It is included to assist the operator in becoming familiar with the code and to insure the code has been installed properly. The first four steps create the calculational files needed for the calculation. The fifth step performs the calculations. After the data has been typed the operator must press <ENTER>.

Step 1: Entering the wind spectrum

To enter a wind spectrum based on a Rayleigh Distribution enter the following at the given menus.

At the Main Menu:

Enter the number of the desired option.>*1*

At the Wind Menu:

Enter the number of the desired option.>*3*

At the Wind Spectrum Calculational Menu:

Enter the number of the desired option.>*1*

Enter the title no longer than 72 characters.
Test Problem for the LIFE2 User's Manual: Wind Spectrum

Enter the units of wind speed no longer than 20 characters.
mph

Enter the upper limit on wind speed that is greater than the expected maximum operating wind speed.>*99*

Enter the number of uniform wind velocity intervals no greater than 100 and not less than 1>*99*

Enter the mean wind speed.>*14*

>>>>> Calculations based on the inputs have been completed. <<<<<

Enter the number of miscellaneous notes for this data set.>*3*

Enter note 1 no longer than 72 characters.
Calculations Based on : Max Wind Speed = 99 mph

Enter note 2 no longer than 72 characters.
: Number of Intervals = 99

Enter note 3 no longer than 72 characters.
To Yield 1 mph Wind Velocity Increments

Do you wish to store these data in the wind library?(Y or N)>*N*

The above responses will create a calculational file as shown in Appendix A page A-3.

Enter a 9 at each menu until the Main Menu is written to the screen.

Step 2: Entering the Fatigue Characterization Data

To enter fatigue characterization data based on the Goodman Rule using the ultimate stress enter the following at the given menus.

At the Main Menu:

Enter the number of the desired option.>*2*

At the Constitutive Properties Menu:

Enter the number of the desired option.>*1*

At the Fatigue Analysis Menu:

Enter the number of the desired option.>*3*

At the Fatigue Properties Calculational Menu:

Enter the number of the desired option.>*2*

Enter the title no longer than 72 characters.
Fatigue Characterization: Test Problem for the LIFE2 User's Manual

Enter the units of stress no longer than 20 characters.
psi

Enter the modulus of elasticity or 0 if unknown.>*1.0e7*

Enter Poissons ratio.>*.3*

Enter the yield strength.>*25000*

Enter the ultimate strength.>*39000*

You have chosen to use a constitutive rule for evaluating the effects of Mean Stress.
NOTE: These formulations assume that the alternating stress is characterized by its amplitude.

Please enter the S-n Diagram for zero Mean Stress as prompted by the program.

Enter the number of cyclic entries, no greater than 100.>*5*

Enter the cyclic stress and press <ENTER>. The cyclic stresses should be in ascending order.

Entry 1>*10000*
Entry 2>*10700*
Entry 3>*14400*
Entry 4>*18300*
Entry 5>*24700*

Enter the cycles to failure corresponding to each mean and cyclic stress and press <ENTER>. The cycles to failure should be in descending order.

For a mean stress of : .00
and a cyclic stress of : 10000.00
Input the number of cycles to failure.>*5e8*

For a mean stress of : .00
and a cyclic stress of : 10700.00
Input the number of cycles to failure.>*1e7*

For a mean stress of : .00
and a cyclic stress of : 14400.00
Input the number of cycles to failure.>*1e6*

For a mean stress of : .00
and a cyclic stress of : 18300.00
Input the number of cycles to failure.>*1e5*

For a mean stress of : .00
and a cyclic stress of : 24700.00
Input the number of cycles to failure.>*1e4*

.... Calculating the number of Cycles to Failure

Enter the number of miscellaneous notes for this data set.>*3*

Enter note 1 no longer than 72 characters.
Fatigue Characterization of 6063 Aluminum

Enter note 2 no longer than 72 characters.
Taken from Ref. 1

Enter note 3 no longer than 72 characters.
Zero Mean Stress Curve Described by the 5 points Listed Below

Do you wish to store these data in the fatigue properties library?(Y or N)>*N*

The above responses will create a calculational file as shown in Appendix A page A-5.

Enter a 9 at each menu until the Main Menu is written to the screen.

Step 3: Entering the Operational Stresses

To enter the operational stresses as calculated by the Veers Model enter the following at the given menus:

At the Main Menu:

Enter the number of the desired option.>*3*

At the Stress State Menu:

Enter the number of the desired option.>*1*

At the Operational Stresses Menu:

Enter the number of the desired option.>*3*

At the Operational Stresses Calculational Menu:

Enter the number of the desired option.>*1*

This option calculates the operational stresses based on the Veers Model.

NOTE: This formulation yields Alternating Stresses that are Characterized by their amplitude.

Enter the title of this data set no longer than 72 characters.
Stress States: Test Problem for the LIFE2 User's Manual

Enter the units of stress no longer than 20 characters.
psi

Enter the units of wind speed no longer than 20 characters.
mph

Enter the number of wind speed intervals.(100 or less)>*75*

The upper bound for the wind regime that is to be characterized in this calculation needs to be entered. The bound should encompass all of the wind speeds that the wind turbine will experience during operation.

Enter the upper wind speed.>75

Enter the mean stress.>7000

The Veers Model requires a transfer function between the wind velocity and the RMS stress level. This function will be input into a table.

Enter the number of entries in the table.(20 or less).>*4*

The wind speed and the corresponding RMS stress are to be entered into the table. The entries should be in ascending order.

Wind Speed 1.>*0*
RMS Stress 1.>*0*

Wind Speed 2.>*10*
RMS Stress 2.>*320*

Wind Speed 3.>*20*
RMS Stress 3.>*700*

Wind Speed 4.>*40*
RMS Stress 4.>*1560*

Enter the frequency of the stress cycles in hertz.>1.6

......Performing the Veers Model Calculations

Enter the number of miscellaneous notes for this data set.>*5*

Enter note 1 no longer than 72 characters.
Operating Stress Characterization Using Veer's Model

Enter note 2 no longer than 72 characters.
Taken from Refs. 1 and 2

Enter note 3 no longer than 72 characters.
Number of Wind Speed Intervals = 75

Enter note 4 no longer than 72 characters.
Upper Limit of Wind Speed = 75 mph

Enter note 5 no longer than 72 characters.
Yields 1 mph Increments in Wind Velocity

Do you wish to store these data in the Operational Parameters library?(Y or N)>*N*

The above responses will create a calculational file as shown in Appendix A page A-9.

Enter a 9 at each menu until the Main Menu is written to the screen.

Step 4: Entering the Operational Parameters

To enter the operational parameters enter the following at the given menus.

At the Main Menu:

Enter the number of the desired option.>*4*

At the Operational Parameters Menu:

Enter the number of the desired option.>*2*

This subroutine inputs the miscellaneous parameters needed for the calculations into the LIFE2 code.

Data are input from the keyboard by the operator.

Enter the title of this data set no longer than 72 characters.
Operational Parameters: Test Problem for the LIFE2 User's Manual

Enter the units of wind speed no longer than 20 characters.
mph

Enter the Cut-In wind speed.>*10.0*

Enter the Cut-Out wind speed.>*45*

Enter the wind speed increment to be used for calculations.
(1 is recommended).>*1*

Enter the stress concentration factor for fatigue analysis.>*2.73*

Enter the stress conversion factor for fracture analysis.>*6.28*

Is the Start/Stop data file to be included in the calculation?(Y or N)>*N*

Is the Buffeting data file to be included in the calculation?(Y or N)>*N*

Enter the number of miscellaneous notes for this data set.>*2*

Enter note 1 no longer than 72 characters.
Calculations Are Based on Operational Stresses only

Enter note 2 no longer than 72 characters.
Wind Speed Interval =1 (not used at this time)

Do you wish to store these data in the Operational Parameters library?(Y or N)>*N*

The above responses will create a calculational file as shown in Appendix A page A-11.

Enter a 9 at each menu until the Main Menu is written to the screen.

Step 5: Calculate the Lifetime

To calculate the lifetime enter the following at the given menus:

At the main menu:

Enter the number of the desired option.>_5_<Enter>

At the Lifetime Calculational Menu:

Enter the number of the desired option.>_2_<Enter>

At the Fatigue Lifetime Calculation Menu:

Enter the number of the desired option.>_1_<Enter>

The LIFE2 code does not AUTOMATICALLY convert the Alternating Stress from a Range Variable to an Amplitude Variable, or from an Amplitude Variable to a Range Variable.

Do you want to change the Alternating Stress variable?(Y or N)_N_

Enter the title of this calculation set, no longer than 72 characters.
Fatigue Characterization: Test Problem for the LIFE2 User's Manual

Will a Start/Stop data file be utilized in the LIFETIME calculations?(Y or N)>_N_

Will a Buffeting data file be utilized in the LIFETIME calculations?(Y or N)>_N_

.......Performing the calculations.

For an S-n Fatigue Analysis of the data given the Lifetime is .12050050E+02 years.

Press <ENTER> to continue

The above responses will create the summary file as shown in Appendix D page A-18.

Option 0
Executive Module

The executive module controls the operation of the computation modules.

A flow diagram for this module is shown in Fig. 1.

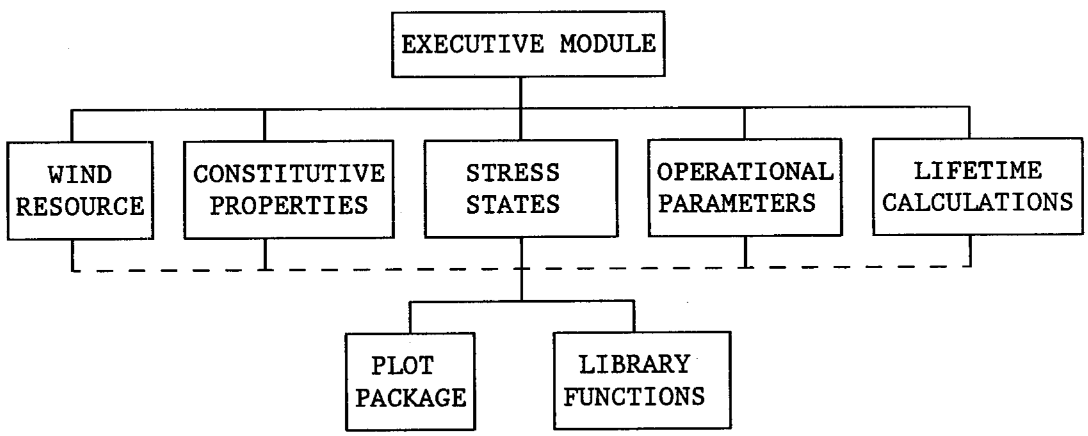

Figure 1. Flow Diagram for the Executive Module.

Main Menu

The first menu for the LIFE2 code is

LIFE2 - Version 2.03

>>> Main Menu <<<

The options at this level are

1) Enter the Wind Spectrum .....page 3-1
2) Enter the Constitutive Properties .....page 4-1
3) Enter the Stress States .....page 5-1
4) Enter the Operational Parameters .....page 6-1
5) Calculate the life of a WECS component .....page 7-1

9) Exit the LIFE2 Code.

Enter the number of the desired option.>

This menu, called the Main Menu, is written by the Executive Module (see Fig.1). It links the five main computational modules of the LIFE2 code to each other. Selection is made by typing the number of the option and pressing <ENTER>.

Option 1

Wind Resource Module

The wind resource is described in the LIFE2 code as the probability density function for the yearly wind speed distribution. Rayleigh and Weibull distributions[6] may be calculated directly by the code. Other distributions may be entered in tabular form.

A flow diagram for this module is shown in Fig. 2.

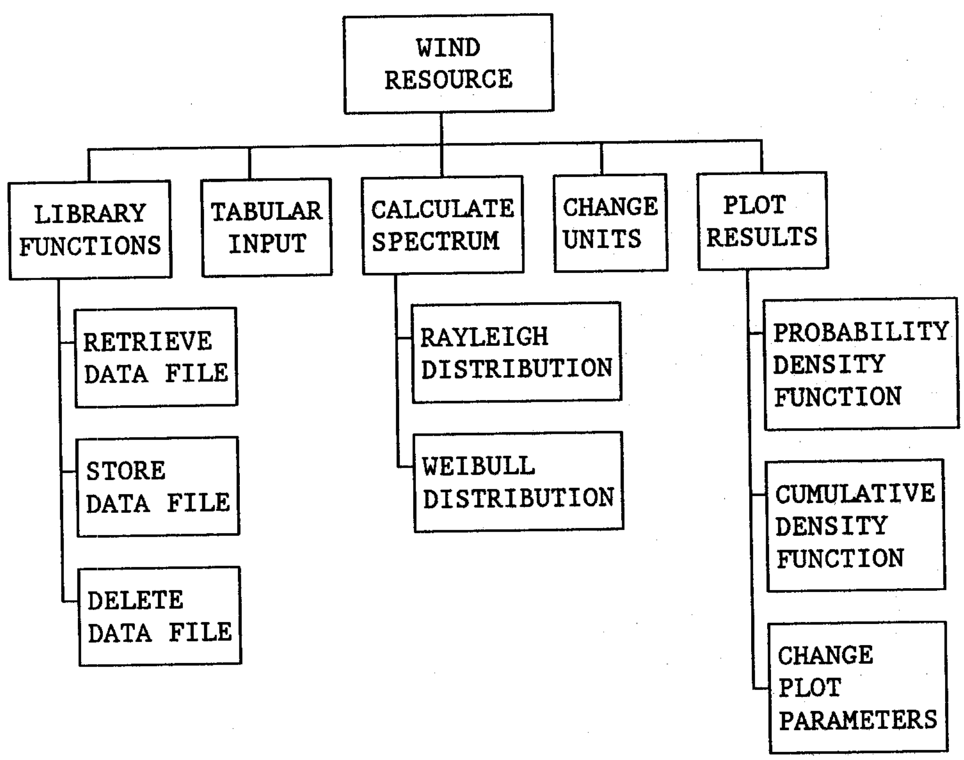

Figure 2. Wind Resource Flow Diagram.

Option 1: Enter the Wind Spectrum

The wind module creates a tabular description of the wind spectrum acting on the wind turbine. The table contains the complementary cumulative density function for the yearly wind speed distribution. This function may be calculated by the code using either a Rayleigh distribution or a Weibull distribution[6]. Other distributions may be entered in tabular form. This module also contains options for converting the wind speed units, plotting the data, and for retrieving/storing the data in the wind library.

When Option 1 is chosen from the Main Menu, the following screen will be displayed:

>>> Wind Menu <<<

This menu allows the operator to generate a WIND SPECTRUM for analysis.

The current Wind Data Base in the operational memory is
Test Problem for the LIFE2 User's Manual: Wind Spectrum

The options at this level are

1) Retrieve Data from the Wind Library .....page 3-3
2) Input Tabular Wind Spectrum Data .....page 3-4
3) Calculate New Wind Spectrum Data .....page 3-6
4) Blank .....page 1-6
5) Plot Wind Data .....page 3-9
6) Change Units of Wind Speed .....page 3-12
7) Add a Data File to the Wind Library .....page 3-13
8) Delete a Data File from the Wind Library .....page 3-14

9) Return to the Main Menu

Enter the number of the desired option.>

When the Wind Resources module is executed, it will read into memory the data set in the WND.CAL calculational file. The title of the file will be printed in the header of the menu. For the above example, the file entitled <u>Test Problem for the LIFE2 User's Manual: Wind Spectrum</u> was read into memory.

Option 1.1: Retrieve Data from the Wind Library

Option 1.1 will copy a specified file from the wind library to the calculational file WND.CAL. These data become the current wind data base. Once the data are in memory they can be plotted, have their units changed, or be used in subsequent calculations. For a listing of the code prompts and example responses see Library Function: Retrieving a Data File From a Library on page 8-1. Once the data have been retrieved, the code returns to the Wind Menu.

Option 1.2: Input Tabular Wind Spectrum Data

Option 1.2 allows data input from the keyboard. Using this option, the code accepts tabular descriptions of the wind resource.

When this option is chosen from the Wind Menu the code responds with the following:

This option inputs wind spectrum data into the LIFE2 code.
Data are input from the keyboard by the operator.

Enter the title no longer than 72 characters.
Example Input for the LIFE2 User's Manual

Enter the units of wind speed no longer than 20 characters.
mph

Enter the turbulence factor.>*0.0*

Enter the number of wind speed entries no greater than 100.>*6*

Enter the COMPLEMENTARY CUMULATIVE DENSITY FUNCTION for the Wind Spectrum. Enter the wind speed and the corresponding fraction of the time the wind speed is ABOVE this value. Enter the values, separated by a space, and hit <ENTER>. NOTE: The wind speeds must be in ASCENDING order and the time fraction is a monotonic decreasing function that does not exceed one(1).
0 1.0
10 0.8
20 0.5
30 0.3
40 0.1
50 0.0

Enter the number of miscellaneous notes for this data set.>*2*

NOTE: If the user inputs 0 for the number of notes, the program will not ask for the note entry as shown below.

Enter note 1 no longer than 72 characters.
This is an example case showing the direct input option.

Enter note 2 no longer than 72 characters.
Operator: Larry Schluter

Do you wish to store these data in the wind library?(Y or N)>*Y*

If the response to the storage question is N, the code returns to the Wind Menu. If the response is a Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. Once the data are stored, the code will return to the Wind Menu.

Option 1.3: Calculate New Wind Spectrum Data

Option 1.3 is used to calculate a wind spectrum that is based on a Rayleigh or a Weibull distribution[6].

When this option is chosen, the following screen will be displayed:

>>> Wind Spectrum Calculational Menu <<<

This menu allows the operator to choose the distribution on which the wind spectrum is based.

The wind spectrum may be determined based on:

1) Rayleigh Distribution	.....page 3-6
2) Weibull Distribution	.....page 3-6
3) Blank	.....page 1-6
4) Blank	.....page 1-6
5) Blank	.....page 1-6

9) Return to the Wind Menu

Enter the number of desired option.>

Option 1.3.1: Rayleigh Distribution

See option 1.3.2 below.

Option 1.3.2: Weibull Distribution

As the Rayleigh distribution is a special case of the Weibull distribution,[6] both of these options require basically the same input information. The following is the code response for either option and examples of typical input:

[Both test problems cited in the Appendices use a Rayleigh distribution with a mean velocity of 14 mph.]

Enter the title no longer than 72 characters.
Test Problem for the LIFE2 User's Manual: Wind Spectrum

Enter the units of wind speed no longer than 20 characters.
mph

Enter the upper limit on wind speed that is greater than the expected maximum operating wind speed.>*99*

Enter the number of uniform wind velocity intervals no greater than 100 and not less than 1>*99*

Enter the mean wind speed.>*14*

For the Weibull distribution the following prompt will appear (a Rayleigh distribution does NOT require this input):

Enter the shape parameter (exponent alpha).>*1.4*

When the calculations are completed, the following statement appears on the screen:

>>>>> Calculations based on the inputs have been completed. <<<<<

The program then asks the operator for miscellaneous notes for this data set. The set used for the test problems is:

Enter the number of miscellaneous notes for this data set.>*3*

If no notes are desired, the response should be 0, and the code will not ask for notes. In the above example, two notes were requested so the program will respond with the following:

Enter note 1 no longer than 72 characters.
Calculations Based on : Max Wind Speed = 99 mph

Enter note 2 no longer than 72 characters.
: Number of Intervals = 99

Enter note 3 no longer than 72 characters.
To Yield 1 mph Wind Velocity Increments

The program automatically adds additional notes to describe the calculation used to determine this distribution. These additions are transparent to the user and will be placed into the data file immediately following the user's notes. For a Rayleigh distribution, the following two notes are added to the data file:

Rayleigh Calculation Performed by the LIFE2 Code
Mean Wind Speed = 14.00 mph

For a Weibull distribution the following three additional notes are added to the data file:

Weibull Calculation Performed by the LIFE2 Code
Mean Wind Speed = 14.00 mph
Shape Factor = 1.400

The data are then copied to the WND.CAL calculational file. The following prompt will then be displayed asking the operator if the data are to be archived:

Do you wish to store these data in the wind library? (Y or N)>*Y*

If the response to the storage question is N, the code returns to the Wind Spectrum Calculational Menu. If the response is a Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. After the data are stored, the code returns to the Wind Spectrum Calculational Menu.

Option 1.5: Plot Wind Data

Option 1.5 plots the wind spectrum data in the WND.CAL file. When this option is selected, the following menu will appear:

>>> Wind Plotting Menu <<<

This menu allows the operator to plot wind spectrum data.

Your options at this level are

Enter the number of the desired option.>

Option 1.5.1: Change Plot Parameters

Option 1.5.1 is used to set up the plotting software to match the hardware that is being used. A data file called PLOT.CNG is created to store the hardware setup information that will be used to create the plot. For more information on this option please see the Plot Parameter Options on page 9-1.

Option 1.5.2: Plot Probability Density Function

See option 1.5.3 below.

Option 1.5.3: Plot Cumulative Density Function

Options 1.5.2 and 1.5.3 will plot the probability density and the cumulative density functions respectively. Both of these options require the same input information.

When one of these options is chosen from the Wind Plotting Menu, the code will respond with the following prompts:

Is a second title desired?(Y or N)>*Y*

The title of the data file will be placed on the plot as the main title. If this is the only title that is desired by the operator, then the response should be an N. If another title is desired, then the response should be a Y and the code will respond with the following prompt:

Enter the second title, no longer than 72 characters.
Test Problem for the LIFE2 User's Manual

The input can be any printable character on the keyboard. The code then prompts the operator as follows:

Are centered symbols to be placed on the plot?(Y or N)>*Y*

Symbols can be placed on the plot to show where all or some of the data points are located. All data points will be plotted and connected with lines. If symbols are requested, they will be placed at the data points specified in the following prompt:

There are 99 data points to plot.
Enter the interval of the symbols.>*10*

The number of data points to plot will vary depending on the data file that is being used. In the above example there are 99. Symbols will always be placed at the first and the last data point. The other symbols will be placed at the interval specified. For the above example, an interval of 10 is requested, meaning that after all of the data points have been plotted and connected with lines, a symbol will be placed at every 10th data point (i.e., the 10th, the 20th, the 30th,...). If a symbol is desired at every data point the interval of symbols should be 1.

When the plot is ready to be displayed on the screen, the following prompt is written:

READY TO DISPLAY DRAWING
Strike any key to continue.

When a key is depressed by the operator, the plot will be displayed on the screen. After viewing the plot, depressing another key will let the code continue. The code will then ask the following:

Is a hard copy of the plot desired?(Y or N)>*N*

Responding with a N to this question will cause the code to return to the Wind Plotting Menu. If a hard copy is desired, the response should be a Y. The code will then display the following message indicating that the plot is being sent to the hard-copy unit:

The plot is being routed to the hard-copy unit.

When the hard-copy plot is completed, the code will return to the Wind Plotting Menu.

Option 1.5.4: Plot Both Density Functions

Option 1.5.4 will plot the probability density function and then the cumulative density function without returning to the Wind Plotting Menu. The code will ask the same questions as in options 1.5.2 and 1.5.3 except that it will go through the questions twice, once for each plot. The code will plot the probability density function, and then the cumulative density function.

[The plots produced for the test problem are shown in the Appendices.]

NOTE: For the plotting option to be enabled, the code must be linked with PLOT88 library routines[5]. If the code was not linked with the PLOT88 library routines, the plotting option will simply rewrite the Wind Menu on the screen.

Option 1.6: Change Units of Wind Speed

Option 1.6 allows the units of wind speed for the data that are in memory to be changed.

For a listing of these prompts and example responses see Changing Units of Wind Speed on page 10-1.

Option 1.7: Add a Data File to the Wind Library

Option 1.7 allows the code to store the current contents of the WND.CAL file in the wind library and to access wind spectrum data that were not generated by the code. When this option is chosen, the code responds with the following prompt:

Are the data to be stored currently in the WND.CAL file?(Y or N)>*Y*

To archive the current contents of the WND.CAL file, the operator should respond with a Y.

To import data from files not created by the LIFE2 code, the operator should respond with an N. The code will ask for the location and name of the data file. The data file must be in the same format as the WND.CAL file in order to be read into memory properly. The format for WND.CAL is defined in Appendix A. The following prompt will be displayed:

Input the path and name of the file to be stored.
A:WIND1.DAT

Note: If no path is called out, the program assumes that the file is in the /LIFE2/DATA subdirectory.

The file will be copied to WND.CAL and read into memory. The program then prompts the operator for archiving the data found in WND.CAL. For more information on these prompts and example responses see Library Function: Adding a Data File to a Library on page 8-1.

Note: See Appendix A for format required for a WND.CAL file.

After the data file is stored in the library, the following prompt will be written:

Is another data file to be stored?(Y or N)>*N*

If another data file is to be stored, the code will repeat this section. If not, the code will return control back to the Wind Menu.

Option 1.8: Delete a Data File from the Wind Library

This option allows the deletion of a file from the wind library list. The file will be deleted from the subdirectory /LIFE2/DATA, and the file name will be taken out of the library list stored in WNDLST.LST. For a listing of the code prompts and example responses see Library Function: Deleting a Data File from a Library on page 8-2.

Option 2
The Constitutive Properties Module

Two sets of constitutive properties are required by the LIFE2 code. The first is the classical "S-n" fatigue characterization that describes the number of stress cycles required to fail the component. Each stress cycles is described as a function of applied stress state. The stress state is characterized by both its mean stress level and its alternating stress level. This relation may be entered in tabular form. In addition, the code can accept a number of constitutive descriptions for this relationship. The relations include Goodman's rule (using either the yield or the ultimate stress), Gerber's rule and the modified Gerber rule[7]. The second set of constitutive properties describes the rate of crack growth as a function of the cyclic change in the stress intensity factor (SIF). The growth rate is assumed to depend on the mean stress intensity factor and the alternating stress intensity factor. Again, the relationship between these variables may be entered in tabular form. A Forman constitutive model is also included in the code[8,9].

A flow diagram for the main constitutive modules is shown in Fig. 3. The flow diagram for the two support modules are shown in Fig. 4 (see page 4-3) and Fig. 5 (see page 4-20)

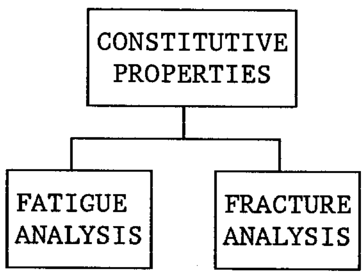

Figure 3. Flow Diagram for the Constitutive Properties Module.

Option 2: Enter the Constitutive Properties

The two constitutive options in the LIFE2 code are accessed through option 2 of the Main Menu. When option 2 (Enter the Constitutive Properties) is chosen from the Main Menu the following screen will be displayed:

>>> Constitutive Properties Menu <<<

This menu allows the user to generate material failure data based on a Fatigue or Fracture Analysis.

The options at this level are

1) Enter Fatigue Analysis Data	.....page 4-3
2) Enter Fracture Analysis Data	.....page 4-20
3) Blank	.....page 1-6
4) Blank	.....page 1-6

9) Return to the Main Menu

Enter the number of the desired option.>

Option 2.1: Enter Fatigue Analysis Data

The "S-n" constitutive formulation used in the LIFE2 code describes the number of stress cycles, n, required to fail the component. The stress state, S, is characterized by a mean stress and a cyclic stress. The data may be calculated by the code using a number of constitutive descriptions for this relationship or the data may be entered in tabular form.

The flow diagram for this section of the code is shown in Fig. 4.

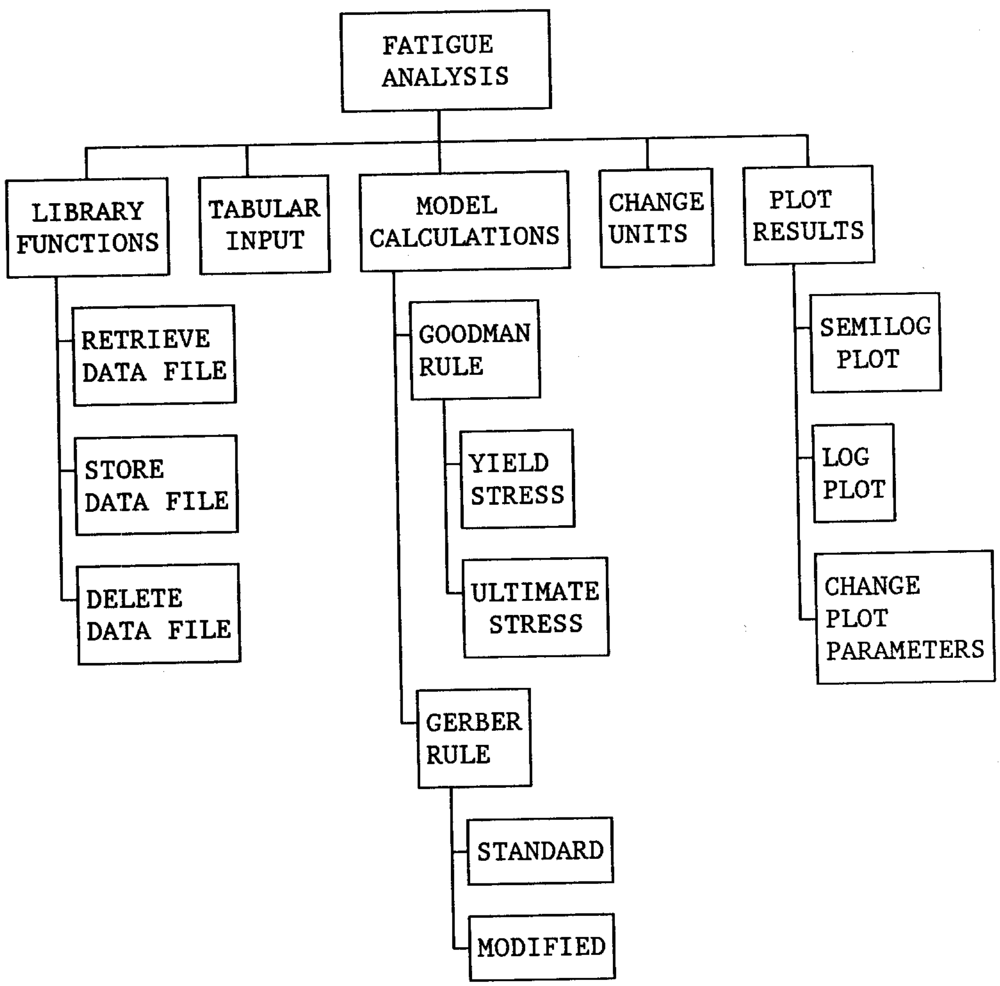

Figure 4. Flow Diagram for the Fatigue Analysis Constitutive Properties Module.

When option 2.1 is chosen the following screen will be displayed:

>>> Fatigue Analysis Menu <<<

This menu allows the user to enter the constitutive properties of a material.

The current Fatigue Analysis Data Base in operational memory is
Fatigue Characterization: Test Problem for the LIFE2 User's Manual

The options at this level are

Enter the number of the desired option.>

When the Fatigue Properties program is executed, it will read into memory the data set in the FAT.CAL calculational file. The title of the file will be printed in the header of the menu. For the above example, the file entitled Fatigue Characterization: Test Problem for the LIFE2 User's Manual, was read into memory.

Option 2.1.1: Retrieve Data from the Fatigue Properties Library

Option 2.1.1 will copy a specified file that is in the fatigue properties library to the calculational file FAT.CAL and place the data into memory. These data become the current fatigue properties data base. Once the data are in memory they can be plotted, can have the units changed, or can be used in subsequent lifetime calculations. For a listing of the code prompts and example responses see Library Function: Retrieving a Data File From a Library on page 8-1. Once the data have been retrieved, the code returns to the Fatigue Analysis Menu.

Option 2.1.2: Input Tabular Fatigue Properties Data

Option 2.1.2 allows data input from the keyboard. Using this option, the code accepts tabular descriptions of the fatigue properties.

When this option is chosen from the Fatigue Analysis Menu the code responds with the following:

This option inputs fatigue properties data into the LIFE2 code.

Data are input from the keyboard by the operator.

Enter the title of this data set no longer than 72 characters.
Example Input for the LIFE2 Users Manual

Enter the units of stress no longer than 20 characters.
psi

Enter the modulus of elasticity or 0 if unknown.>*1e7*

Enter Poissons ratio.>*0.3*

Enter the yield stress.>*25000*

Enter the ultimate stress.>*39000*

Enter the number of mean stress entries no greater than 100.>*10*

Enter the mean stress and press <ENTER>. The mean stress entries should be in ascending order.

Entry 1>*0*
Entry 2>*3000*
Entry 3>*5500*

.

.

.

Entry 10>*25000*

Enter the number of cyclic entries, no greater than 100.>*5*

Enter the cyclic stress and press <ENTER>. The cyclic stress entries should be in ascending order.

Entry 1>*10000*
Entry 2>*10700*
Entry 3>*14400*
Entry 4>*18300*
Entry 5>*24700*

Enter the cycles to failure corresponding to each mean and cyclic stress value. The cycles to failure should be in descending order.

For a mean stress of : 0.00
and a cyclic stress of : 1000.00
Enter the number of cycles to failure.>*5e8*

For a mean stress of : 0.00
and a cyclic stress of : 10700.00
Enter the number of cycles to failure.>*1e7*

For a mean stress of : 0.00
and a cyclic stress of : 14400.00
Enter the number of cycles to failure.>*1e6*

.

.

.

Enter the number of miscellaneous notes for this data set.>*2*

NOTE: If the user inputs 0 for the number of notes, then the program does not ask for the note entry as shown below.

Enter note 1 no longer than 72 characters.
This is an example case showing the direct input option.

Enter note 2 no longer than 72 characters.
Operator: Larry Schluter

The program automatically adds additional notes to describe the type of input used and to show the miscellaneous input parameters. These additions are transparent to the user and will be placed into the data file immediately following the user's notes.

For the inputs given in this section the additional notes would be as follows:

```
Tabular Input Used in this Calculation
Miscellaneous input parameters:
   Modulus of Elasticity = .10000E+08
   Poissons Ratio        = .30000E+00
   Yield Stress          = .25000E+05
   Ultimate Stress       = .39000E+05
```

The data are then copied to the FAT.CAL calculational file. The following prompt will then be displayed asking the operator if the data are to be archived:

Do you wish to store these data in the fatigue properties library?(Y or N)>*Y*

If the response to the storage question is N, the code returns to the Fatigue Analysis Menu. If the response is a Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. Once the data are stored, the code will return to the Fatigue Properties Menu.

Option 2.1.3: Calculate New Fatigue Properties Data

Option 2.1.3 is used to calculate the fatigues properties data based on Goodman's rule (using either the yield stress or the ultimate stress), Gerber's rule or the modified Gerber rule[7].

When this option is chosen, the following screen will be displayed:

>>> Fatigue Properties Calculational Menu <<<

The methods for calculating the S-n fatigue characterization are

1) Goodman Rule using the yield stress
2) Goodman Rule using the ultimate stress
3) Gerber Rule
4) Modified Gerber Rule

9) Return to the Fatigue Analysis Menu

Enter the number of desired option.>*2*

All of the options in the Fatigue Properties Calculational Menu need the same input except the modified Gerber rule[7] which needs additional information. The following is the code response for the options and examples of typical input:

Enter the title no longer than 72 characters.
Fatigue Characterization: Test Problem for the LIFE2 User's Manual

Enter the units of stress no longer than 20 characters.
psi

Enter the modulus of elasticity or 0 if unknown.>*1.0e7*

Enter Poissons ratio.>*.3*

Enter the yield stress.>*25000*

Enter the ultimate stress.>*39000*

You have chosen to use a constitutive rule for evaluating the effects of Mean Stress.
NOTE: These formulations assume that the alternating stress is characterized by its amplitude.

Please enter the S-n Diagram for zero Mean Stress as prompted by the program.

Enter the number of cyclic entries, no greater than 100.>*5*

Enter the cyclic stress and press <ENTER>. The cyclic stresses should be in ascending order.

Entry 1>*10000*
Entry 2>*10700*
Entry 3>*14400*
Entry 4>*18300*
Entry 5>*24700*

Enter the cycles to failure corresponding to each mean and cyclic stress and press <ENTER>. The cycles to failure should be in descending order.

For a mean stress of : .00
and a cyclic stress of : 10000.00
Input the number of cycles to failure.>*5e8*

For a mean stress of : .00
and a cyclic stress of : 10700.00
Input the number of cycles to failure.>*1e7*

For a mean stress of : .00
and a cyclic stress of : 14400.00
Input the number of cycles to failure.>*1e6*

For a mean stress of : .00
and a cyclic stress of : 18300.00
Input the number of cycles to failure.>*1e5*

For a mean stress of : .00
and a cyclic stress of : 24700.00
Input the number of cycles to failure.>*1e4*

For the first three options of the Fatigue Properties Calculational Menu the code will now perform the calculations. If option 2.1.3.4 was chosen (the Modified Gerber Rule), the following prompt is also displayed.

Input the Gerber Exponent.>

The program will display the following message on the screen to inform the user that the calculations are being preformed.

.... Calculating the number of Cycles to Failure

The program then asks the operator for miscellaneous notes for this data set.

Enter the number of miscellaneous notes for this data set.>*3*

If no notes are desired, the response should be 0, and the code will not ask for notes. In the above example, three notes were requested so the program will respond with the following:

Enter note 1 no longer than 72 characters.
Fatigue Characterization of 6063 Aluminum

Enter note 2 no longer than 72 characters.
Taken from Ref. 1

Enter note 3 no longer than 72 characters.
Zero Mean Stress Curve Described by the 5 points Listed Below

The program automatically adds additional notes to describe the calculation used to determine the material properties and to show the miscellaneous input parameters. These additions are transparent to the user and will be placed into the data file immediately following the user's notes.

For the inputs given in this section the additional notes would be as follows:

Miscellaneous Input Parameters:
Modulus of Elasticity = .10000E+08
Poissons Ratio = .30000E+00
Yield Stress = .25000E+05
Ultimate Stress = .39000E+05
Goodman Rule Using Ultimate Stress
Note: Stress Amplitude Used to Describe the Alternating Stress
Based on the Zero Mean Stress S-n Curve
Data Input Into The Calculation

Alt Stress	Cyc to Failure	Alt Stress	Cyc to Failure
10000.00	500000000.00	18300.00	100000.00
10700.00	10000000.00	24700.00	10000.00
14400.00	1000000.00		

Final Point Automatically Added to Zero Mean Stress S-n Input
39000.00 1.00

The data are then copied to the FAT.CAL calculational file. The following prompt will then be displayed asking the operator if the data are to be archived:

Do you wish to store these data in the fatigue properties library?(Y or N)>*Y*

If the response to the storage question is N, the code returns to the Fatigue Properties Calculational Menu. If the response is a Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. After the data are stored, the code returns to the Fatigue Properties Calculational Menu.

Option 2.1.5: Plot Fatigue Properties Data

Option 2.1.5 plots the fatigue properties data in the FAT.CAL file. When this option is selected, the following menu will appear:

>>> Fatigue Data Plotting Menu <<<

Your options at this level are

1)	**Change Plot Parameters**	.....page 4-13
2)	**Semilog Plot of the Data**	.....page 4-13
3)	**Log Plot of the Data**	.....page 4-13
4)	**Do both types of Plots**	.....page 4-15
9)	**Return to Fatigue Analysis Menu**	

Enter the number of the desired option.>

Option 2.1.5.1: Change Plot Parameters

Option 2.1.5.1 is used to set up the plotting software to match the hardware that is being used. A data file called PLOT.CNG is created to store the hardware setup information that will be used to create the plot. For more information on this option please see the Plot Parameter Options on page 9-1.

Option 2.1.5.2: Semilog Plot of Data

See option 2.1.5.3 below

Option 2.1.5.3: Log Plot of Data

Options 2.1.5.2 and 2.1.5.3 of the Fatigue Properties Plotting Menu will do a semilog plot and a log plot of the properties data, respectively. Both of these options require the same input information.

When one of these options is chosen from the Fatigue Properties Plotting Menu, the code will respond with the following prompts:

Is a second title desired?(Y or N)>*Y*

The title of the data file will be placed on the plot as the main title. If this is the only title that is desired by the operator, then the response should be an N. If another title is desired, then the response should be a Y and the code will respond with the following prompt:

Enter the second title, no longer than 72 characters.
Test Problem for the LIFE2 User's Manual

The input can be any printable character on the keyboard. The code then prompts the operator as follows:

Enter the number of curves for this plot

++ maximum number for any one plot is 15
++ maximum number for the current calculational matrix is 10
++ the suggested number is 5

Enter the desired number.>*5*

The maximum number of curves that can be on a single plot is limited to the number of curves that are in the current calculational matrix (in the file FAT.CAL), or 15 whichever is smaller. In the above example the maximum number is 10. If the current calculational matrix has data for 15 or more curves then the maximum number will be 15. The suggested number for good appearance is 5.

When the number of curves requested is smaller than the number of curves in the current calculational matrix, the first curve and the last curve are plotted. The rest of the curves are chosen so that the interval between all curves is approximately the same.

The code then prompts to see if symbols are to be placed on the plot.

Are centered symbols to be placed on the plot?(Y or N)>*Y*

Symbols can be placed on the plot to show where all or some of the data points are located. All data points will be plotted and connected with lines. If symbols are requested then they will be placed at the data points specified in the following prompt:

There are 100 data points to plot.
Enter the interval of the symbols.>*10*

The number of data points to plot will vary depending on the data file that is being used. In the above example there are 100. Symbols will always be placed at the first and the last data point. The other symbols will be placed at the interval specified. For the above example, an interval of 10 is requested, meaning that after all of the data points have been plotted and connected with lines, a symbol will be placed at every 10th data point (i.e., the 10th, the 20th, the 30th,...). If a symbol is desired at every data point the interval of symbols should be 1.

When the plot is ready to be displayed on the screen, the following prompt is written:

READY TO DISPLAY DRAWING
Strike any key to continue.

When a key is depressed by the operator, the plot will be displayed on the screen. After viewing the plot, depressing another key will let the code continue. The code will then ask the following:

Is a hard copy of the plot desired?(Y or N)>*N*

Responding with a N to this question will cause the code to return to the Wind Plotting Menu. If the plot is acceptable and a hard copy is desired, then the response should be a Y. The code will then display the following message indicating that the plot is being sent to the hard-copy unit:

The plot is being routed to the hard-copy unit.

When the hard-copy plot is completed, the code will return to the Wind Plotting Menu.

Option 2.1.5.4: Do Both Types of Plots

Option 2.1.5.4 will do the semilog plot and then the log plot without returning to the Fatigue Properties Plotting Menu. The code will ask the same questions as in options 2.1.5.2 and 2.1.5.3 except that it will go through the questions twice, once for each plot. The code will do the semilog plot, and then the log plot.

<u>NOTE:</u> For the plotting option to be enabled, the code must be linked with PLOT88 library routines[5]. If the code was not linked with the PLOT88, library routines the plotting option will simply rewrite the Fatigue Properties Menu on the screen.

Option 2.1.6: Change Units of Stress

Option 2.1.6 allows the units of stress for the data that are in memory to be changed.

For a listing of the code prompts and example responses see Changing Units of Stress on page 10-3.

Option 2.1.7: Add a Data File to the Fatigue Properties Library

Option 2.1.7 allows the code to store the current contents of the FAT.CAL file in the fatigue properties library and to access fatigue characterizations that were not generated by the code. When this option is chosen, the code responds with the following prompt:

Are the data to be stored currently in the FAT.CAL file?(Y or N)>*Y*

To archive the current contents of the FAT.CAL file, the operator should respond with a Y.

To import data from files not created by the LIFE2 code, the operator should respond with an N. The code will ask for the location and name of the data file. The data file must be in the same format as the FAT.CAL file in order to be read into memory properly. The format for FAT.CAL is defined in Appendix A. The following prompt will be displayed:

Input the path and name of the file to be stored.
A:FAT1.DAT

Note: If no path is called out it is assumed that the file is in the /LIFE2/DATA subdirectory.

The file will be copied to FAT.CAL and then read into memory.
The program then prompts the operator for archiving the data found in FAT.CAL. For more information on these prompts and example responses see Library Function: Adding a Data File to a Library on page 8-1.

NOTE: See Appendix A for the format required for a FAT.CAL file.

After the data file is stored in the library, the following prompt will be written:

Is another data file to be stored?(Y or N)>*N*

If another data file is to be stored, the code will repeat this section. If not, the code will return control back to the Fatigue Properties Menu.

Option 2.1.8: Delete a Data File from the Fatigue Properties Library

This option allows the deletion of a file from the fatigue properties library list. The file will be deleted from the subdirectory /LIFE2/DATA, and the file name will be taken out of the library list stored in FATLST.LST. For a listing of the code prompts and example responses see Library Function: Deleting a Data File from a Library on page 8-2.

Option 2.2: Enter Fracture Analysis Data

The second damage rule that may be used to calculate the lifetime of a WECS component is based on linear, "da/dn" fracture characterization data. These data describe the rate of crack growth as a function of the cyclic change in the stress intensity factor (SIF). The data may be calculated by the code using a Forman constitutive model[8,9] or the data may be entered in tabular form.

The flow diagram for this section of the code is shown in Fig. 5.

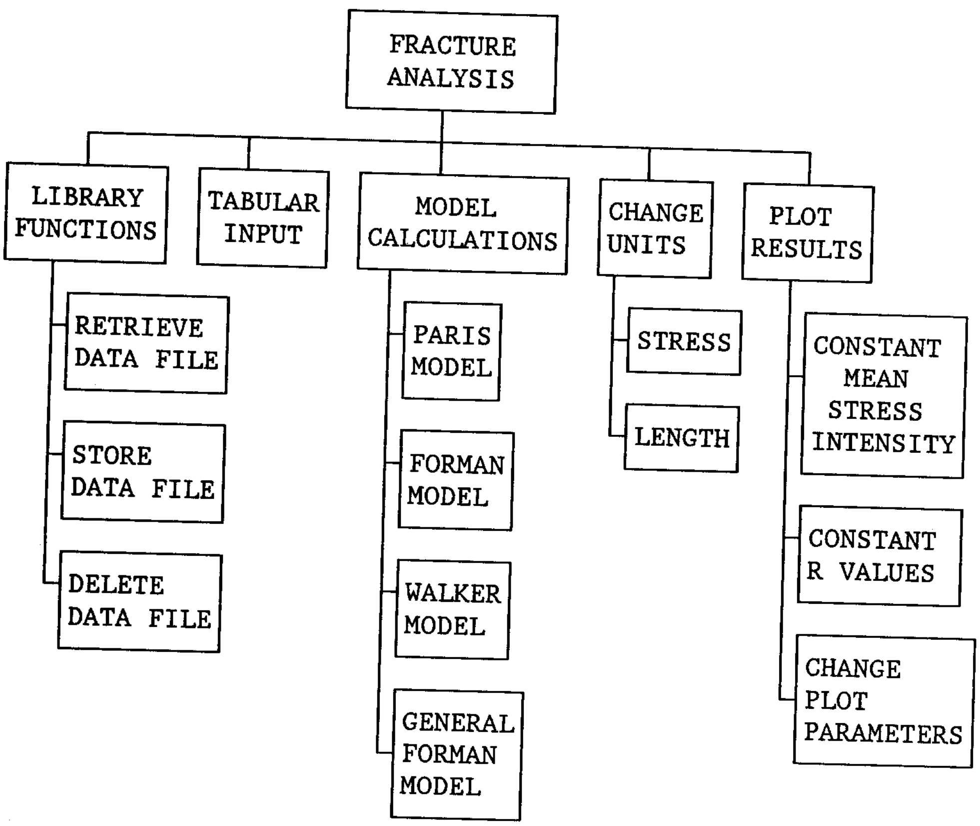

Figure 5. Flow Diagram for the Fracture Analysis Constitutive Properties Module.

When option 2.2 is chosen, the following screen will be displayed:

>>> Fracture Analysis Menu <<<

This menu allows the operator to enter the constitutive properties of a material.

The current Fracture Analysis Data Base in operational memory is
Fracture Characterization: Test Problem for the LIFE2 User's Manual

The options at this level are

9) Return to the Constitutive Properties Menu

Enter the number of the desired option.>

When the Fracture Properties program is executed, it will read into memory the data set in the FRC.CAL calculational file. The title of the file will be printed in the heading of the menu. For the above example, the file entitled Fracture Characterization: Test Problem for the LIFE2 User's Manual, was read into memory.

Option 2.2.1: Retrieve Data from the Fracture Properties Library

Option 2.2.1 will copy a specified file from the fracture properties library to the calculational file FRC.CAL and place the data into memory. These data become the current fracture properties data base. Once the data are in memory they can be plotted, have the units changed, or be used in subsequent lifetime calculations. For a listing of the code prompts and example responses see Library Function: Retrieving a Data File From a Library on page 8-1. Once the data have been retrieved, the code returns to the Fracture Analysis Menu.

Option 2.2.2: Input Tabular Fracture Properties Data

Option 2.2.2 allows data input from the keyboard. Using this option, the code accepts tabular descriptions of the fracture properties.

When this option is chosen from the Fracture Analysis Menu the code responds with the following:

This option inputs fracture properties data into the LIFE2 code.
Data are input from the keyboard by the operator.

Enter the title of this data set no longer than 72 characters.
Fracture Characterization: Test Problem for the LIFE2 User's Manual

Enter the units of stress no longer than 20 characters.
psi

Enter the units of length no longer than 20 characters.
in

Enter the modulus of elasticity or 0 if unknown.>*1e7*

Enter Poissons ratio.>*0.3*

Enter the yield stress.>*25000*

Enter the ultimate stress.>*39000*

Is the data independent of the mean stress?(Y or N)>*Y*

If the data is independent of the mean stress, the Mean Stress-Intensity-Factor entries are not asked for. For a "N" input, the code will prompted for these entries as follows:

Enter the number of Mean Stress-Intensity-Factor (SIF) entries no greater than 100.>*2*

Enter each mean SIF and press <ENTER>. The mean SIF entries should be in ascending order.

Entry 1>*0*
Entry 2>*10000*

Enter the number of Alternating Stress-Intensity-Factor (SIF) entries, no greater than 100.>*3*

Enter each alternating SIF and press <ENTER>. The alternating SIF entries should be in ascending order.

Entry 1>*1.23e4*
Entry 2>*3.162e4*
Entry 3>*6.31e4*

Enter the crack growth rate corresponding to each mean SIF and alternating SIF value.

For a mean SIF of :	**0.00**
and an alternating SIF of :	**.123e5**
Enter the crack growth rate.>	*1e-5*
For a mean SIF of :	**0.00**
and an alternating SIF of :	**.3162e5**
Enter the crack growth rate.>	*8e-5*
For a mean SIF of :	**0.00**
and an alternating SIF of :	**.631e5**
Enter the crack growth rate.>	*1e-3*

For inputs that are not independent of mean stress, the prompts are repeated at each mean stress level.

Enter the number of miscellaneous notes for this data set.>*2*

NOTE: If the user inputs 0 for the number of notes, the program does not ask for the note entry.

Enter note 1 no longer than 72 characters.
Crack Propagation Rate for Aluminum - Lower Curve

Enter note 2 no longer than 72 characters.
Data Taken from Ref. 2

The program automatically adds additional notes to describe the type of input used and to show the miscellaneous input parameters. These additions are transparent to the user and will be placed into the data file immediately following the user's notes.

For the inputs given in this section the additional notes would be as follows:

Tabular Input Used in this Calculation
Crack Growth Rate Independent of Mean Stress with the following input:

Alt SIF	Growth Rate	Alt SIF	Growth Rate
.12300E+05	.10000E-04	.31620E+05	.80000E-04
.63100E+05	.10000E-02		

Miscellaneous input parameters:
Modulus of Elasticity = .10000E+08
Poissons Ratio = .30000E+00
Yield Stress = .25000E+05
Ultimate Stress = .39000E+05

The data are then copied to the FRC.CAL calculational file. The following prompt will then be displayed asking the operator if the data are to be archived:

Do you wish to store these data in the fracture properties library?(Y or N)>*Y*

If the response to the storage question is N, the code returns to the Fracture Analysis Menu. If the response is a Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. Once the data are stored, the code will return to the Fracture Properties Menu.

Option 2.2.3: Calculate Fracture Properties Data Using a Forman Equation

Option 2.2.3 is used to calculate the fracture properties data based on the generalized Forman Equation[8,9].

When this option is chosen, the following screen is displayed:

>>> Fracture Properties Calculational Menu <<<

This menu allows the operator to choose which form of the Forman equation to use.

NOTE: This formulation assumes that the Alternating Stress Intensity Factor is based on the range.

The options for the form of the equation are

1) **Paris form**
2) **Forman form**
3) **Walker form**
4) **General form**

9) **Return to the Fracture Analysis Menu**

Enter the number of desired option.>*4*

After choosing the desired form of the equation the code will continue with the following prompts:

Enter the title of this data set no longer than 72 characters.
Example input based on 300M Steel

Enter the units of stress no longer than 20 characters.
KSI

Enter the units of length no longer than 20 characters.
in

Enter the modulus of elasticity or 0 if unknown.>*1.0e4*

Enter Poissons ratio.>*.3*

Enter the yield stress.>*240*

Enter the ultimate stress.>*266*

At this point the code will write the general form of the equation, shown below, on the screen and start to prompt for the values of the parameters in the equation. The number of inputs will depend on the form that was chosen. Table I shows the parameters that need to be input along with default values for exponents in the Foreman, Paris, and Walker forms of the equation.

General Forman Equation:

$$\frac{da}{dN} = \frac{C\,(1 - R)^m + \Delta K^n\,(\Delta K - \Delta K_{th})^p}{[(1 - R)K_c - \Delta K]^q}$$

See Ref. 1 for a complete description of these constitutive parameters.

For a detailed discussion on the equation and the parameters listed in the Table I please refer to Sutherland[3] and Forman[9].

Equation Form	User Input Parameters	Exponent Default Values
Foreman	C and n	m = 0 p = 0 q = 1
Paris	C and n	m = 0 p = 0 q = 0
Walker	C, n, and Mw	m = (Mw -1)n p = 0 q = 0
General	All user input variables: KIo, KIc, Ak, Bk, C, n, p, q, DKo, Co, d, DK1, α, and th (th = thickness)	

Table I. Constitutive Constants for the Forman Model.

For the Forman, Paris, and Walker forms of the equation the code will only prompt for those parameters shown in the table under User Input Parameters. For the General form of the equation the code will prompt for the variables shown in the table and will give the operator a choice for doing the calculations based on constant mean Stress Intensity Factors (SIF) or constant R values. The code prompts for the General form with example responses for 300M Steel[9] follow:

Input the growth rate coefficient (C).>*0.615e-8*

Input the exponent n.>*2.166*

Input the value for variable KIo.>*60*

Input the value for variable KIc.>*55*

Input the value for variable Ak.>.*75*

Input the value for variable Bk.>.*50*

Input the value for exponent p.>.*25*

Input the value for exponent q.>.*25*

Input the value for variable Dko.>*3.0*

Input the value for variable Co.>*1.0*

Input the value for exponent d.>.*25*

Input the value for variable Dk1.>*12.48*

Input the value for variable Alpha.>*2.5*

Input the thickness value.>.*25*

After all of the variables are entered the following prompt is written to the screen (only for the General form of the equation, option 4):

Calculations can be based on one of the following options:

1) Constant Mean Stress Intensity Factors
2) Constant R values

Note: Option 2 should be used for plotting purposes only.

Option 1 is REQUIRED for the calculations.

Enter the number of the desired option.>*2*

As the note in the menu indicates the constant R value calculations should be used <u>only for plotting purposes</u>. The constant Mean SIF option must be used if the data are to be used in the lifetime calculations.

If option 1, constant mean SIF, is chosen the code will inform the operator that the calculations are being done with the following message:

.......Calculating Crack Growth Rate

After the calculations are done the code will continue and prompt for notes for the data set.

If option 2, constant R values, is chosen the code will ask for the R values with the following prompts:

Input the number of R values to be calculated.>*3*

Enter the R values in ascending order.
R must be less than 1.0.

Input R value 1.>*-1.0*
Input R value 2.>*0.0*
Input R value 3.>*0.5*

The program then asks the operator for miscellaneous notes for this data set.

Enter the number of miscellaneous notes for this data set.>*2*

If no notes are desired, the response should be 0, and the code will not ask for notes. In the above example, two notes were requested so the code will respond with the following:

Enter note 1 no longer than 72 characters.
Example input for the LIFE2 code.

Enter note 2 no longer than 72 characters.
Duplication of 300M Steel Data

The program automatically adds additional notes to describe the calculation used to determine the material properties. These additions are transparent to the user and will be placed into the data file immediately following the user's notes.

For the example inputs used in this section (General form, Constant R value) the following additional notes will be added:

Modified Forman Equation Used in this Calculation
General Form Used in this Calculation
Equation Input Parameters:

KIo = .60000E+02	KIc = .55000E+02	Ak = .75000E+00
Bk = .50000E+00	C = .61500E-08	n = .21660E+01
p = .25000E+00	q = .25000E+00	DKo = .30000E+01
Co = .10000E+01	d = .25000E+00	DK1 = .12480E+02
alpha = .25000E+01	thickness = .25000E+00	

This Formulation Assumes that the Alternating Stress is based on the Range of the Stress Cycle.
The formulation is for constant values of R.
It is not suitable for the calculations.
Miscellaneous Input Parameters:
Modulus of Elasticity = .10000E+05 KSI
Poissons Ratio = .30000E+00
Yield Stress = .24000E+03 KSI
Ultimate Stress = .36600E+03 KSI

The data are then copied to the FRC.CAL calculational file. The following prompt will then be displayed asking the operator if the data are to be archived:

Do you wish to store these data in the fracture properties library?(Y or N)>*Y*

If the response is a Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. If the data are based on constant Mean SIFs then after the data are stored or the response to the above storage prompt was N, the code returns to the Fracture Properties Calculational Menu. If the data are based on constant R values, the code will continue with the following prompt:

The crack growth rates must be calculated for Constant Mean Stress Intensity Factors for these Calculations.

Do you want to calculate them now?(Y or N)>*N*

If the operator chooses to calculate the crack growth rate with constant Mean SIFs at this time, the new data is written over the constant R value data. Therefore, if the constant R value data were not stored they will be lost. When the code is performing the calculations it will inform the operator with the following prompt:

........Calculating Crack Growth Rates

The code will then proceed to prompt for notes and storage information as before. If the calculations based on constant Mean SIFs are not desired at this time, then the operator response should be an N and the code will return to the Fracture Properties Calculational Menu.

Option 2.2.5: Plot Fracture Properties Data

Option 2.2.5 plots the fracture properties data in the FRC.CAL file. When this option is selected, the following menu will appear:

>>> Fracture Properties Plotting Menu <<<

This menu allows the operator to plot fracture data.

Your options at this level are:

Enter the number of the desired option.>

Option 2.2.5.1: Change Plot Parameters

Option 2.2.5.1 is used to set up the plotting software to match the hardware that is being used. A data file called PLOT.CNG is created to store the hardware setup information that will be used to create the plot. For more information on this option please see the Plot Parameter Options on page 9-1.

Option 2.2.5.2: Constant Mean SIF Plots

See option 2.2.5.3 below.

Option 2.2.5.3: Constant R Value Plots

Options 2 and 3 of the Fracture Properties Plotting Menu will plot the constant mean SIF data and constant R value data respectively. Both of these options require the same input information.

When one of these options is chosen from the Fracture Properties Plotting Menu, the code will respond with the following prompts:

Is a second title desired?(Y or N)>*Y*

The title of the data file will be placed on the plot as the main title. If this is the only title that is desired by the operator, then the response should be an N. If another title is desired, then the response should be a Y and the code will respond with the following prompt:

Enter the second title, no longer than 72 characters.
Forman Model: Test Problem for LIFE2 User's Manual

The input can be any printable character on the keyboard. The code then prompts the operator as follows:

Enter the number of curves for this plot

++ maximum number for any one plot is 15
++ maximum number for the current calculational matrix is 10
++ the suggested number is 5

Enter the desired number.>*5*

The maximum number of curves that can be on a single plot is limited to the number of curves that are in the current calculational matrix (in the file FRC.CAL), or 15, which ever is smaller. In the above example the maximum number is 10. If the current calculational matrix has data for 15 or more curves then the maximum number will be 15. The suggested number for good appearance is 5.

When the number of curves requested is smaller than the number of curves in the current calculational matrix, the first curve and the last curve are plotted. The rest of the curves are chosen so that the interval between all curves is approximately the same.

The code then prompts to see if symbols are to be placed on the plot.

Are centered symbols to be placed on the plot?(Y or N)>*Y*

Symbols can be placed on the plot to show where all or some of the data points are located. All data points will be plotted and connected with lines. If symbols are requested then they will be placed at the data points specified in the following prompt:

There are 100 data points to plot.
Enter the frequency of the symbols.>*10*

The number of data points to plot will vary depending on the data file that is being used. In the above example there are 100. Symbols will always be placed at the first and the last data point. The other symbols will be placed at the frequency specified. For the above example, a frequency of 10 is requested, meaning that after all of the data points have been plotted and connected with lines, a symbol will be placed at every 10th data point (i.e., the 10th, the 20th, the 30th,...).

When the plot is ready to be displayed on the screen, the following prompt is written:

READY TO DISPLAY DRAWING
Strike any key to continue.

When a key is depressed by the operator, the plot will be displayed on the screen. After viewing the plot, depressing another key will let the code continue. The code will then ask the following:

Is a hard copy of the plot desired? (Y or N)>*N*

Responding with a N to this question will cause the code to return to the Wind Plotting Menu. If the plot is acceptable and a hard copy is desired, then the response should be a Y. The code will then display the following message indicating that the plot is being sent to the hard-copy unit:

The plot is being routed to the hard-copy unit.

When the hard-copy plot is completed, the code will return to the Wind Plotting Menu.

NOTE: For the plotting option to be enabled, the code must be linked with PLOT88 library routines[4]. If the code was not linked with the PLOT88, library routines the plotting option will simply rewrite the Fracture Analysis Menu on the screen.

Option 2.2.6: Change Units of Stress and/or Length

Option 2.2.6 allows the units of stress and/or length for the data that are in memory to be changed.

When this option is chosen, the code will respond with the following menu:

>>> Fracture Unit Conversion Menu <<<

This menu allows the operator to change the units of stress and/or the units of length of the data currently in memory.

The options at this level are

Enter the number of the desired option.>

Option 2.2.6.1: Change Units of Stress

As the stress intensity factor has units of stress and the square root of length, two unit change options are offered. Option 1 allows the operator to change the units of stress for the data that is in memory.

For a listing of the code prompts and example responses see Changing Units of Stress on page 10-3.

Option 2.2.6.2: Change Units of Length

This option allows the operator to change the units of length for the data that are in memory.

For a listing of the code prompts and example responses see Changing Units of Length on page 10-5.

Option 2.2.7: Add a Data File to the Fracture Properties Library

Option 2.2.7 allows the code to store the current contents of the FRC.CAL file in the fracture properties library and to access fracture properties data that were not generated by the code. When this option is chosen, the code responds with the following prompt:

Are the data to be stored currently in the FRC.CAL file?(Y or N)>*Y*

To archive the current contents of the FRC.CAL file, the operator should respond with a Y.

To import data from files not created by the LIFE2 code, the operator should respond with an N. The code will ask for the location and name of the data file. The data file must be in the same format as the FRC.CAL file in order to be read into memory properly. The format for FRC.CAL is defined in Appendix A. The following prompt will be displayed:

Input the path and name of the file to be stored.
A:FRC1.DAT

Note: If no path is called out, it is assumed that the file is in the default directory.

The file will be copied to FRC.CAL and then read into memory. The program then prompts the operator for archiving the data found in FRC.CAL. For more information on these prompts and example responses see Library Function: Adding a Data File to a Library on page 8-1.

NOTE: See Appendix A for the format required for a FRC.CAL file.

After the data file is stored in the library, the following prompt will be written:

Is another data file to be stored?(Y or N)>*N*

If another data file is to be stored, the code will repeat this section. If not, the code will return control back to the Fracture Properties Menu.

Option 2.2.8: Delete a Data File from the Fracture Properties Library

This option allows the deletion of a file from the fracture properties library list. The file will be deleted from the subdirectory /LIFE2/DATA, and the file name will be taken out of the library list stored in FRCLST.LST. For a listing of the code prompts and example responses see Library Function: Deleting a Data File from a Library on page 8-2.

Option 3
Stress States Module

The third section of the code describes the cyclic content of the stress state imposed on the turbine component. Classes of stress states include operational stresses, buffeting stresses (i.e., stresses induced by the wind buffeting a parked blade) and start-stop stresses. The first two are taken to be functions of the wind speed. The start-stops are grouped by type of event. For each of these stress states, the code accepts a cycle count matrix in which the number of stress cycles (for a specified time period) are characterized as a function of the mean stress and the alternating stress. This matrix, commonly called a "rain-flow" matrix, is accepted in tabular form. A narrow-band Gaussian model for operational stresses in vertical axis wind turbines (VAWTs)[10] is included in the code.

A flow diagram for this section of the code is shown in Fig. 6.

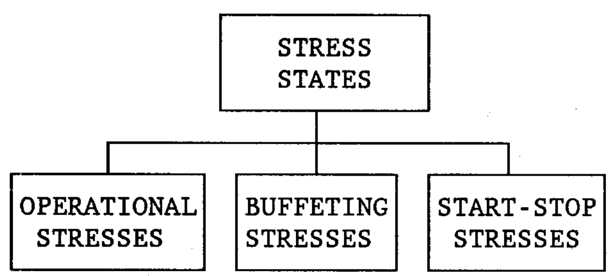

Figure 6. Flow Diagram for Stress States Module.

Option 3: Enter the Stress States

This module allows the operator to describe the stress states that the turbine components experience. The matrices are cycle count matrices that are divided into three classes: the operational stresses, the buffeting stresses (i.e., stresses from the wind when the turbine is parked), and start/stop stresses.

When Option 3 is chosen from the Main Menu, the following screen will be displayed:

>>> Stress State Menu <<<

This menu allows the operator to select which type of stress matrix to input.

The options at this level are

1) Enter Operational Stresses ....page 5-3
2) Enter Buffeting Stresses ....See NOTE
3) Enter Start/Stop Stresses ....See NOTE

9) Return to Main Menu

Enter the number of the desired option.>

The calculational file for the operational stresses, created with option 3.1, must exist to calculate the lifetime of a WECS component. The calculational files for the buffeting stresses and the start/stop stresses are optional and need not be present to calculate the lifetime.

NOTE: These options all have very similar prompts and inputs. What follows is a discussion on entering the operational stresses (option 3.1). As discussions for buffeting and start/stop stresses would be quite similar, we have chosen not to present them in this report. The only difference between these three classes of stress states is that they are stored in separate files: the operational stresses calculational file is OPS.CAL, the buffeting stresses calculational file is BUF.CAL and the start/stop stresses calculational file is STS.CAL. Library files have extensions .OPS, .BUF and . STS, respectively. At this time, no models are included for the buffeting and start-stop stress states.

Option 3.1: Enter the Operational Stresses

Option 3.1 allows the operator to input the stresses the wind turbine experiences during operation. As the cycle counts for the operational stress states are a function of the mean stress, the alternating stress and the wind speed, the matrix is 3 dimensional (3D). The matrix is handled numerically as a series of 2 dimensional (2D) matrices (mean and alternating stress dependence for a particular wind velocity). The entire operation stress matrix can be entered in tabular form or can be calculated using a narrow-band Gaussian model (Veers model[10]).

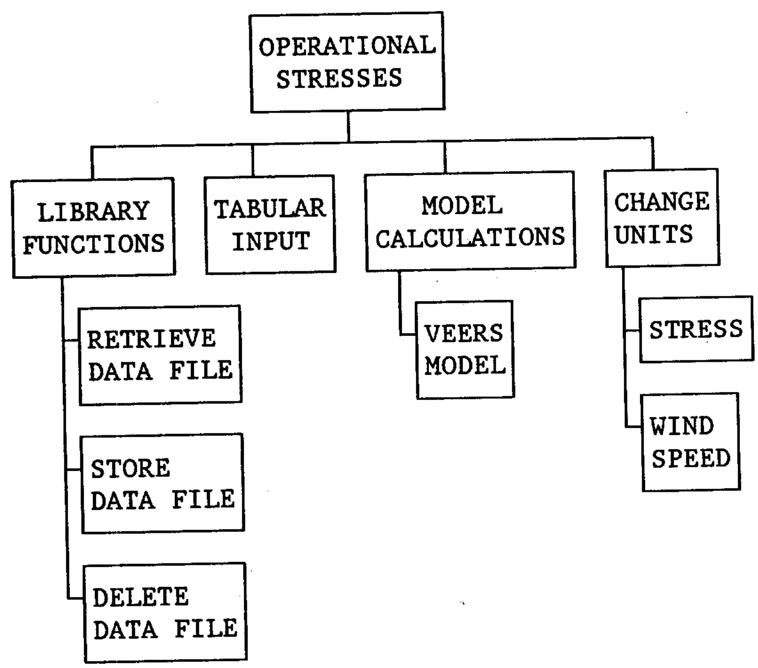

Figure 7. Flow Diagram for Operational Stress States Module.

When Option 3.1 is chosen from the State Stress Menu, the following screen will be displayed :

>>> Operational Stresses Menu <<<

This option allows the operator to input the operational stresses for a wind turbine.

The current Operational Stress Data Base in the operational memory is
Stress States: Test Problem for the LIFE2 User's Manual

The options at this level are

Enter the number of the desired option.>

When this option is chosen the data in the operational stress calculational file (OPS.CAL) is read into memory. The title of the file will be printed in the header of the menu. For the above example, the file entitled Stress States: Test Problem for the LIFE2 User's Manual is read into memory.

Option 3.1.1: Retrieve Data from the Operational Stresses Library

Option 3.1.1 will copy a specified file from the operational stresses library to the calculation file OPS.CAL and place the data into memory. These data become the current operational stress data base. Once the data are in memory they can have the units changed or be used in subsequent lifetime calculations. For a listing of the code prompts and example responses see Library Function: Retrieving a Data File From a Library on page 8-1. Once the data have been retrieved, the code returns to the Operational Stresses Menu.

Option 3.1.2: Input Tabular Operational Stresses Data

Option 3.1.2 allows entry of the operational stress data matrix from the keyboard. The cycle counts are entered as a series of 2 dimensional matrices (mean and alternating stress) with each matrix corresponding to a particular wind speed interval (i.e. 5 to 10 mph). Each interval is identified using the upper wind speed.

When this option is chosen from the Operational Stresses Menu the code responds with the following:

This option inputs the operational stresses data into the LIFE2 code.

Data are input from the keyboard by the operator.

Enter the title of this data set no longer than 72 characters.
CRACK Propagation Test Case: Setup @ 3ksi

Enter the units of stress no longer than 20 characters.
ksi

Enter the units of wind speed no longer than 20 characters.
mph

Enter the number of wind speed intervals.(100 or less)>*3*

Is each interval characterized by one mean stress value?(Y or N)>*Y*

Wind Speed Interval 1

Enter the upper bound of the wind speed interval for this data set.>*4*

Wind Speed Interval 1

Enter the frequency of the cycling stress in hertz.>*1.6*

If each wind speed interval is characterized by one mean stress, the code will prompt for one mean stress value within each data set. Otherwise, the code will ask for the number of mean stress entries and then the mean stress values. In this example each data set is characterized by one mean stress. The code continues as follows:

Wind Speed Interval 1

Enter the mean stress for this data set.>*0*

Wind Speed Interval 1

Enter the number of cyclic stress intervals.(50 or less)>*10*

Wind Speed Interval 1

Enter the cyclic stress entries in ascending order.

Entry 1>*3*
Entry 2>*5*
Entry 3>*7*
.
.
.

Wind Speed Interval 1

For a Mean Stress = 0.0000
and an Alternating Stress = 3.0000

Enter the Cycle Count.>*10*

.
.
.

This completes the information for the wind speed interval. This same information must be input for all of the intervals. In the above example the number of intervals was three. Therefore, the code will prompt for this information for wind speed interval 2 and 3.

The code now asks for the miscellaneous notes to include in the data file with the following prompts:

Enter the number of miscellaneous notes for this data set.>*2*

NOTE: If the user inputs 0 for the number of notes, the program does not ask for the note entry.

Enter note 1 no longer than 72 characters.
Setup for the CRACK Propagation Test Case @ 3ksi

Enter note 2 no longer than 72 characters.
Setup @ 1 Cyc per Sec

Do you wish to store these data in the Operational Parameters library?(Y or N)>*Y*

If the response to the storage question is N, the code returns to the Operational Stresses Menu. If the response is a Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. Once the data are stored, the code will return to the Operational Stresses Menu.

Option 3.1.3: Calculate New Operational Stresses

NOTE: This option is blank for the buffeting and start/stop stresses.

Option 3.1.3 is used to calculate new operational stresses. At this time one technique, the Veers Model[10], is supported by the code.

When this option is chosen from the Operational Stresses Menu the following screen is displayed:

>>> Operational Stresses Calculational Menu <<<

This option will calculate the operational stresses for a wind turbine.

The options at this level are

1) Veers Model ....page 5-10
2) Blank ....page 1-6
3) Blank ....page 1-6
4) Blank ....page 1-6
5) Blank ....page 1-6

9) Return to Operational Stresses Menu

Enter the number of the desired option.>

Option 3.1.3.1: Veers Model Calculations

The operational stresses may be calculated using the Veers Model[10].

When this option is chosen the code will prompt for input information as follows:

This option calculates the operational stresses based on the Veers Model.

NOTE: This formulation yields Alternating Stresses that are Characterized by their amplitude.

Enter the title of this data set no longer than 72 characters.
Stress States: Test Problem for the LIFE2 User's Manual

Enter the units of stress no longer than 20 characters.
psi

Enter the units of wind speed no longer than 20 characters.
mph

Enter the number of wind speed intervals.(100 or less)>*75*

The upper bound for the wind regime that is to be characterized in this calculation needs to be entered. The bound should encompass all of the wind speeds that the wind turbine will experience during operation.

Enter the upper wind speed.>75

Enter the mean stress.>7000

The Veers Model requires a transfer function between the wind velocity and the RMS stress level. This function will be input into a table.

Enter the number of entries in the table.(20 or less).>*4*

The wind speed and the corresponding RMS stress are to be entered into the table. The entries should be in ascending order.

Wind Speed 1.>*0*
RMS Stress 1.>*0*

Wind Speed 2.>*10*
RMS Stress 2.>*320*

Wind Speed 3.>*20*
RMS Stress 3.>*700*

Wind Speed 4.>*40*
RMS Stress 4.>*1560*

Enter the frequency of the stress cycles in hertz.>1.6

......Performing the Veers Model Calculations

The code now asks for the miscellaneous notes to include in the data file with the following prompts:

Enter the number of miscellaneous notes for this data set.>*5*

NOTE: If the user inputs 0 for the number of notes, the program does not ask for the note entry.

Enter note 1 no longer than 72 characters.
Operating Stress Characterization Using Veer's Model

Enter note 2 no longer than 72 characters.
Taken from Refs. 1 and 2

Enter note 3 no longer than 72 characters.
Number of Wind Speed Intervals = 75

Enter note 4 no longer than 72 characters.
Upper Limit of Wind Speed = 75 mph

Enter note 5 no longer than 72 characters.
Yields 1 mph Increments in Wind Velocity

The code automatically adds additional notes to describe the model that was used to determine the operational stresses. These additions are transparent to the user and will be placed into the data file immediately following the operator's notes. The notes for the Veers Model calculations with the inputs given in this section are as follows:

Veers Model Calculation for the Operational Stresses
Note: This Formulation yields alternating stresses
that are characterized by their amplitude.
Mean Stress = 7000.00 psi
Frequency = 1.6 Hz
Wind Speed Units: mph

Wind Speed	RMS Stress	Wind Speed	RMS Stress
.00	.00	20.00	700.00
10.00	320.00	40.00	1560.00

The data are then copied to the OPS.CAL calculational file. The following prompt will then be displayed asking the operator if the data are to be archived:

Do you wish to store these data in the Operational Parameters library?(Y or N)>*Y*

If the response to the storage question is N, the code returns to the Wind Menu. If the response is Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. Once the data are stored, the code will return to the Operational Stresses Menu.

Option 3.1.6: Change Units of Wind Speed and/or Stress

This option allows the operator to change the units of wind speed and/or stress for the data currently in memory.

When this option is chosen the following menu will be displayed:

>>> Operational Stress Unit Conversion Menu <<<

This option allows the operator to change the units of wind speed and/or stress of the data.

The options at this level are

9) Return to the Operational Stresses Menu

Enter the number of the desired option.>

Option 3.1.6.1: Change Units of Wind Speed

Option 3.1.6.1 allows the units of wind speed for the data that are in memory to be changed.

For a listing of the code prompts and example responses see Changing Units of Wind Speed on page 10-1.

Option 3.1.6.2: Change Units of Stress

Option 3.1.6.2 allows the units of stress for the data that are in memory to be changed.

For a listing of the code prompts and example responses see Changing Units of Stress on page 10-3.

Option 3.1.7: Add a Data File to the Operational Stresses Library

Option 3.1.7 allows the code to store the current contents of the OPS.CAL file in the library and to access stress data that were not generated by the code. When this option is chosen, the code responds with the following prompt:

Are the data to be stored currently in the OPS.CAL file?(Y or N)>*Y*

To archive the current contents of the OPS.CAL file, the operator should respond with a Y.

To import data from files not created by the LIFE2 code, the operator should respond with an N. The code will ask for the location and name of the data file. The data file must be in the same format as the OPS.CAL file in order to be read into memory properly. The format for OPS.CAL is defined in Appendix A. The following prompt will be displayed:

Input the path and name of the file to be stored.
A:VAWT17.DAT

Note: If no path is called out, it is assumed that the file is in the /LIFE2/DATA subdirectory.

The file will be copied to OPS.CAL and then read into memory. The program then prompts the operator for archiving the data found in OPS.CAL. For more information on these prompts and example responses see Library Function: Adding a Data File to a Library on page 8-1.

NOTE: See Appendix A for format required for an OPS.CAL file.

After the data file is stored in the library, the following prompt will be written:

Is another data file to be stored?(Y or N)>*N*

If another data file is to be stored, the code will repeat this section. If not, the code will return control back to the Operational Stresses Menu.

Option 3.1.8: Delete a Data File from the Operational Stresses Library

This option allows the deletion of a file from the operational stresses library list. The file will be deleted from the subdirectory /LIFE2/DATA, and the file name will be taken out of the library list stored in OPSLST.LST. For a listing of the code prompts and example responses see Library Function: Deleting a Data File from a Library on page 8-2.

Option 3.2: Enter the Buffeting Stresses

Option 3.3: Enter the Start/Stop Stresses

As noted above, options 3.1, 3.2, and 3.3 have very similar prompts and inputs. Here, we have chosen not to present them in this report. See the discussion for option 3.1 to determine the type of responses expected by the LIFE2 code for Options 3.2 and 3.3.

Option 4
Operational Parameters Module

The fourth section of the code records the miscellaneous parameters required for the calculations. Typical inputs include such parameters as the cut-in wind speed, the cut-out wind speed and the stress concentration factor(s).

A flow diagram for this module is shown in Fig. 2.

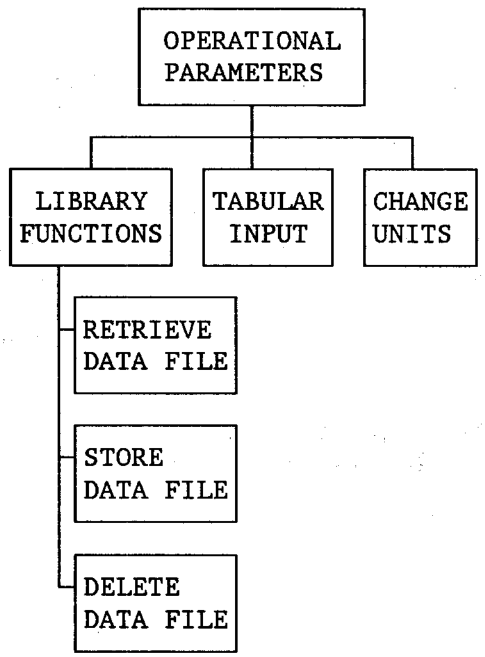

Figure 8. Flow Diagram for Operation Parameters Module.

Option 4: Enter the Operational Parameters

The operational parameters module allows the operator to enter miscellaneous parameters, such as cut-in wind speed, cut-out wind speed, and stress intensity factors. This module also contains options for converting the units of wind speed and for retrieving/storing the data in the operational parameters library.

When Option 4 is chosen from the Main Menu, the following screen will be displayed:

>>> Operational Parameters Menu <<<

This menu allows the operator to input the operational parameters for a wind turbine.

The current Operational Parameters Data Base in the operational memory is
Operational Parameters: Test Problem for the LIFE2 User's Manual

The options at this level are

9) Return to the Main Menu

Enter the number of the desired option.>

When the Operational Parameters module is executed, it will read into memory the data set in the OPP.CAL calculational file. The title of the file will be printed in the header of the menu. For the above example, the file entitled Operational Parameters: Test Problem for the LIFE2 User's Manual was read into memory.

Option 4.1: Retrieve Data from the Operational Parameters Library

Option 4.1 will copy a specified file from the operational parameters library to the calculation file OPP.CAL and place the data into memory. These data become the current operational parameters data base. Once the data are in memory they can have the units changed or be used in subsequent lifetime calculations. For a listing of the code prompts and example responses see Library Function: Retrieving a Data File From a Library on page 8-1. Once the data have been retrieved, the code returns to the Operational Parameters Menu.

Option 4.2: Input New Operation Parameters Data

Option 4.2 allows data input from the keyboard. Using this option, the miscellaneous parameters required for the calculations may be entered.

When this option is chosen from the Operational Parameters Menu the code responds with the following:

This subroutine inputs the miscellaneous parameters needed for the calculations into the LIFE2 code.

Data are input from the keyboard by the operator.

Enter the title of this data set no longer than 72 characters.
Operational Parameters: Test Problem for the LIFE2 User's Manual

Enter the units of wind speed no longer than 20 characters.
mph

Enter the Cut-In wind speed.>*10.0*

Enter the Cut-Out wind speed.>*45*

**Enter the wind speed increment to be used for calculations.
(1 is recommended).>***1*

Enter the stress concentration factor for fatigue analysis.>*2.73*

Enter the stress conversion factor for fracture analysis.>*6.28*

For a discussion on the stress conversion factor see Ref 3.

If a start/stop calculational file (STS.CAL) exists in the current directory the operator is asked if the data will be included in the calculations with the following prompt:

Is the Start/Stop data file to be included in the calculation?(Y or N)>*N*

If the operator wishes to use a start/stop data file in the calculations, the code will write the title of the data file on the screen. The code will then write the description of the data set on the screen and prompt the user for the number of times in a year the turbine will start and stop. The code's output will be as follows:

The current Start/Stop Data Base in the operational memory is:
Start/Stop data for the 34M VAWT

A description of this data set is:
Orderly shut down of the VAWT

The reference wind speed is:
24 mph

Enter the number of times this will occur PER YEAR.>*730*

In the above example, an orderly shut down of the turbine will occur an average of twice per day throughout the year. Therefor, the number of times that this data set is seen is 2 * 365 or 730 times per year.

For each set of data in STS.CAL the description of the set, the reference wind speed, and the prompt for the number of occurrences will be written on the screen. The operator's input to the prompt will be stored in memory and also in the operational parameters calculational file OPP.CAL.

If STS.CAL does not exist in the current directory, the code assumes that no start/stop data will be used in the calculations. The code will put the following information into OPP.CAL:

No Start/Stop data
1
0

The first line is a note to document that no start/stop data was used. However, the code will always try to read in data so the next two numbers are dummy data for the code to read.

The same note and dummy data are used if STS.CAL exists but the operator does not want to include the data in the calculations.

When the start/stop information is entered, the code checks to see if a buffeting data file (BUF.CAL) exists in the current directory. If the buffeting data file is present the code print the following prompt:

Is the Buffeting data file to be included in the calculation?(Y or N)>*N*

If the operator wants to include buffeting information, the code prompts for the information in the same manner as it did with the start/stop information. The code first writes the title of the data file on the screen followed by the average wind speed and the time of exposure to the buffeting wind. The code then prompts for the fraction of the year that the buffeting occurs. The code's output is as follows:

A description of this data set is
Buffeting data for the 34M VAWT

The average wind speed is
60 mph

The time of this buffeting record is
1.29e5 seconds

Enter the FRACTION OF A YEAR that this will occur.>*5.48e-3*

In the above example the buffeting wind that is described will occur 2 days of the year. Therefore, the fraction of the year that the data set occurs is 2/365.25 or 5.48e-3.

For each data set in BUF.CAL, the data set information and the prompt for the fraction of the year the set will occur are written to the screen. The operator's input to the prompt will be stored in memory and in the calculational file OPP.CAL

If BUF.CAL does not exist, the code assumes that the calculations will not include buffeting data and puts the following notes into OPP.CAL:

No Buffeting Data
1
0

The first line is to document that no buffeting data will be used in the calculations. However, the code will always try to read in data so the next two numbers are used as dummy data for the code to read.

The same note and dummy data are used if BUF.CAL is present but the operator does not want to include the data in the calculations.

The code then asks for the miscellaneous notes to include in the data file with the following prompts:

Enter the number of miscellaneous notes for this data set.>*2*

NOTE: If the user inputs 0 for the number of notes, the program does not ask for the note entry.

Enter note 1 no longer than 72 characters.
Calculations Are Based on Operational Stresses only

Enter note 2 no longer than 72 characters.
Wind Speed Interval =1 (not used at this time)

Do you wish to store these data in the Operational Parameters library?(Y or N)>*Y*

The following notes are automatically added to the data file:

The Wind Velocity Units Are: mph
Cutin Velocity = 10.000 mph
Cutout Velocity = 45.000 mph
Fatigue Stress Conc. Factor = 2.73
Fracture Stress Conversion = 6.28

If the response to the storage question is N, the code returns to the Wind Menu. If the response is Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. Once the data are stored, the code will return to the Wind Menu.

Option 4.6: Change Units of Wind Speed

Option 4.6 allows the units of wind speed for the data that are in memory to be changed.

For a listing of the code prompts and example responses see Changing Units of Wind Speed on page 10-1.

<u>Option 4.7: Add a Data File to the Operational Parameters Library</u>

Option 4.7 allows the code to store the current contents of the OPP.CAL file in the operational parameters library and to access operational parameters data files that were not generated by the code. When this option is chosen, the code responds with the following prompt:

Are the data to be stored currently in the OPP.CAL file?(Y or N)>*Y*

To archive the current contents of the OPP.CAL file, the operator should respond with a Y.

To import data from files not created by the LIFE2 code, the operator should respond with an N. The code will ask for the location and name of the data file. The data file must be in the same format as the OPP.CAL file in order to be read into memory properly. The format for OPP.CAL is defined in Appendix A. The following prompt will be displayed:

Input the path and name of the file to be stored.
A:VAWT17.DAT

Note: If no path is called out, it is assumed that the file is in the /LIFE2/DATA subdirectory.

The file will be copied to OPP.CAL and then read into memory. The program then prompts the operator for archiving the data found in OPP.CAL. For more information on these prompts and example responses see <u>Library Function: Adding a Data File to a Library</u> on page 8-1.

<u>NOTE:</u> See Appendix A for format required for a OPP.CAL file.

After the data file is stored in the library, the following prompt will be written:

Is another data file to be stored?(Y or N)>*N*

If another data file is to be stored, the code will repeat this section. If not, the code will return control back to the Operational Parameters Menu.

Option 4.8: Delete a Data File from the Operational Parameters Library

This option allows the deletion of a file from the operational parameters library list. The file will be deleted from the subdirectory /LIFE2/DATA, and the file name will be taken out of the library list stored in OPPLST.LST. For a listing of the code prompts and example responses see Library Function: Deleting a Data File from a Library on page 8-2.

Option 5
Lifetime Calculations Module

The fifth section of the code has two calculational modules. The S-n fatigue analysis module uses Miner's Rule[7] to determine the initial portion of the service lifetime of a turbine component; namely, the initiation of micro-cracks and their growth and coalescence into macro-cracks. In this formulation, the damage rule is integrated over all stress cycles to determine the rate at which damage is being accumulated. The lifetime of the component is inversely proportional to this damage accumulation rate.

In the second calculational module, the crack propagation characteristics of a pre-existing macro-crack are analyzed using a da/dn constitutive rule.[7] In this formulation, the crack growth rate, da/dn, is integrated over all stress cycles. As da/dn is a function of the crack length, the calculation is divided into a finite number of steps. For each step, the crack length is taken to be a constant, and an average growth rate is determined. The time required for the crack to grow across that integration segment is calculated. The sum over all of the integration segments yields the time of growth for the crack from its initial size to its final size.

A flow diagram for the main constitutive modules is shown in Fig. 9.

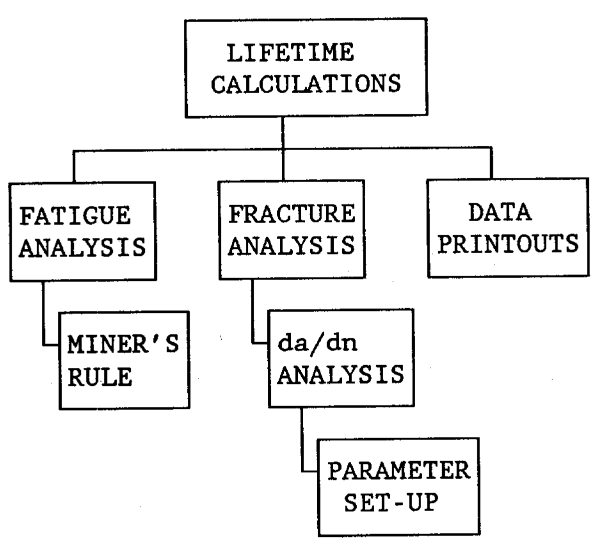

Figure 9. Flow Diagram for the Lifetime Calculations Module.

Option 5: Calculate Lifetime of a WECS component

Option 5 will calculate the lifetime of a WECS component based on the data stored in the calculational files. The code will calculate the lifetime using fatigue analysis data or fracture analysis data. This module also creates a file called SUMMARY.DAT which contains a summary of the data used by and generated by the calculations.

When option 5 is chosen from the Main Menu the following screen is displayed:

>>> Lifetime Calculational Menu <<<

This option calculates the lifetime of a WECS component based on the current calculational files.

The options at this level are

9) Return to the Main Menu

Enter the number of the desired option.>

NOTE: The following calculational files must exist in the current directory before the lifetime of a WECS can be calculated - WND.CAL, FAT.CAL or FRC.CAL, OPS.CAL, and OPP.CAL. The calculational files for the buffeting stresses (BUF.CAL) and the start/stop stresses (STS.CAL) are optional. If any of these files do not exist they may be created with their respective modules.

Option 5.2: Fatigue Lifetime Calculation

Option 5.2 will calculate the lifetime of a WECS component with material characterization data based on Miner's Rule[7].

When this option is chosen from the Lifetime Calculational Menu the following screen appears:

>>> Fatigue Lifetime Calculation Menu <<<

This option will calculate the lifetime of a WECS with material characterization data based on a fatigue analysis.

The options for calculating the lifetime are

1) Miners Rule with SCF applied to the Cyclic Stress	....page 7-4
2) Miners Rule With SCF applied to the Mean & Cyclic Stress	....page 7-4
3) Blank	....page 1-6
4) Blank	....page 1-6
5) Blank	....page 1-6

9) Return to Lifetime Calculational Menu

Enter the number of the desired option.>

Option 5.2.1: Miners Rule with SCF applied to the Cyclic Stress

See option 5.2.2 below.

Option 5.2.2: Miners Rule with SCF applied to the Mean & Cyclic Stress

Both options 5.2.1 and 5.2.2 require the same input. Option 5.2.1 is used for the sample calculations cited in Appendix B. When either one of these options are chosen the code continues as follows:

The LIFE2 code does not AUTOMATICALLY convert the Alternating Stress from a Range Variable to an Amplitude Variable, or from an Amplitude Variable to a Range Variable.

Do you want to change the Alternating Stress variable?(Y or N)*N*

If the operator does not wish to change the alternating stress variable, the response to the above prompt should be an N. The code will then skip the next prompt and ask for the title of the calculation set. If the response to the above prompt is a Y, the code will continue as follows:

Note: The operator is referred to the detailed discussion contained in Ref. 3 to determine if this option needs to executed.

Enter 0.5 for Range Variable to Amplitude Variable conversion.
Enter 2.0 for Amplitude Variable to Range Variable conversion.

Enter the Alternating Stress amplitude correction factor.>

This correction factor is applied to the alternating stresses of the operational stresses, buffeting stresses and start/stop stress states as a multiplier.

Enter the title of this calculation set, no longer than 72 characters.
Fatigue Characterization: Test Problem for the LIFE2 User's Manual

Will a Start/Stop data file be utilized in the
LIFETIME calculations?(Y or N)>*N*

Will a Buffeting data file be utilized in the LIFETIME calculations?(Y or N)>*N*

Once the above information is entered, the code creates a summary file. The summary file contains information on which calculational files are used in the calculation. The code informs the operator of the status of the program with the following prompt:

.......Performing the calculations.

Once the lifetime is calculated, the result is written to the screen.

For an S-n Fatigue Analysis of the data given the Lifetime is .12050050E+02 years.

Press <ENTER> to continue

The lifetime is also written to the summary file. The code then returns to the Fatigue Lifetime Calculation Menu.

Option 5.3: Fracture Lifetime Calculation

Option 5.3 will calculate the lifetime of a WECS component with material characterization data based on a fracture analysis.

When this option is chosen from the Lifetime Calculational Menu the following screen appears:

>>> Fracture Lifetime Calculation Menu <<<

This option will calculate the lifetime of a WECS with material characterization data based on a fracture analysis.

The options at this level are

1) Review/Change the Parameters for Calculations ....page 7-7
2) Calculate the Lifetime from a known crack size ....page 7-9
3) Blank ....page 1-6
4) Blank ....page 1-6
5) Blank ....page 1-6

9) Return to Lifetime Calculational Menu

Enter the number of the desired option.>

Option 5.3.1: Review/Change the Parameters for Calculations

Option 5.3.1 allows the operator to set parameters the code will need to do the lifetime calculation.

When this option is chosen the following screen is displayed:

>>> Fracture Calculation Setup Menu <<<

This menu allows the operator to set parameters used in the lifetime calculation.

The current setup is

1) Initial crack size	**= 0.01**
2) Final crack size	**= 1.0**
3) The number of intervals per decade	**= 2**
4) Finite width correction	**= Not Used**
5) Yield Stress correction	**= Not Used**

9) Return to the Fracture Lifetime Calculation Menu

Enter the number of the parameter to change.>

The code uses a crack size array to determine the amount of time it takes for a crack to grow from the initial size to the final size. The array begins on the next lowest decade from the initial value and ends on the next highest decade from the final value. For the setup given above, the crack size array would be from .001 to 10.0. Within each decade, there are 2 intervals in the current setup. A larger number of intervals will give a more accurate result but the calculations will take more time. The code calculates the time for the crack to grow through each interval in the crack size array. The lifetime is found by summing the intervals.

The operator also has a choice of using two correction factors. One is a correction for width and the other is a correction for yield stress.

If one of the parameters needs to be changed, the number corresponding to the parameter is entered.

The following is the code response when changing each parameter:

1 - Initial Crack Size

Current Initial Crack Size is = 0.001

Input the new Initial Crack Size.>*.003*

2 - Final Crack Size Value

Current Final Crack Size is = 0.1

Input the new Final Crack Size.>*.75*

3 - Number of intervals per decade

Current number of intervals per decade = 5

Input the new number of intervals per decade.>*10*

4 - Correction for width

The current width correction = Not Used

The correction formula is as follows:
SQRT(1 / cos(3.14 * a/w))

Variable "a" is the crack length.

Input the value of "w" to be used (enter 0 for "Not Used").>*1.0*

5 - Correction for yield stress

The current yield stress correction = Not Used

Is the yield stress correction to be used?(Y or N)>*Y*

Option 5.3.2: Calculate Lifetime from a known crack size

This option will use the parameters that are input in option 5.3.1 to calculate the lifetime. When this option is chosen the code continues as follows:

The LIFE2 code does not AUTOMATICALLY convert the Alternating Stress from a Range Variable to an Amplitude Variable, or from an Amplitude Variable to a Range Variable.

Do you want to change the Alternating Stress variable?(Y or N)*Y*

If the operator does not wish to change the alternating stress variable, the response to the above prompt should be an N. The code will then skip the next prompt and ask for the title of the calculation set. If the response to the above prompt is a Y, the code will continue as follows:

Enter 0.5 for Range Variable to Amplitude Variable conversion.
Enter 2.0 for Amplitude Variable to Range Variable conversion.

Enter the Alternating Stress amplitude correction factor.>*2*

Note: The operator is referred to the detailed discussion contained in Ref. 3 to determine if this option needs to executed.

Enter the title of this calculation set, no longer than 72 characters.
Example calculation for the LIFE2 Users Manual

Will a Start/Stop data file be utilized in the LIFETIME calculations?(Y or N)>*N*

Will a Buffeting data file be utilized in the LIFETIME calculations?(Y or N)>*N*

Once the above information is entered the code creates a summary file. This file contains information on which calculational files where used in this calculation. The code informs the operator of the status of the program by writing data onto the terminal as it is calculated. The code output is as follows:

Crack Size	Time
.10000000E-02	.00000000E+00
.31622789E-02	.58050410E-02
.10000000E-01	.51667400E-02
.31622789E-01	.45986250E-02
.10000000E+00	.40929770E-02
.31622789E+00	.36425530E-02
.10000000E+01	.31854450E-02
.31622789E+01	.22883390E-02
.10000000E+02	.11089420E-02

The time data is the number of years it takes for the crack to grow within each interval. The lifetime is the summation of the time for the crack to grow from the initial size to the final size given in the setup. Once the lifetime is calculated, the result is written to the screen.

For a Fracture Analysis of the data given the Lifetime is
.15519600E-01 years.

Press <ENTER> to continue

The lifetime is also written to the summary file. The code then returns to the Fatigue Lifetime Calculation Menu.

Option 5.4: Print the file SUMMARY.DAT

This option allows the operator to get a hard copy of the summary data file. The file contains summary information about the calculational files used in a lifetime calculation.

When this option is chosen the code sends the file SUMMARY.DAT to the computer's printer port and displays the following message:

.....Printing SUMMARY.DAT

Option 5.5: Print the file WIND.DAM

This option prints the wind damage file, which lists the upper wind speed for each wind speed interval and the corresponding damage for the interval.

When this option is chosen the code sends the file WNDDAM.DAT to the computer's printer port and displays the following message:

.....Printing WNDDAM.DAT

Library Functions

Library Function: Adding a File to a Library

This function allows data files to be archived in a permanent library. They may be recalled at a later time without having to be recalculated or reentered.

When this function is called, the code will respond with the following prompts:

The following is a list of data files currently available in the library:

1 RAY16 2 RAY14

Enter a 1-6 character name under which to store
the file just created, revised, or added.>*RAY14*

The name that is entered can contain any character or number and is not case dependent (i.e., *TEST1* is the same as *test1*). If the file name is the same one that appears in the list, then the following prompt occurs:

A file already exist under that name.
Is this file to be overwritten with new data?(Y or N)>*Y*

If the data are to be overwritten, the responses should be Y. In this case the old file is opened and the module's calculational file will be copied to it. If the file is not to be overwritten, the response should be N. The library list will be written on the screen again and another file name requested.

When the data have been stored, the function will return control to the calling menu.

Library Function: Retrieving a Data File From a Library

This function allows the data stored in a module's library file to be recalled. There are two steps to this process. First, the data file is copied from the data file to the current module's calculational file. Then the data is read into memory from the calculational file.

When this option is chosen from the Wind Menu the code responds with the following prompt:

The following is a list of data files currently available in the library:

1 WEI16 2 RAY14

Enter the number of the desired file.>

WEI16 and RAY14 are examples of names of files that may be in the library. The files that are listed are the archived data files from previous inputs/calculations. All of the listed files have an extension that corresponds to the current module and are contained in the subdirectory LIFE2/DATA. If option 1.1 was chosen (Retrieve Data from the Wind Library), the file names on the disk for the above example would be WEI16.WND and RAY14.WND. Only the files belonging to the wind module are listed, (i.e., only files with extension .WND). Upon completion, the program will return to the calling menu.

<u>Library Function: Deleting a Data File from a Library</u>

This function will delete unwanted data files from a module's library. There are two deletions that need to be made when removing a file. One deletes the file from the subdirectory /LIFE2/DATA, and the other takes the file name out of the module's library list.

When this function is called, the code responds with the following prompt:

The following is a list of data files currently available in the library:

1 RAY16 2 RAY14

Enter the number of the file to be deleted.
Type in 0 for no deletion.>*1*

If no deletion is desired at this point, the response should be a 0 and the function will return control to the calling menu. Otherwise, the number of the file should be entered; the code will first delete the file from the subdirectory /LIFE2/DATA and then remove the file name from the module's library list. In this case RAY16.WND is deleted from the library. When the file has been deleted the code will print the following prompt:

Is another file to be deleted?(Y or N)>*N*

If another file is to be deleted the function will repeat itself. If no more files are to be deleted, the function will return control to the calling menu.

Plot Parameters

The plotting options must be set the first time the LIFE2 code accesses a plot routine. Thereafter, the options routine needs to be accessed only to modify the current configuration.

Option 1 from the plotting menus creates a file called PLOT.CNG, which stores the configuration information. The data contained in this file insure that the plotting parameters match the hardware configuration of the computer system in use. There are two main hardware devices that must be configured. One is the preview device, which is the terminal, and the other is the output device, which can be a printer or a plotter.

When this function is called from a module's plotting menu, the code responds with the following menu:

>>> Plot Parameters Menu <<<

This menu allows the operator to change the plotting parameters.

The options at this level are

1) Review/Change parameters

9) Return to Plotting Menu

Enter the number of the desired option.>

To review or change the plotting parameters the response should be a 1. The code will first display the parameters for the preview plot. When these parameters have been selected, the code will display the parameters for the hardcopy plot.

The first time the code is run after installation the current parameters do not exist. Therefore, the code will ask for the desired parameters first and then display them.

When option 1 is chosen from the Plot Parameters Menu the code responds with the following prompts:

The current parameters for the preview plot are

1) Hardware interface type: 97
2) Output device: 97
3) X-axis length: 6.0

4) Y-axis length: 4.0
5) X zero position: 1.5
6) Y zero position: 1.5

9) Continue

Enter the number of the parameter to be changed.>

This is the set-up for the preview plot, or monitor. The first option refers to the type of interface card being used to drive the monitor, i.e., EGA, CGA, etc. The second option refers to the type of monitor. The number that is listed is the code number that corresponds to the device as listed in the PLOT88 manual. For a listing of the devices and their corresponding code numbers please see the PLOT88 manual and Appendix F.

The third and forth options specify the length of the X and Y axes, respectively, in inches. The fifth and sixth options specify where the origin is to be located, measured in inches from the bottom left corner of the terminal.

When changing the first option, the following prompt is written to the screen:

The hardware interface options are

1) HGC: Hercules Graphics Adapter
2) EGA: Enhanced Graphics Adapter
3) CGA: IBM Color Graphics Adapter

Enter the number of the desired option.>

To make a selection, type in the number corresponding to the type of interface card the computer system is using.

When changing the second option, the following prompt is written to the screen:

The output device options are

1) Monochrome Monitor (used with HGC Adapter)
2) EGA Monitor
3) CGA Monitor

Enter the number of the desired option.>

To make a selection, type in the number corresponding to the type of monitor the computer system is using.

For setting the X-axis length, the following prompt is written to the screen:

Enter the X-axis length.
Suggested value is 6.0 inches.>*6.0*

A similar prompt is written to the screen for the Y-axis length.

The fifth and sixth options are used together to set the origin of the plot. The fifth option has the following prompt:

Enter the X coordinate of the origin.
Suggested value is 1.5 inches.>*1.5*

A similar prompt is written for the Y-axis zero position.

When all of the values are set for the preview plot, entering a 9 will have the code continue to the hardcopy set-up menu, which is very similar to the preview menu.

The current parameters for the hardcopy plot are

1) Hardware interface type: 0
2) Output device: 64
3) X-axis length: 6.0
4) Y-axis length: 5.0
5) X zero position: 1.5
6) Y zero position: 1.5

9) Continue

Enter the number of the parameter to be changed.>

Options 3,4,5 and 6 have the same prompts as the preview parameters menu. Options 1 and 2 are slightly different. When changing the hardware interface type, the following prompt is written to the screen:

The hardware interface options are

1) PRN:
2) LPT1:
3) LPT2:
4) LPT3:
5) COM1: baud rate 1200
parity none

data bits 8
stop bits 1
6) COM2: baud rate 1200
parity none
data bits 8
stop bits 1

Enter the number of the desired option.>

Option 1 is chosen if the output device is the system printer. Options 2, 3 and 4 are the system parallel ports. Options 5 and 6 are the system serial ports. The serial ports need to be set-up as shown in the menu at the system level before the LIFE2 code can use these ports. The hardcopy unit should be connected to the interface port chosen here.

When changing the output device, option 2, the following menu is written to the screen:

The hardcopy output device options are

1) **Epson FX-80 Printer, single density**
2) **Epson FX-80 Printer, double density**
3) **HP 7470A Graphics Plotter**
4) **HP 7475A Graphics Plotter**
5) **HP Laserjet Printer (75 dots/in)**
6) **HP Laserjet Printer (150 dots/in)**
7) **HP Laserjet Printer (300 dots/in)**

Enter the number of the desired option.>

These are the output devices supported by the hardcopy plotting routine.

When the parameters for the hardcopy plot have been set-up, entering a 9 will have the code continue to the following prompt:

Are the new plot parameters to be saved?(Y or N)>*Y*

For the new parameters to be active, they must be saved. When the parameters are saved, they are written to the PLOT.CNG file. The plotting routines open the PLOT.CNG file and use the set-up stored there. All of the modules' plotting routines use the same set-up file; i.e., the Wind Resource plotting routines use the same set-up file as the Constitutive Properties plotting routines.

Following the above prompt, the code will return to the Plot Parameters Menu.

NOTE: PLOT88[5] offers many more choices for interfaces and output devices, options 1 and 2 of the hardcopy setup menu, than displayed by the code. The code lists only the most widely used devices. The PLOT88 manual or Appendix F may be used to determine if a device not listed as a choice by the code is supported by the PLOT88 package. To use a different device, enter the number corresponding to that device. For example, if an HP ThinkJet printer with high density is to be used as an output device for the hardcopy unit, the number 71 would be entered instead of one of the choices given in the set-up.

Changing Units

Changing Units of Wind Speed

This option allows the units of wind speed for the data that are in memory to be changed.

WARNING: The new data that are calculated will be written over the current data. If the current data are not stored in a library file, they will be lost and will have to be recalculated.

When this option is chosen, the code will respond with the following prompts:

>>> Wind Unit Conversion Menu <<<

This menu allows the operator to change the units of wind speed for the data in memory.

The current units of wind speed are mph
The conversions available are

1) mph to ft/sec	**2) ft/sec to mph**
3) km/hr to m/sec	**4) m/sec to km/hr**
5) mph to m/sec	**6) m/sec to mph**
7) input multiplier	

9) Return to Wind Menu

Enter the number of the desired conversion.>

In the above example the current wind speed units are mph. If the desired conversion is to convert to m/sec the number 5 is entered. The code will respond with the following:

The units were converted from: mph
to: m/sec

Do you want to store the new data in the library?(Y or N)>*Y*

If the response to the storage question is N, the code returns to the Wind Unit Conversion Menu. If the response is Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. When complete, the code will return to the Wind Unit Conversion Menu.

Several conversions may be done in succession. For example, if the data are currently in mph and it is desired to convert them to km/hr the first conversion to do is from mph to m/sec (conversion 5). And, the second conversion is from m/sec to km/hr (conversion 4). The data have now been converted from mph to km/hr. The data may be stored in a wind library file (if desired) at any or every step in this process.

Conversion 7 allows the input of a conversion factor and unit descriptor from the keyboard. When this option is chosen, the code responds with the following prompts:

Input the conversion factor.>*3600*

Input the new units of wind speed no longer than 20 characters. *m/hr*

NOTE: The wind speed is multiplied by the conversion factor. If the old units were m/s, the above example would convert the wind speed to m/hr.

The code then precedes with the conversion and returns to the Wind Unit Conversion Menu.

When the necessary conversions have been completed, option 9 will return control to the calling menu.

Note: The operator may use any spelling for the units of wind velocity that is less than or equal to 20 characters. The abbreviations used here are

mph	- Miles per Hour
ft/sec	- Feet per Second
km/hr	- Kilo-Meter per Hour
m/sec	- Meter per Second

Changing Units of Stress

This option allows the units of stress for the data that are in memory to be changed.

WARNING: The new data that are calculated will be written over the current data. If the current data are not stored in a library file, they will be lost and will have to be recalculated.

When this option is chosen, the code will respond with the following prompts:

>>> Stress Unit Conversion Menu <<<

The current units of stress are psi
The conversions available are

1) psi to psf	**2) psf to psi**
3) MPa to psi	**4) psi to MPa**
5) MPa to psf	**6) psf to MPa**
7) input multiplier	

9) Return to Fatigue Analysis Menu

Enter the number of the desired conversion.>

In the above example the current stress units are psi. If the desired conversion is to MPa, the number 4 is entered. The code will respond with the following:

The units are being converted	**from:**	**psi**
	to:	**MPa**

Do you want to store the new data in the library?(Y or N)>*Y*

If the response to the storage question is N, the code returns to the Stress Conversion Menu. If the response is Y, the code will prompt the user for storage information. For a list of code prompts and example responses on storing data files see Library Functions: Adding a Data File to a Library on page 8-1. When complete, the code will return to the Stress Unit Conversion Menu.

Conversion 7 allows the input of a conversion factor and unit descriptor from the keyboard. When this option is chosen, the code responds with the following prompts:

Input the conversion factor.>*0.0680*

Input the new units of stress.>*atm*

NOTE: The stress parameters are multiplied by the conversion factor. If the old units were psi then the above example would convert the stress to atm [i.e. psi/14.7 = (psi)(0.0680) = atm].

The code then proceeds with the conversion and returns to the Stress Unit Conversion Menu.

When the necessary conversions have been done, selection 9 will return control to the calling menu.

NOTE: The operator may use any spelling for the units of stress that is less than are equal to 20 characters. The abbreviations used here are

psi	- pounds per square inch
psf	- pounds per square foot
MPa	- mega pascal

Changing Units of Length

This option allows the operator to change the units of length for the data that are in memory. When this option is chosen the code responds with the following menu:

>>> Length Unit Conversion Menu <<<

The current units of length are in
The conversions available are

1) m to mm	**2) mm to m**
3) m to in	**4) in to m**
5) mm to in	**6) in to mm**
7) input multiplier	

9) Return to the Fracture Units Conversion Menu

The code will function in the same way as with the stress conversion described previously.

Note: The length is a square root function. In option 7 (input multiplier), the multiplier is the direct conversion factor (i.e. to convert from m to cm the multiplier is 100). The code will use the square root of this multiplier.

When the necessary conversions have been done, selection 9 will return control to the calling menu.

Note: The operator may use any spelling for the units of stress and length that are less than are equal to 20 characters. The abbreviations used here are:

psi	- pounds per square inch
psf	- pounds per square foot
m	- meter
mm	- millimeter
in	- inch

SUMMARY STATEMENT

The LIFE2 computer code is a fatigue/fracture analysis code that is specifically for the analysis of wind turbine components. This report describes the inputs expected by the code and is designed to be a User's Manual. Two example problems are used to illustrate its capabilities.

ACKNOWLEDGMENTS

The LIFE2 code is an outgrowth of the LIFE code. The latter code was initially conceived and written by P. S. Veers[10] and subsequently modified by H. J. Sutherland, T. D. Ashwill and N. Slack[11]. Several individuals have contributed to the writing of this version of the LIFE2 code; they include K. A. Naassan, J. R. Wright and D. Vetter. The authors wish to thank these peoples for their contributions to the development of the LIFE2 computer code.

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Appendix A

Formats for Calculational Files

The following appendix gives the formats for the calculational files. A description of a file is given first followed by an example of what would be created if the code were given the example inputs shown in this manual.

WND.CAL

The title of the file	
Wind Speed Units	
Turbulence Factor	
Number of Entries - N	
Wind Velocity #1	Fraction #1*
Wind Velocity #2	Fraction #2
Wind Velocity #3	Fraction #3
.	.
.	.
.	.
Wind Velocity #N	Fraction #N
Number of Miscellaneous Notes - M	
Note #1	
Note #2	
.	
.	
.	
Note #M	

*The n^{th} Fraction is the cumulative density function that covers the wind velocity interval from 0 to Velocity n.

The following is for the inputs given in option #1.3.1, page 3-6.

```
Test Problem for the LIFE2 User's Manual: Wind Spectrum
mph
 .00000000E+00
 99
  .1000000E+01        .9960009E+00
  .2000000E+01        .9840992E+00
  .3000000E+01        .9645784E+00
  .4000000E+01        .9378979E+00
  .5000000E+01        .9046761E+00
  .6000000E+01        .8656654E+00
  .7000000E+01        .8217249E+00
  .8000000E+01        .7737886E+00
  .9000000E+01        .7228324E+00
  .1000000E+02        .6698420E+00
        .
        .
        .
  .8900000E+02        .1641617E-13
  .9000000E+02        .8012395E-14
  .9100000E+02        .3879470E-14
  .9200000E+02        .1863382E-14
  .9300000E+02        .8878727E-15
  .9400000E+02        .4196807E-15
  .9500000E+02        .1967917E-15
  .9600000E+02        .9154066E-16
  .9700000E+02        .4224164E-16
  .9800000E+02        .1933690E-16
  .9900000E+02        .8781171E-17
  5
 Calculations Based on            :Max Wind Speed = 99 mph
                                  :Number of Intervals = 99
 To Yield 1 mph Wind Velocity Increments
 Rayleigh Calculation Preformed by the LIFE2 Code
 Mean Wind Speed =  14.00 mph
```

FAT.CAL

The title of the file
Stress Units
Modulus of Elasticity
Poissons Ratio
Yield Strength
Ultimate Strength
Number of Mean Stress Entries - I
Number of Cyclic Stress Entries - J

Mean Stress #1	Mean Stress #2	Mean Stress #3	Mean Stress #4
Mean Stress #5	Mean Stress #6	Mean Stress #7	Mean Stress #8
.			
.			
.			
Mean Stress #I			
Cyclic Stress #1	Cyclic Stress #2	Cyclic Stress #3	Cyclic Stress #4
Cyclic Stress #5	Cyclic Stress #6	Cyclic Stress #7	Cyclic Stress #8
.			
.			
.			
Cyclic Stress #J			
Cycles to Failure(1,1)*	Cycles to Failure(1,2)	Cycles to Failure(1,3)	Cycles to Failure(1,4)
.			
.			
.			
Cycles to Failure(1,J)			
Cycles to Failure(2,1)	Cycles to Failure(2,2)	Cycles to Failure(2,3)	Cycles to Failure(2,4)
.			
.			
.			
Cycles to Failure(2,J)			
.			
.			
.			
Cycles to Failure(I,1)	Cycles to Failure(I,2)	Cycles to Failure(I,3)	Cycles to Failure(I,4)
.			
.			
.			
Cycles to Failure(I,J)			

Number of Miscellaneous Notes - M
Note #1
Note #2
.
.
.
Note #M

---

*Here, cycles to failure (i,j) is the number of stress cycles that are required to fail the specimen at mean stress i and cyclic stress j.

The following example is for inputs given in option #2.1.3.2, page 4-9.

```
Fatigue Characterization: Test Problem for the LIFE2 User's Manual
psi
.10000000E+08
.30000000E+00
.25000000E+05
.39000000E+05
10
6
.00000000E+00 .43333330E+04 .86666670E+04 .13000000E+05
.17333330E+05 .21666670E+05 .26000000E+05 .30333330E+05
.34666670E+05 .39000000E+05
.10000000E+05 .10700000E+05 .14400000E+05 .18300000E+05
.24700000E+05 .39000000E+05
.50000000E+09 .10000000E+08 .10000000E+07 .10000000E+06
.10000000E+05 .10000000E+01
.67798810E+07 .40123940E+07 .32252790E+06 .40481970E+05
.93010270E+03 .10000000E+01
.24076760E+07 .14248840E+07 .91449660E+05 .14521520E+05
.62972070E+02 .10000000E+01
.67557900E+06 .35267970E+06 .28001340E+05 .11900000E+04
.28131580E+01 .10000000E+01
.11721020E+06 .67532540E+05 .37826190E+04 .30122400E+02
.10000000E+01 .10000000E+01
.20467320E+05 .12174710E+05 .42038110E+02 .10000000E+01
.10000000E+01 .10000000E+01
.19843560E+03 .50711700E+02 .10000000E+01 .10000000E+01
.10000000E+01 .10000000E+01
.10000000E+01 .10000000E+01 .10000000E+01 .10000000E+01
.10000000E+01 .10000000E+01
.10000000E+01 .10000000E+01 .10000000E+01 .10000000E+01
.10000000E+01 .10000000E+01
.10000000E+01 .10000000E+01 .10000000E+01 .10000000E+01
.10000000E+01 .10000000E+01
18
Fatigue Characterization of 6063 Aluminum
Taken from Ref. 1
Zero Mean Stress Curve Described by the 5 points Listed Below
 Miscellaneous Input Parameters:
   Modulus of Elasticity =  .10000E+08 psi
   Poissons Ratio        =  .30000E+00
   Yield Stress          =  .25000E+05 psi
   Ultimate Stress       =  .39000E+05 psi
 Goodman Rule Calculation Using Ultimate Stress
  Note: Stress Amplitude Used to Describe the Alternating Stress
  Based on the Zero Mean Stress S-n Curve
  Data Input into the Calculation
   Alt Stress   Cyc to Failure    Alt Stress   Cyc to Failure
    10000.00    500000000.00       18300.00     100000.00
    10700.00     10000000.00       24700.00      10000.00
    14400.00      1000000.00
 Final Point Automatically Added to Zero Mean Stress S-n Input
    39000.00           1.00
```

FRC.CAL

The title of the file
Stress Units
Length Units
Modulus of Elasticity
Poissons Ratio
Yield Strength
Ultimate Strength
Number of Mean SIF Entries - N
Number of Alternating SIF Entries - M

Mean SIF #1	Mean SIF #2	Mean SIF #3	Mean SIF #4
Mean SIF #5	Mean SIF #6	Mean SIF #7	Mean SIF #8
.			
.			
.	Mean SIF #I		
Cyclic SIF #1	Cyclic SIF #2	Cyclic SIF #3	Cyclic SIF #4
Cyclic SIF #5	Cyclic SIF #6	Cyclic SIF #7	Cyclic SIF #8
.			
.			
.			
Cyclic SIF #J			
Growth Rate (1,1)*	Growth Rate(1,2)	Growth Rate (1,3)	Growth Rate (1,4)
.			
.			
.			
Growth Rate (1,J)			
Growth Rate (2,1)	Growth Rate(2,2)	Growth Rate (2,3)	Growth Rate (2,4)
.			
.			
.			
Growth Rate (2,J)			
.			
.			
.			
Growth Rate (I,1)	Growth Rate(I,2)	Growth Rate (I,3)	Growth Rate (I,4)
.			
.			
.			
Growth Rate (I,J)			

Number of Miscellaneous Notes - M
Note #1
Note #2
.
.
.
Note #x

*Here, growth rate (i,j) is da/dn at mean stress intensity factor (SIF) i and cyclic SIF j.

The following example is for inputs given in option #2.2.2, page 4-23.

```
 Fracture Characterization: Test Problem for the LIFE2 User's Manual
psi
in
 .10000000E+08
 .30000000E+00
 .25000000E+05
 .39000000E+05
  2
  3
 .00000000E+00  .25000000E+05
 .12300000E+05  .31620000E+05  .63100000E+05
 .10000000E-04  .80000000E-04  .10000000E-02
 .10000000E-04  .80000000E-04  .10000000E-02
 12
 Crack Propagation Rate for Aluminum - Lower Curve
 Data Taken from Ref. 2
 Tabular Input Used in this Calculation
  Crack Growth Rate Independent of Mean Stress with the following input
    Alt SIF       Growth Rate     Alt SIF       Growth Rate
   .12300E+05     .10000E-04      .31620E+05     .80000E-04
   .63100E+05     .10000E-02
  Miscellaneous input parameters:
    Modulus of Elasticity =  .10000E+08 psi
    Poissons Ratio        =  .30000E+00
    Yield Stress          =  .25000E+05 psi
    Ultimate Stress       =  .39000E+05 psi
```

OPS.CAL, BUF.CAL, and STS.CAL

The title of the file
Stress Units
Time Units
Wind Speed Units
Data Characterized by one Mean Stress - 'y' or 'n'
Number of Wind Speed Intervals - N
Title of Data Set #1*
Upper bound of wind speed for data set #1
Time Interval for series #1 of cycle counts (sec)
Number of Mean Stress Entries - I
Number of Cyclic Stress Entries - J

Mean Stress #1	Mean Stress #2	Mean Stress #3	Mean Stress #4
. . .			
Mean Stress #I			
Cyclic Stress #1	Cyclic Stress #2	Cyclic Stress #3	Cyclic Stress #4
. . .			
Cyclic Stress #J			
Cycles to failure(1,1)	Cycle Count(1,2)	Cycles to failure(1,3)	Cycle Count (1,4)
. . .			
Cycle Count (1,J)			
. . .			
Cycle Count (I,1)	Cycle Count(I,2)	Cycle Count (I,3)	Cycle Count (I,4)
. . .			
Cycle Count (I,J)			

Title of Data Set #2*
.
.
.
Title of Data Set #N*
.
.
.
Number of Miscellaneous Notes - x
Note #1
.
.
.
Note #x

*The title of a data set that is generated by the LIFE2 code automatically uses the title of 'Operational Stresses' for the set of cycle counts at each velocity interval.

The following example is for inputs given in option #3.1.3.1, page 5-10.

```
Stress States: Test Problem for the LIFE2 User's Manual
psi
seconds
mph
n
 75
Operational Stresses
 .10000000E+01
 .62500000E+00
 1
50
 .70000000E+04
 .19591840E+01  .39183670E+01  .58775510E+01  .78367350E+01
 .97959180E+01  .11755100E+02  .13714290E+02  .15673470E+02
     .
     .
     .
 .96000000E+02  .19200000E+03
 .74688450E-02  .22073500E-01  .35703660E-01  .47789230E-01
 .57870910E-01  .65628520E-01  .70896020E-01  .73662210E-01
     .
     .
     .
 .16284980E-07  .15229980E-07
Operational Stresses
     .
     .
     .
Operational Stresses
     .
     .
     .
 14
Operating Stress Characterization Using Veer's Model
Taken from Refs. 1 and 2
Number of Wind Speed Intervals = 75
Upper Limit of Wind Speed = 75 mph
Yields 1 mph Increments in Wind Velocity
Veers Model Calculation for the Operational Stresses
Note: This Formulation yields Alternating Stresses
    that are Characterized by their Amplitude.
Mean Stress for the Calculation =    7000.00 psi
Frequency =      1.60 Hz
Wind Speed Units      : mph
     Wind Speed          RMS Stress               Wind Speed          RMS Stress
        .00                 .00                     20.00               700.00
       10.00              320.00                    40.00              1560.00
```

OPP.CAL

The title of the file
Wind Speed Units
Cut In Wind Speed
Cut Out Wind Speed
Wind Speed Increment
Fatigue Stress Concentration Factor
Fracture Stress Concentration Factor
Title of Start/Stop File
Number of Start/Stop Data Sets - I
Number of times Data Set #1 occurs
Number of times Data Set #2 occurs

.
.
.

Number of time Data Set #I occurs
Title of Buffeting File
Number of Buffeting Data Sets - J
Fraction of year Data Set #1 occurs
Fraction of year Data Set #2 occurs

.
.
.

Fraction of year Data Set #J occurs
Number of Miscellaneous Notes - z
Note #1
Note #2

.
.
.

Note #z

The following example is for inputs given in option #4.2, page 6-4.

```
Operational Parameters: Test Problem for the LIFE2 User's Manual
mph
 .10000000E+02
 .45000000E+02
 .10000000E+01
 .27300000E+01
 .62800000E+01
NONE
 1
 .00000000E+00
NONE
 1
 .00000000E+00
 7
Calculations are Based on Operational Stresses only
Wind Speed Interval = 1 (not used at this time)
 The Wind Velocity Units Are: mph
  Cutin Velocity =  10.0000 mph
  Cutout Velocity =  45.0000 mph
 Fatigue Stress Conc. Factor =  2.73
 Fracture Stress Conversion =  6.28
```

Appendix B

Example Problems

To illustrate the use of this code, consider the analyses, performed in Refs. 1 and 2, on the lower blade joint on the DOE 100-kW Low Cost VAWT. This joint was analyzed using the fatigue and fracture analysis capabilities of the LIFE2 code. They are repeated here for illustration purposes.

Typical plots of the data generated by this calculation are shown in Appendix C.

Wind Spectrum

The wind regime was assumed to have a Rayleigh distribution with a mean velocity of 6.26 m/s (14 mph). The inputs used here are given as the inputs for Option 1.3.1.

Constitutive Description

The blade joint was made of 6063 aluminum. An S-n curve and a da/dn curve for this material are shown in Refs. 1 and 2, respectively. The inputs to the code for these two descriptions are given as the inputs for Option 2.1.3.2 and Option 2.2.2.

Stress State

The stress state for the joint was determined using Veers' narrow band Gaussian model and the distribution of the vibratory stresses, as a function of wind speed, cited in Ref. 1. The inputs to the code for this description of the stress states encountered by a vertical axis wind turbine is given as the inputs for Option 3.1.3.1.

Operational Parameters

The turbine was assumed to operate between 10 mph and 45 mph. The stress concentration for fatigue was assumed to be 2.73 and the stress conversion factor for fracture was assumed to 6.28. The inputs to the code for this operational conditions are given as the inputs for Option 4.2.

Service Lifetime

This turbine joint was analyzed first using an S-n fatigue analysis and a da/dn analysis. The inputs for these are given in Option 5.2.1 and 5.3.2 respectively.

Appendix C

Typical Plots Generated by the LIFE2 Code

The following plots were generated by the LIFE2 code. They were produced using the high density plot parameters for a LaserJet II printer. They have not been enhanced here to permit critical evaluation of their quality.

The first 6 plots were generated using the data base from the example problems cited in Appendix B. The last plot was generated using the inputs cited in Option 2.2.3.4

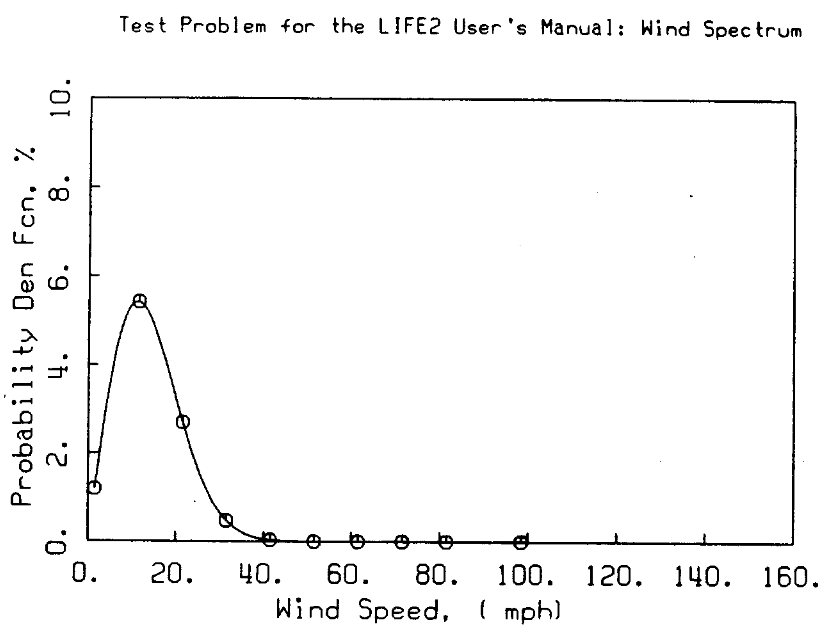

Figure C-1. Probability Density Function Plot from the Wind Module.

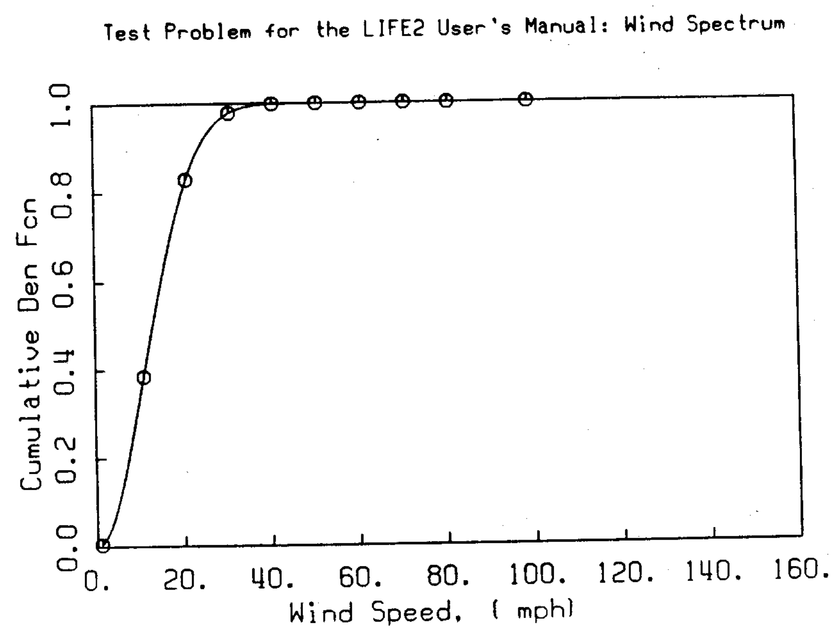

Figure C-2. Cumulative Density Function Plot from the Wind Module.

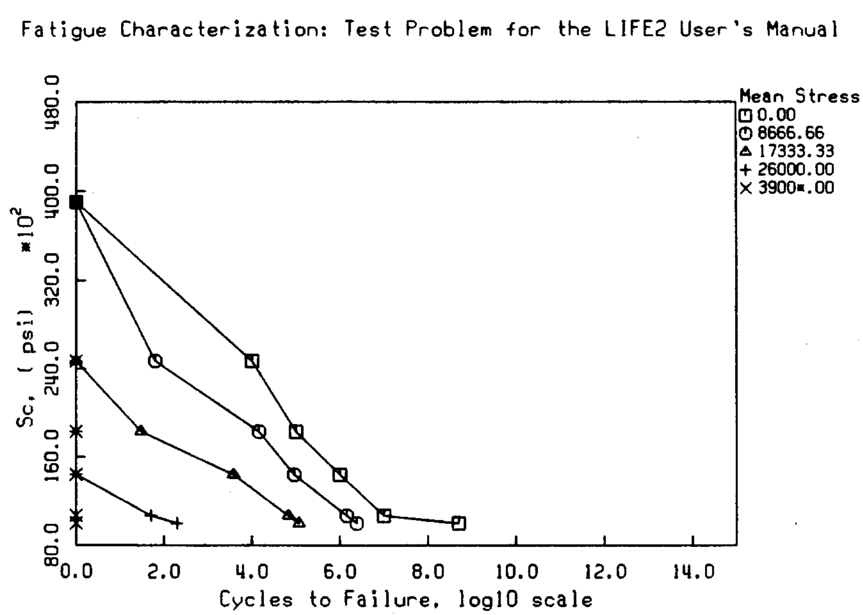

Figure C-3. Semilog Plot from the Fatigue Constitutive Module.

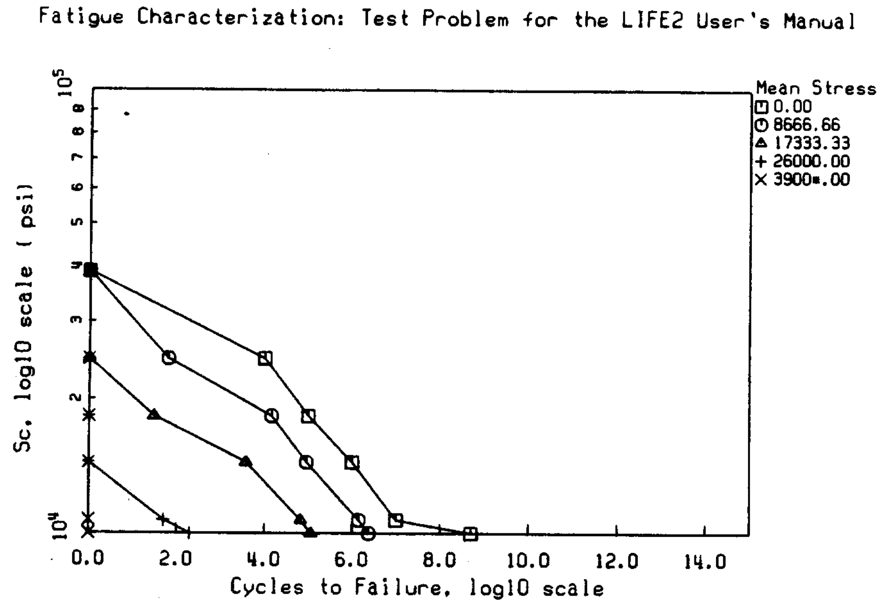

Figure C-4. Log Plot from the Fatigue Constitutive Module.

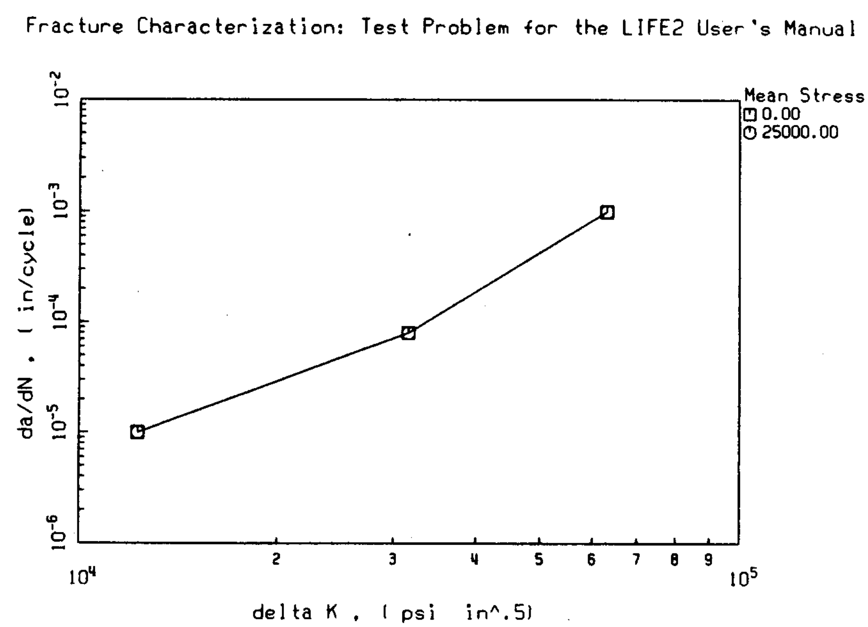

Figure C-5. Constant Mean Stress-Concentration-Factor Plot from the Fracture Constitutive Module.

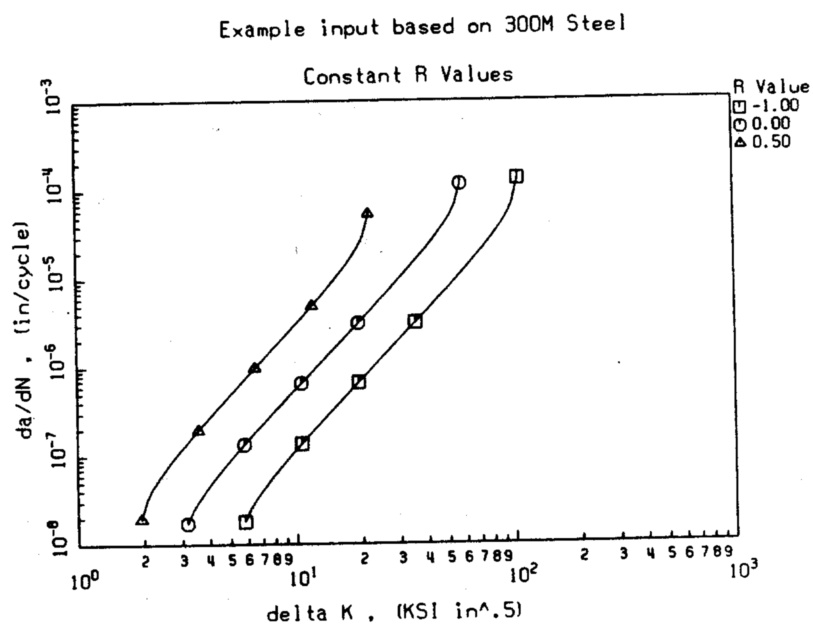

Figure C-6. Constant R Value Plot for the Generalized Forman Model from the Fracture Constitutive Module.

Appendix D

Summary File from the Fatigue Life Analysis

Fatigue Analysis: Example Calculation for the LIFE2 User's Manual

THE WIND SPECTRUM USED IN THIS CALCULATION IS
Test Problem for the LIFE2 User's Manual: Wind Spectrum

The Wind Velocity Units Are: mph
The Turbulence Factor is : .000

NOTES:
Calculations Based on :Max Wind Speed = 99 mph
:Number of Intervals = 99
To Yield 1 mph Wind Velocity Increments
Rayleigh Calculation Preformed by the LIFE2 Code
Mean Wind Speed = 14.00 mph

THE OPERATIONAL STRESS SPECTRUM USED IN THIS CALCULATION IS
Stress States: Test Problem for the LIFE2 User's Manual

The Maximum Wind Speed = 75.00 mph
The Time of Each Segment = .62500 seconds

NOTES:
Operating Stress Characterization Using Veer's Model
Taken from Refs. 1 and 2
Number of Wind Speed Intervals = 75
Upper Limit of Wind Speed = 75 mph
Yields 1 mph Increments in Wind Velocity
Veers Model Calculation for the Operational Stresses
Note: This Formulation yields Alternating Stresses
that are Characterized by their Amplitude.
Mean Stress for the Calculation = 7000.00 psi
Frequency = 1.60 Hz
Wind Speed Units : mph

Wind Speed	RMS Stress	Wind Speed	RMS Stress
.00	.00	20.00	700.00
10.00	320.00	40.00	1560.00

SUMMARY OF MATERIAL CHARACTERIZATION: FATIGUE DATA USED.
Fatigue Characterization: Test Problem for the LIFE2 User's Manual

The Stress Units Are : psi

NOTES:
Fatigue Characterization of 6063 Aluminum
Taken from Ref. 1

Zero Mean Stress Curve Described by the 5 points Listed Below
Miscellaneous Input Parameters:
Modulus of Elasticity = .10000E+08 psi
Poissons Ratio = .30000E+00
Yield Stress = .25000E+05 psi
Ultimate Stress = .39000E+05 psi
Goodman Rule Calculation Using Ultimate Stress
Note: Stress Amplitude Used to Describe the Alternating Stress
Based on the Zero Mean Stress S-n Curve
Data Input into the Calculation

Alt Stress	Cyc to Failure	Alt Stress	Cyc to Failure
10000.00	500000000.00	18300.00	100000.00
10700.00	10000000.00	24700.00	10000.00
14400.00	1000000.00		

Final Point Automatically Added to Zero Mean Stress S-n Input
39000.00 1.00

SUMMARY OF OPERATIONAL PARAMETERS
Operational Parameters: Test Problem for the LIFE2 User's Manual

NOTES:
Calculations are based on Operational Stresses only
Wind Speed Interval = 1 (not used at this time)
The Wind Velocity Units Are: mph
Cutin Velocity = 10.0000 mph
Cutout Velocity = 45.0000 mph
Fatigue Stress Conc. Factor = 2.73
Fracture Stress Conversion = 6.28

THE STRESS CONCENTRATION FACTOR FOR THIS ANALYSIS = 2.730

The SCF was applied to the Cyclic Stress

For an S-n Fatigue Analysis of the data given the Lifetime is
.12050050E+02 years.

Appendix E

Summary File from the Fracture Life Analysis

Fracture Analysis: Example calculation for the LIFE2 User's Manual

THE WIND SPECTRUM USED IN THIS CALCULATION IS
Test Problem for the LIFE2 User's Manual: Wind Spectrum

The Wind Velocity Units Are: mph
The Turbulence Factor is : .000

NOTES:
Calculations Based on :Max Wind Speed = 99 mph
:Number of Intervals = 99
To Yield 1 mph Wind Velocity Increments
Rayleigh Calculation Preformed by the LIFE2 Code
Mean Wind Speed = 14.00 mph

THE OPERATIONAL STRESS SPECTRUM USED IN THIS CALCULATION IS
Stress States: Test Problem for the LIFE2 User's Manual

The Maximum Wind Speed = 75.00 mph
The Time of Each Segment = .62500 seconds

NOTES:
Operating Stress Characterization Using Veer's Model
Taken from Refs. 1 and 2
Number of Wind Speed Intervals = 75
Upper Limit of Wind Speed = 75 mph
Yields 1 mph Increments in Wind Velocity
Veers Model Calculation for the Operational Stresses
Note: This Formulation yields Alternating Stresses
that are Characterized by their Amplitude.
Mean Stress for the Calculation = 7000.00 psi
Frequency = 1.60 Hz
Wind Speed Units : mph

Wind Speed	RMS Stress	Wind Speed	RMS Stress
.00	.00	20.00	700.00
10.00	320.00	40.00	1560.00

SUMMARY OF MATERIAL CHARACTERIZATION: FRACTURE DATA USED.
Fracture Characterization: Test Problem for the LIFE2 User's Manual

The Stress Units Are : psi
The Length Units Are : in

NOTES:
Crack Propagation Rate for Aluminum - Lower Curve

Data Taken from Ref. 2
Tabular Input Used in this Calculation
Crack Growth Rate Independent of Mean Stress with the following input

Alt SIF	Growth Rate	Alt SIF	Growth Rate
.12300E+05	.10000E-04	.31620E+05	.80000E-04
.63100E+05	.10000E-02		

Miscellaneous input parameters:
Modulus of Elasticity = .10000E+08 psi
Poissons Ratio = .30000E+00
Yield Stress = .25000E+05 psi
Ultimate Stress = .39000E+05 psi

SUMMARY OF OPERATIONAL PARAMETERS
Operational Parameters: Test Problem for the LIFE2 User's Manual

NOTES:
Calculations are based on Operational Stresses only
Wind Speed Interval = 1 (not used at this time)
The Wind Velocity Units Are: mph
Cutin Velocity = 10.0000 mph
Cutout Velocity = 45.0000 mph
Fatigue Stress Conc. Factor = 2.73
Fracture Stress Conversion = 6.28

THE FACTOR USED TO CONVERT STRESS TO THE STRESS INTENSITY FACTOR = 6.280

THE ALTERNATING STRESS ADJUSTED FACTOR USED FOR THIS ANALYSIS = 2.000

The FRACTURE ANALYSIS used the following calculation parameters:

Initial crack size of .0100
Final crack size of 1.0000
Number of decade intervals of 2.
The correction for finite thickness was NOT USED
The yield stress correction was Not Used

TIME HISTORY

Crack Length	Time
.10000000E-01	.00000000E+00
.31622780E-01	.45986250E-02
.10000000E+00	.40929770E-02
.31622780E+00	.36425530E-02
.10000000E+01	.31854450E-02

For a Frature Analysis of the data given the Lifetime is
.15519600E-01 years.

Appendix F

Configuration Variables for the Plot Package

The following is a list of hardware interface types and output devices that are currently supported by the PLOT88 software. Not all of these devices are given as choices in the code. To use a device that is not listed in the code type in the input value corresponding to the desired option when the code prompts for it.

Hardware Interface Type		Input Value
HGC: Hercules Graphics Card		93
EGA: IBM Enhanced Graphics Card		97
CGA: IBM Color Graphics Card		99
PRN:		0
LPT1:		1
LPT2:		2
LPT3:		3
COM1:	baud rate 300 parity none data bits 8 stop bits 1	300
COM1:	baud rate 300 parity odd data bits 7 stop bits 1	301
COM1:	baud rate 300 parity even data bits 7 stop bits 1	302
COM1:	baud rate 1200 parity odd data bits 7 stop bits 1	1201
COM1:	baud rate 1200 parity even data bits 7 stop bits 1	1202
COM1:	baud rate 2400 parity none data bits 8	

	stop bits 1	2400
COM1:	baud rate 2400 parity odd data bits 7 stop bits 1	2401
COM1:	baud rate 2400 parity even data bits 7 stop bits 1	2402
COM1:	baud rate 4800 parity none data bits 8 stop bits 1	4800
COM1:	baud rate 4800 parity odd data bits 7 stop bits 1	4801
COM1:	baud rate 4800 parity even data bits 7 stop bits 1	4802
COM1:	baud rate 9600 parity none data bits 8 stop bits 1	9600
COM1:	baud rate 9600 parity odd data bits 7 stop bits 1	9601
COM1:	baud rate 9600 parity even data bits 7 stop bits 1	9602
COM2:	Add 50 to the value for COM1: For example, output to a device attached to COM2 with data transmitted at 9600 baud, 8 data bits, no parity would use an hardware interface number of 9650.	

Output Device	Input Value
Epson FX-80 Printer, single density	0
Epson FX-80 Printer, double density	1

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