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User's Guide for LIFE2's Rainflow Counting Algorithm

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USER'S GUIDE FOR LIFE2'S RAINFLOW COUNTING ALGORITHM*

by

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ABSTRACT

The LIFE2 computer code is a fatigue/fracture code for the analysis of wind turbine components. The numerical formulation of the code uses a series of cycle count matrices to describe the cyclic stress states imposed upon the component. In this formulation, each stress cycle is counted, or "binsed,"according to the magnitude of its mean stress and cyclic stress components and by the operating condition of the turbine. This paper describes a set of numerical algorithms that have been incorporated into the LIFE2 code. These algorithms determine the cycle count matrices for a turbine component using stress-time histories of the imposed stress states. A user's manual is included that explains the operation of these algorithms. An example session illustrates the use of these algorithms.

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INTRODUCTION

The LIFE2 computer code is a fatigue/fracture analysis code specifically designed for the analysis of wind turbine components (1,2). It is a PC-compatible Fortran code that is written in a top-down modular format with a "user friendly" interactive interface. In this numerical formulation, an "S-n" fatigue analysis is used to describe the initiation, growth and coalescence of micro-cracks into macro-cracks. A linear, "da/dn" fracture analysis is used to describe the growth of a macro-crack.

In the LIFE2 formulation, each stress cycle imposed on the turbine component is characterized by the magnitude of its mean stress and cyclic (range or alternating) stress components and by the operating condition of the turbine. This paper describes a set of numerical algorithms that permits the code to analyze stress-time histories of component stress states. The main algorithm is a rainflow counting algorithm. It defines a stress cycle to be a closed stress/strain hysteresis loop. It determines the mean stress level and the **range** for each stress cycle in a given stress-time history.

These algorithms have been incorporated into the LIFE2 code. A user's manual is included in this paper to illustrate their operation. An example session is included for reference. A detailed description of how the algorithms have been implemented with Fortran 77 is in Schluter (3).

BACKGROUND INFORMATION

The prime algorithm used here is a rainflow counting algorithm (4). It defines a stress cycle to be a closed stress/ strain hysteresis loop. It determines the mean stress level and the range for each stress cycle in the histogram. To illustrate the use of this algorithm, consider the typical stress-time history for a turbine component shown in Fig. 1. As this history is being used for illustrative purposes only, the stresses have been normalized.

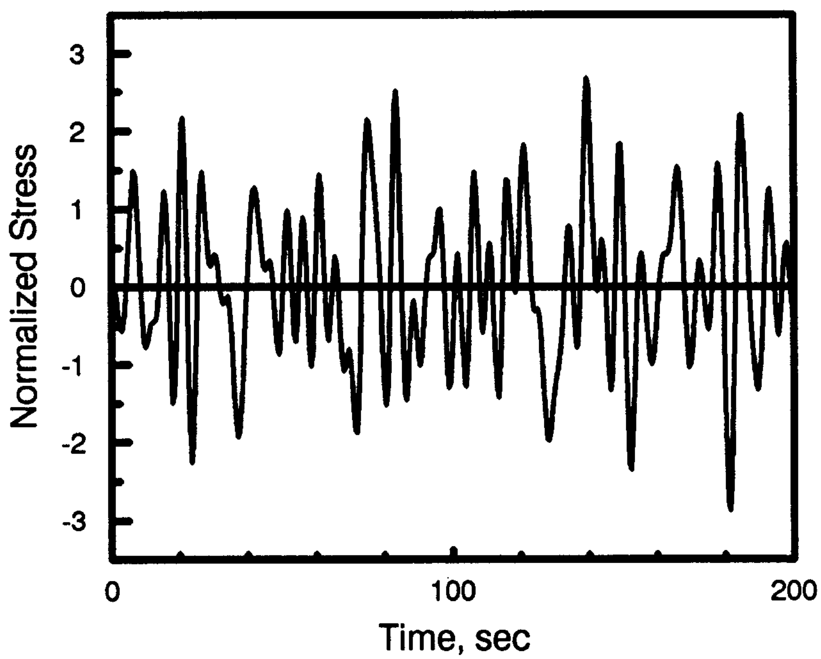

Figure 1 Typical stress-time history data

Pre-Count Algorithms

Several auxiliary algorithms are used to support the rain-flow counting. The initial set of algorithms prepares the full time series data for counting by selecting peaks and valleys and discarding "small" stress cycles. After counting, other algorithms record and store the cycle count data in an appropriate format for the LIFE2 analysis.

Peak-Valley Selection. The first algorithm identifies peaks and valleys in the data record by scanning for changes in the sign of the slope.

Typically, the data contained in this class of stress records are taken at uniform time intervals. This constant-time-interval sampling technique may or may not record actual extrema in the data, because the extrema may be "squared off"; e.g., the peak at approximately 185 seconds in Fig. 2 (an expanded view of the data shown in Fig. 1). To obtain a better estimate of the actual extrema at a change in the slope, a parabola is fit to the three data points nearest that change. The extrema determined using this curve-fitting technique are shown as squares in Fig. 2.

As shown in Fig. 2, this technique for choosing the extrema may or may not significantly change the maxima recorded in the data. In particular, the extrema recorded in the data record at approximately 140, 150, 165 and 180 seconds in Fig. 2 are very close to the true peaks, because the sampling technique has not squared off their peaks. However, when the extrema have been squared off, as with the peak at approximately 185 seconds, the extrema are significantly increased by this curve fitting technique producing a peak much closer to the true value.

All of the extrema chosen for the sample record (Fig. 1) are shown in Fig. 3.

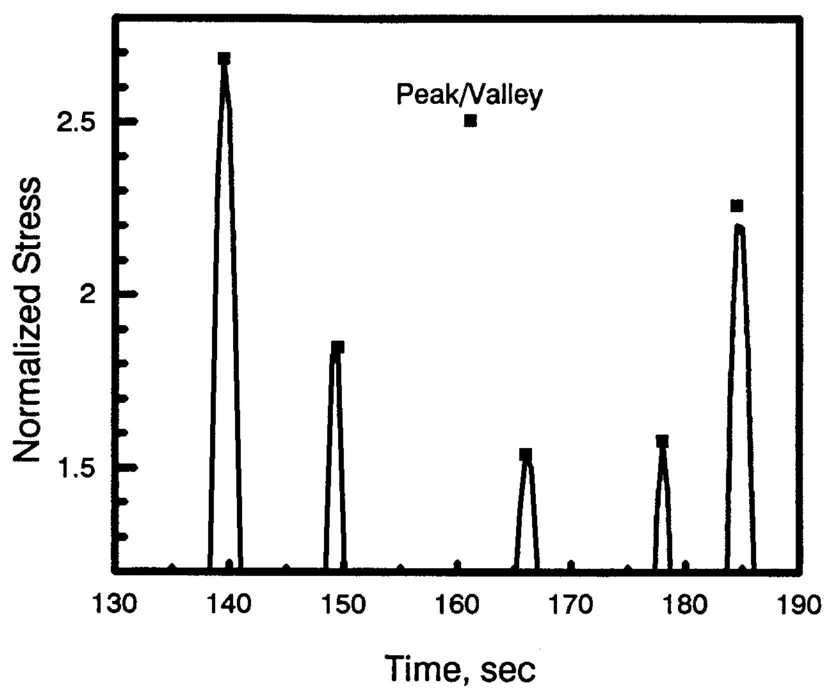

Figure 2 **Estimation of peaks and valleys**

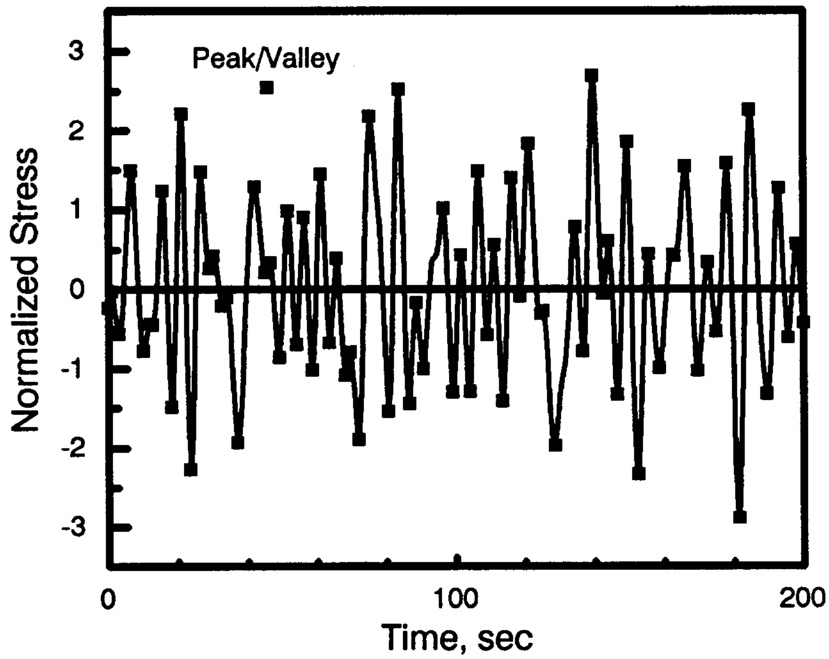

Figure 3 **Selected peaks and valleys (no filter)**

Filter. A "race-track" filtering algorithm has been incorporated into the pre-processing algorithms to eliminate stress cycles smaller than a threshold value set by the operator (5). When the absolute value of the difference between the maximum and minimum values of a stress cycle is greater than the threshold, the algorithm retains that cycle. When the difference is less than the threshold, the cycle is discarded. Figure 4 illustrates the peak and valleys retained for the sample data record when the threshold is set to a value of 2.

The pre-count algorithms reduce the data record to a sequential list of peaks and valleys. This list is stored in a temporary file for processing by the count algorithm.

Rainflow Counting Algorithm

The rainflow counting algorithm used here (4) counts the number of closed stress/strain hysteresis loops in the data. The mean and the peak-to-peak (i.e. the range) stress levels for each stress cycle are stored in a temporary file for post processing. To speed operation, the algorithm uses "one-pass" through the data to count the stress cycles; i.e., the peak-valley data are read only once during processing by the count algorithm.

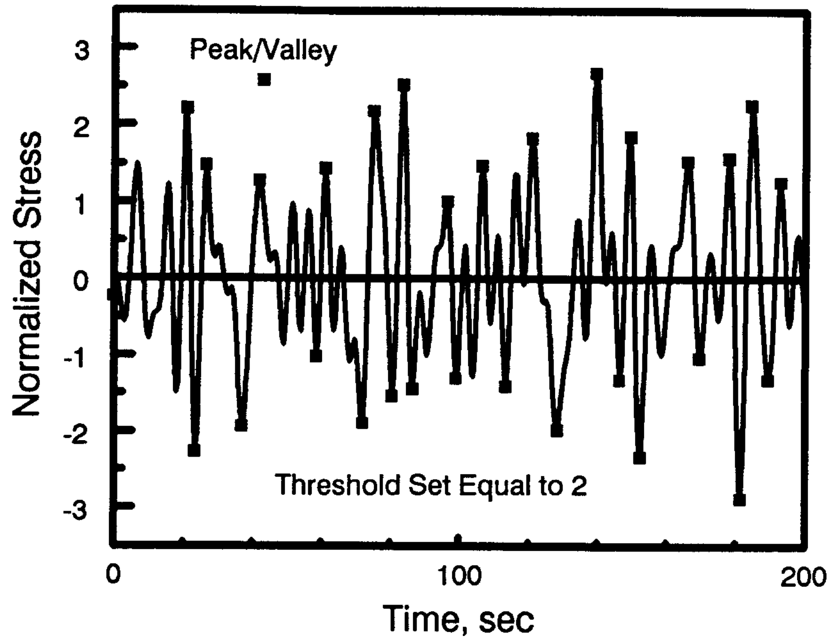

Figure 4 **Selected peaks and valleys with a threshold of 2**

Post-Count Algorithm

The final algorithm maps each stress cycle into a cycle count matrix that can be processed by the LIFE2 code. The algorithm sorts the stress cycle data into bins that are functions of mean stress level and the range.

The cycle counts from a data record may be used to create a new cycle count matrix, or they may be added to an existing cycle count matrix, at the discretion of the operator.

REFERENCE MANUAL

This section describes the format of the time series data file and how the code creates and maintains the data files containing the counted cycles. Also discussed are the pre-count algorithms for finding the peaks and valleys in the time series data file and for filtering out small stress cycles (the race-track filter algorithm).

The pre-count, rainflow counting, and post-count algorithms have been incorporated into the LIFE2 code in the stress states module. The operator may input operational stresses, buffeting stresses, or start/ stop stresses. The algorithms have been added as Option 4 under these respective menus (see Schluter and Sutherland (1) for a complete description of the menuing system used by the LIFE2 code).

This section discusses the time series file, the basic structure of the stress states data files, the manipulation of the data files, and the display of information contained in the data files.

The Time Series Input Data File

The file that contains the stress data to be rainflow counted is referred to as the *time series data file* or simply *time series*. LIFE2 will prompt the operator for the name of the time series file and the length of the time series in seconds.

The time series data file needs to be created as a sequential file that has one stress entry per line. The stress entry may be any desired format (e.g., real, exponential, etc.). The following is an example of a time series data file with nine entries:

```
-5.2
4.12
1.34
3.02
2.8
0.55
-1.03
-1.75
-0.65
```

The length of the data file is limited only by the amount of free storage space on the computer's hard disc.

Data Files for the Stress States Module

LIFE2 creates and uses *data files* to transfer data between computational modules and to archive data. Their operation is transparent to the operator. However, it is necessary to understand the basic structure of the stress states data files in order to understand how the LIFE2 code manipulates them.

The data files for the stress states module consist of a series of two-dimensional cycle count matrices (mean vs. cyclic stress where the cyclic stress may either be the alternating stress value or the range stress value). When working with operational or buffeting stresses each matrix corresponds to a particular wind speed interval (i.e., 5 to 10 mph). When working with start/stop stresses, each matrix corresponds to a particular start or stop condition. An example cycle count matrix is shown in Fig. 5. When adding data to an existing data file, the matrices that currently exist are listed. The operator may add the data to an existing matrix or specify that a new matrix be created.

Mean Stress Array

	3	6	9	12	18	21	24	27	30	33
5	10	40	66	138	150	198	84	28	10	2
10	4	2	16	28	46	38	16	2		
15			6	16	40	22	8			
20				36	32	26	2			
25			2	14	20	10	2			
30				2	4	2				
35				2		2	2			
40					2					

Figure 5 Example matrix

Each time series that is inserted into a data file is considered to be one *record*. The number of records contained in a matrix is incremented by one for each time series added. Each matrix may have up to 50 stress intervals for both the mean and the cyclic stresses.

When creating a new matrix, the program will ask the operator for the desired resolutions of the stress intervals in the stress arrays. The arrays are calculated so that the maximum value found in the time series data will always be included within the matrix. Intervals are added to the stress arrays until the maximum is included or the number of intervals is 50. The first stress interval will contain all values less than a specific stress level. All other intervals have lower and upper bounds. For example, in Fig. 5 the mean stress array has 10 intervals with a resolution of 3. The cyclic stress array has 8 intervals with a resolution of 5. For the mean stress array the first interval is associated with all values less than or equal to 3. The second interval is associated with the range of values greater than 3 and less than or equal to 6.

It should be noted that the smaller the resolution the smaller the range of values that can be covered by the matrix. For example, with a 1 MPa resolution the matrix will cover a total of 50 MPa. With a .5 MPa resolution the matrix will cover a total of 25 MPa.

The rainflow counting algorithms will record the mean stress value and the range for each cycle. The program will then insert this information into the matrix. In Fig. 5 there are 10 cycles with a mean value less than or equal to 3 and a range value less than or equal to 5; there are 40 cycles with a mean value greater than 3 but less than or equal to 6 and a range value less than 5, etc.

Once a matrix has been set up, time series data may be added to it whenever desired. However, the resolution cannot be changed. Since large stress values cause significantly more damage than small stress values, it is important that the matrix always contain the maximum values for both the mean and cyclic stresses. If the current maximum for one of the stress arrays is less than the maximum value found in a time series, the matrix will be added to or shifted so that the new maximum is included. If the stress array does not have 50 intervals, then intervals will be added until the maximum is contained in the matrix. An example of adding a cyclic stress interval to the matrix in Fig. 5 is shown in Fig. 6. If a new cycle is found with a mean stress of 11.5 and cyclic stress of 41.8 then the matrix must be expanded. In this case a new cyclic interval is added as shown in Fig. 6.

If the stress array already contains 50 intervals, then the matrix is shifted. An example of this is shown in Fig. 7. The matrix in Fig. 7 has a cyclic stress array that contains 50 intervals. If a cycle is found that has a mean value of 19.25 and cyclic value of 252.1, then the matrix must be shifted. This is done by summing the first two rows and then shifting the

Mean Stress Array

	3	6	9	12	18	21	24	27	30	33
5	10	40	66	138	150	198	84	28	10	2
10	4	2	16	28	46	38	16	2		
15			6	16	40	22	8			
20				36	32	26	2			
25			2	14	20	10	2			
30				2	4	2				
35				2		2	2			
40					2					
45				1						

Figure 6 Adding a mean stress interval

Mean Stress Array

	3	6	9	12	18	21	24	27	30	33
5	10	40	66	138	150	198	84	28	10	2
10	4	2	16	28	46	38	16	2		
⋮					⋮					
245			2		4		1			
250				2						

Figure 7 Example matrix before shifting to contain the maximum

Mean Stress Array

	3	6	9	12	18	21	24	27	30	33
10	14	42	82	166	196	236	100	30	10	2
15			6	16	40	22	8			
. . .					. . .					
245			2		4		1			
250				2						
255						1				

Figure 8 Example matrix after shifting to contain the maximum

intervals up adding a new interval on the bottom. The resulting matrix is illustrated in Fig. 8.

Two words of caution about this shifting procedure. First, notice that before the shift for cycles with a mean stress less than 3, there are 10 cycles that have a cyclic stress less than or equal to 5, and 4 cycles with a cyclic stress between 5 and 10 (see Fig. 7). After the shift, all of these cycles are all in the interval less than 10 (see Fig 8). This changed stress state increases the damage caused by the 10 cycles that were in the first interval before the shift. If shifts continue to occur, the first interval will continue to increase the damage produced by the small stress cycles. In the shifting procedure, this can not be avoided. The operator is encouraged not to use all 50 intervals when initializing the matrix to allow room for the matrix to grow. When existing intervals for a data file are displayed, the operator may choose to list information about the interval. Included is the number of cycles in the first interval for both the mean and cyclic stresses and the number of cycles in the rest of the matrix. This information can be used to tell if there is a significant portion of the cycles in the first interval as compared to the rest of the matrix.

The second caution is that the matrix will be added to or shifted so that it contains the maximum. This is not the case for the minimum. For example, if the current minimum is 35 and the time series contains a large amount of counts at 5, all of them will be seen as having a value of 35 or less, thus increasing the amount of damage caused by the smaller stress cycles.

In both of the above cases it should be noted that small stress cycles will probably not affect the lifetime calculation since they cause much less damage than large stress cycles. If an effect is seen, it will be that the lifetime calculation will always be a conservative estimate.

Finding the Peaks and Valleys in the Time Series Data

Typically, data contained in the time series are taken at uniform time intervals, with several data points between the peaks and valleys. The time series that the rainflow algorithm uses must only contain the peaks and valleys with no data points in between. Therefore, an algorithm is used to delete these intermediate points from the time series. Another result from sampling at uniform time intervals is that the time series will rarely record the actual extrema in the data (see Peak-Valley Selection, page 4). To obtain the best estimate of a peak or valley, the algorithm fits a parabola through the three data points nearest the peak or valley.

The program will ask the operator whether to find the peaks and valleys in the time series with the following prompt:

Do you want to find the peaks and valleys in the data? (Y or N)

If the time series already contains only peaks and valleys, the operator should answer 'N' to this prompt. The parabola fit works best when there are three data points near a peak or valley. If the time series already contains only peaks and valleys, the parabola fit may lead to substantial errors.

Using the Race- Track Filter

A filter algorithm has been incorporated into the code to eliminate small stress cycles. The program will prompt the operator for a threshold value. When the absolute value of a cycle is greater than this value, the cycle is kept. If the absolute value of a cycle is less than or equal to this value, the cycle is discarded. If the operator does not wish to use this filter, a threshold value of 0 may be used, and all cycles will be kept.

Before the code prompts for the threshold value, it will display the statistics for the time series as follows:

Time Series Statistics

Minimum = -4.000
Maximum = 4.000
Mean Value = 0.680
Standard Deviation = 2.340

One recommendation for a threshold value is the standard deviation of the time series. This value will filter out much of the noise while keeping the cycles that do most of the damage. For a complete discussion of why this is the case please see Veers (6).

Displaying Matrix Information

When adding a time series to an existing data file, LIFE2 will list the matrices that currently exist. The following is an example of what may be displayed:

Total number of matrices: 7

1) Operational Stresses; # of records = 3; Wind Speed Range 8 to 10
2) Operational Stresses; # of records = 5; Wind Speed Range 10 to 12
3) Operational Stresses; # of records = 2; Wind Speed Range 12 to 14
4) Operational Stresses; # of records = 4; Wind Speed Range 14 to 16
5) Operational Stresses; # of records = 4; Wind Speed Range 16 to 18
6) Operational Stresses; # of records = 2; Wind Speed Range 18 to 20
7) Operational Stresses; # of records = 1; Wind Speed Range 20 to 22

Options:

F - Forward	**B - Backward**
N - Create New Matrix	**A - Add to Existing Matrix**
I - Matrix Information	**E - Exit**

Press Enter after choosing the desired option.>

If the above matrices are used for a lifetime calculation the code will use the first matrix for wind speeds 0 to 10. The lower wind speed is given as a reference.

LIFE2 will display the total number of matrices contained in the file followed by a short description of the matrices. Only 10 matrices can be displayed at any one time. If more matrices exist, the operator may page forward and backward through the list with the **F** and **B** options respectively.

If a time series is to be inserted into a matrix that exists, then the **A** option is chosen. The code will prompt for the number corresponding to the desired matrix.

If a new matrix must be created for the time series data, then option **N** is chosen. The code will then prompt for the wind range corresponding to the matrix and a new matrix is created.

The operator may choose to display more information on a particular matrix. To do this option **I** is chosen. LIFE2 will then display a screen similar to the following:

Number of Records: 5

Units of Wind Speed are mph
Lower Wind Speed = 10.00 Upper Wind Speed = 12.00

Units of Stress are KPa

Number of Mean Stress Intervals = 10
Minimum Mean Stress = 0.0 Maximum Mean Stress = 50.00

Number of Cyclic Stress Intervals = 20
Minimum Cyclic Stress = 10.0 Maximum Cyclic Stress = 110.00

Number of Counts in the first mean interval = 0
Number of Counts in the first cyclic interval = 0
Number of Counts in rest of matrix = 103

Press ENTER to continue

When LIFE2 continues, it will redisplay the matrices that currently exist.

<u>Documenting Units</u>

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 data files.

EXAMPLE SESSION

The following illustrates an example session using the rainflow counting algorithms with operational stress data. In the session, a new data file is created and time series data are rainflow counted and placed into a matrix. Next another time series data set that corresponds to a different wind speed is counted and placed in a different matrix. Then time series data are added to the first matrix. Finally the data file is saved in the operational stresses library. Sessions for entering start/ stop stresses and buffeting stresses are similar.

In the example, LIFE2 code prompts are written in **bold letters**. The operator's responses to the prompts are written in *italics*.

The time series files used in this example are shown in the appendix. These are very simple files and are meant for illustrative purposes. Also shown in the appendix is the data file that is created after each time series is inserted.

After choosing the rainflow counting option from the operational stresses menu, the following prompts appear:

>>> Rainflow Counting <<<

This menu allows the operator to use the rainflow counting algorithms on a time series data file.

Your options at this level are

1) Create a New Data File
2) Add Data to an Existing Data File

9) Return to the Operational Stresses Menu

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

Enter the title of the data file no longer than 72 characters
Example Data File for the Rainflow Manual

Enter the units of stress.>*MPa*

Enter the units of wind speed.>*m/s*

Enter the lower range of wind speed for this data set.>*10*

Enter the upper range of wind speed for this data set.>*12*

Enter the name of the time series data file.>*example1.dat*

Enter the length of the time series in seconds.>*30*

Do you wish to find the peaks and valleys in the time series?(Y or N)>*Y*

.....Calculating Statistics for the time series

Time Series Statistics

Minimum = -4.000
Maximum = 4.000
Mean Value = 0.680
Standard Deviation = 2.340

Input the Racetrack Filter threshold value.(0 for no filter)>*0*

The extreme values for the mean stress are

Minimum = 0.000

Maximum = 3.000

Enter the resolution for the mean stress intervals.>*.5*

The extreme values for the cyclic stress are

Minimum = 1.000

Maximum = 8.000

Enter the resolution for the cyclic stress intervals.>*1*

Do you wish to add another time series to this data file.(Y or N)>*Y*

Total number of matrices: 1

1) Operational Stresses; # Records = 1; Wind Speed Range 10 to 12

Options:

F - Page Forward	**B - Page Backward**
N - Create New Matrix	**A - Add to Existing Matrix**
I - Matrix Information	**E - Exit**

Enter the desired option.>*n*

Input the lower range of wind speed for this data set.>*12*

Input the upper range of wind speed for this data set.>*14*

Enter the name of the time series data file.>*example2.dat*

Enter the length of the time series in seconds.>*20*

Do you wish to find the peaks and valleys in the time series?(Y or N)>*Y*

.....Calculating Statistics for the time series

Time Series Statistics

Minimum = -5.000
Maximum = 5.000
Mean Value = 0.500
Standard Deviation = 2.690

Input the Racetrack Filter threshold value.(0 for no filter)>*0*

The extreme values for the mean stress are

Minimum = -1.49082600

Maximum = 2.85526500

Enter the resolution for the mean stress intervals.>*.75*

The extreme values for the cyclic stress are

Minimum = 1.03276900

Maximum = 10.07811000

Enter the resolution for the cyclic stress intervals.>*2*

Do you wish to add another time series to this data file.(Y or N)>*Y*

Total number of matrices: 2

1) Operational Stresses; # of records = 1; Wind Speed Range 10 to 12
2) Operational Stresses; # of records = 1; Wind Speed Range 12 to 14

Options:

F - Page Forward	**B - Page Backward**
N - Create New Matrix	**A - Add to Existing Matrix**
I - Matrix Information	**E - Exit**

Enter the desired option.>*a*

Input the matrix number to add data to.>*2*

Enter the name of the time series data file.>*example2.dat*

Enter the length of the time series in seconds.>*16*

Do you wish to find the peaks and valleys in the time series?(Y or N)>*Y*

.....Calculating Statistics for the time series

Time Series Statistics

Minimum = -5.000
Maximum = 5.000
Mean Value = 0.500
Standard Deviation = 2.690

Input the Racetrack Filter threshold value.(0 for no filter)>*2.69*

Do you wish to add another time series to this data file.(Y or N)>*n*

Enter the number of miscellaneous notes for this data set.>*1*

Enter note 1, no longer than 72 characters.
This is an example data file for the Rainflow User's Manual

Do you wish to store this in the library?(Y or N)>*y*

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

1) 17M45R **2) 17M36R** **3) 34M28R**
4) 34M36R

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

SUMMARY

A set of algorithms that rainflow count time-series stress data has been incorporated into the LIFE2 fatigue/fracture analysis code. Support algorithms that structure the data in a format compatible with the LIFE2 code have also been implemented. This report describes the rainflow counting algorithms and the support algorithms.

A user's manual is included that describes the format of the time series files and how the code manipulates the data files, and shows an example session with the code. For anyone interested in how the algorithms have been implemented using Fortran 77, a programmer's guide (3) is available. The programmer's guide describes the major design decisions that were made in implementing the algorithms and details of the subroutines used to implement the algorithms.

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4. Downing, S. D., and Socie, D. F., "Simple Rainflow Counting Algorithms," *International Journal of Fatigue*, Vol. 4, N. 1, 1982, pp. 31-40.

5. Veers, P. S., Winterstein, S. R., Nelson, D. V. and Cornell, C. A., "Variable Amplitude Load Models for Fatigue Damage and Crack Growth," *Development of Fatigue Loading Spectra*, ASTM STP 1006, J. M. Potter and R. T. Watanabe, eds., 1989, pp. 172-197.

6. Veers, P. S., Fatigue Crack Growth Due to Random Loading, SAND87-2039, Sandia National Laboratories, Albuquerque, NM, November 1987.

Appendix

Example Session Files

The following appendix shows the time series data files used for the example session and the stress state data file that results.

Time Series Data Files

example1.dat

```
-3
-2
-1
 0
 1
 2
 3
 4
 3
 2
 3
 4
 3
 2
 1
 2
 1
 0
-1
-2
-3
-4
```

example2.dat

```
-5
-3.5
-2
 .5
 1
 2
 1.75
 1.12
 1
 3.5
 5
 2.34
 1.67
 1
 1.12
 3.56
 4.28
 5
 4.07
 1.25
-.75
-1.87
-2
-1.37
-1
-2.25
-2.88
-3.5
```

Format of Stress States Data File

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 Matrices - N
Title of Matrix #1
Upper bound of wind speed for data set #1
Time Matrix 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 following is the Stress States Data File after the first insertion.

```
Example Data File for the Rainflow Manual
MPa
seconds
m/s
n
 1
Operational Stresses; # Records = 1; Wind Speed Range 10 to 12
 .12000000E+02
 .30000000E+02
 7
 8
 .00000000E+00  .50000000E+00  .10000000E+01  .15000000E+01
 .20000000E+01  .25000000E+01  .30000000E+01
 .100000000+01  .20000000E+01  .30000000E+01  .40000000E+01
 .50000000E+01  .60000000E+01  .70000000E+01  .80000000E+01
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .10000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .100000000+01  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .10000000E+01  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
     0
```

The following is the Stress States Data File after the second insertion.

```
Example Data File for the Rainflow Manual
MPa
seconds
m/s
n
 2
Operational Stresses; # Records = 1; Wind Speed Range 10 to 12
 .12000000E+02
 .30000000E+02
7
8
 .00000000E+00  .50000000E+00  .10000000E+01  .15000000E+01
 .20000000E+01  .25000000E+01  .30000000E+01
 .100000000+01  .20000000E+01  .30000000E+01  .40000000E+01
 .50000000E+01  .60000000E+01  .70000000E+01  .80000000E+01
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .10000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .100000000+01  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .10000000E+01  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 Operational Stresses; # Records = 1; Wind Speed Range 12 to 14
 .14000000E+02
 .20000000E+02
7
7
-.15000000E+01 -.75000000E+00  .00000000E+00  .75000000E+00
 .15000000E+01  .22500000E+01  .30000000E+01
 .000000000+00  .20000000E+01  .40000000E+01  .60000000E+01
 .80000000E+01  .10000000E+02  .12000000E+02
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .10000000E+01  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .10000000E+01
 .000000000+00  .10000000E+01  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .10000000E+01
 .00000000E+00  .00000000E+00  .00000000E+00
    0
```

The following is the Stress States Data File after the third insertion.

```
Example Data File for the Rainflow Manual
MPa
seconds
m/s
n
 2
Operational Stresses; # Records = 1; Wind Speed Range 10 to 12
 .12000000E+02
 .30000000E+02
7
8
 .00000000E+00  .50000000E+00  .10000000E+01  .15000000E+01
 .20000000E+01  .25000000E+01  .30000000E+01
 .100000000+01  .20000000E+01  .30000000E+01  .40000000E+01
 .50000000E+01  .60000000E+01  .70000000E+01  .80000000E+01
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .10000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .100000000+01  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .10000000E+01  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00  .00000000E+00
 Operational Stresses; # Records = 1; Wind Speed Range 12 to 14
 .14000000E+02
 .36000000E+02
7
7
-.15000000E+01 -.75000000E+00  .00000000E+00  .75000000E+00
 .15000000E+01  .22500000E+01  .30000000E+01
 .000000000+00  .20000000E+01  .40000000E+01  .60000000E+01
 .80000000E+01  .10000000E+02  .12000000E+02
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .10000000E+01  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .20000000E+01
 .000000000+00  .10000000E+01  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .00000000E+00
 .00000000E+00  .00000000E+00  .00000000E+00
 .000000000+00  .00000000E+00  .00000000E+00  .20000000E+01
 .00000000E+00  .00000000E+00  .00000000E+00
     1
This is an example data file for the Rainflow User's Manual
```

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