RAINFLOW CYCLE COUNTING IN FATIGUE ANALYSIS
Revision B

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Introduction

The rainflow method is a method for counting fatigue cycles from a time history. The fatigue cycles are stress-reversals. The rainflow method allows the application of Miner's rule in order to assess the fatigue life of a structure subject to complex loading.

The resulting tabular data is sometimes referred to as a spectra.

Algorithm

1. Reduce the time history to a sequence of (tensile) peaks and (compressive) troughs.
2. Imagine that the time history is a pagoda.
3. Turn the sheet clockwise 90°, so the starting time is at the top.
4. Each tensile peak is imagined as a source of water that "drips" down the pagoda.
5. Count the number of half-cycles by looking for terminations in the flow occurring when either:
    a. It reaches the end of the time history
    b. It merges with a flow that started at an earlier tensile peak; or
    c. It encounters a trough of greater magnitude.
6. Repeat step 5 for compressive troughs.
7. Assign a magnitude to each half-cycle equal to the stress difference between its start and termination.
8. Pair up half-cycles of identical magnitude (but opposite sense) to count the number of complete cycles. Typically, there are some residual half-cycles.

The ASTM standard in Reference 1 gives algebraic formulas using Boolean operators for carrying out this process.

An example is given in the next section using the ASTM implementation.

Rainflow Counting Example

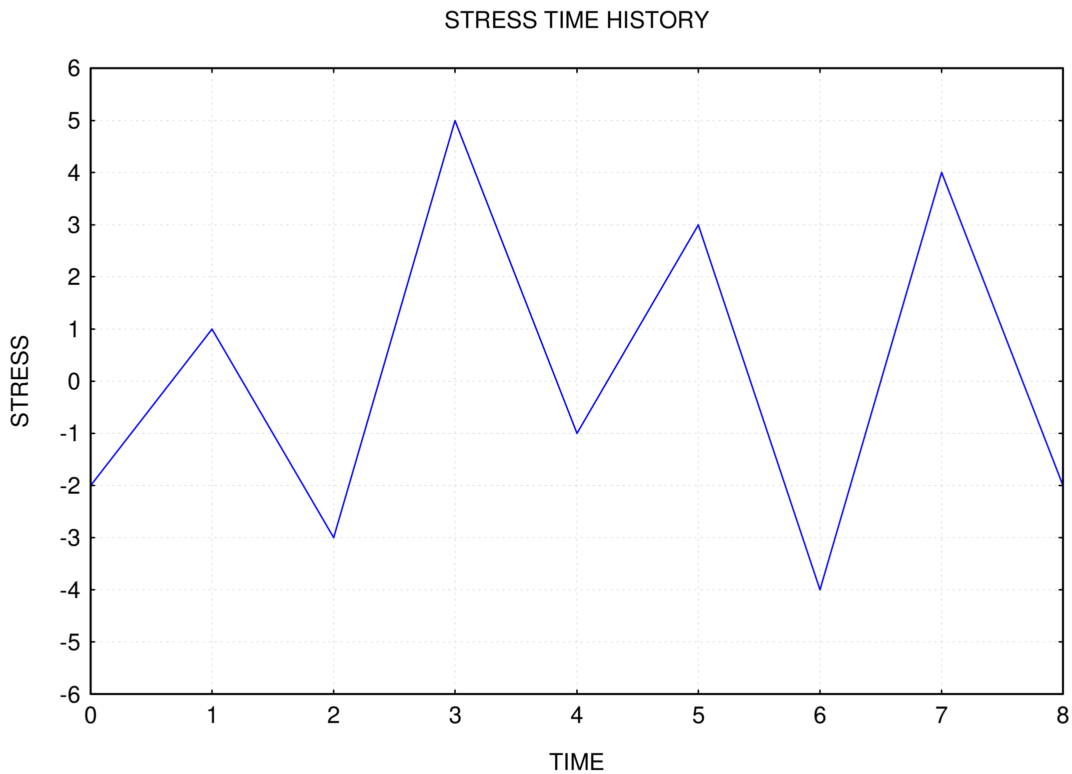

Figure 1.

A stress time history is given in Figure 1.

The same time history is shown rotated 90 degrees in Figure 2 along with the rainflow lines.

The rainflow data is summarized for individual paths in Table 1 and for range bins in Table 2.

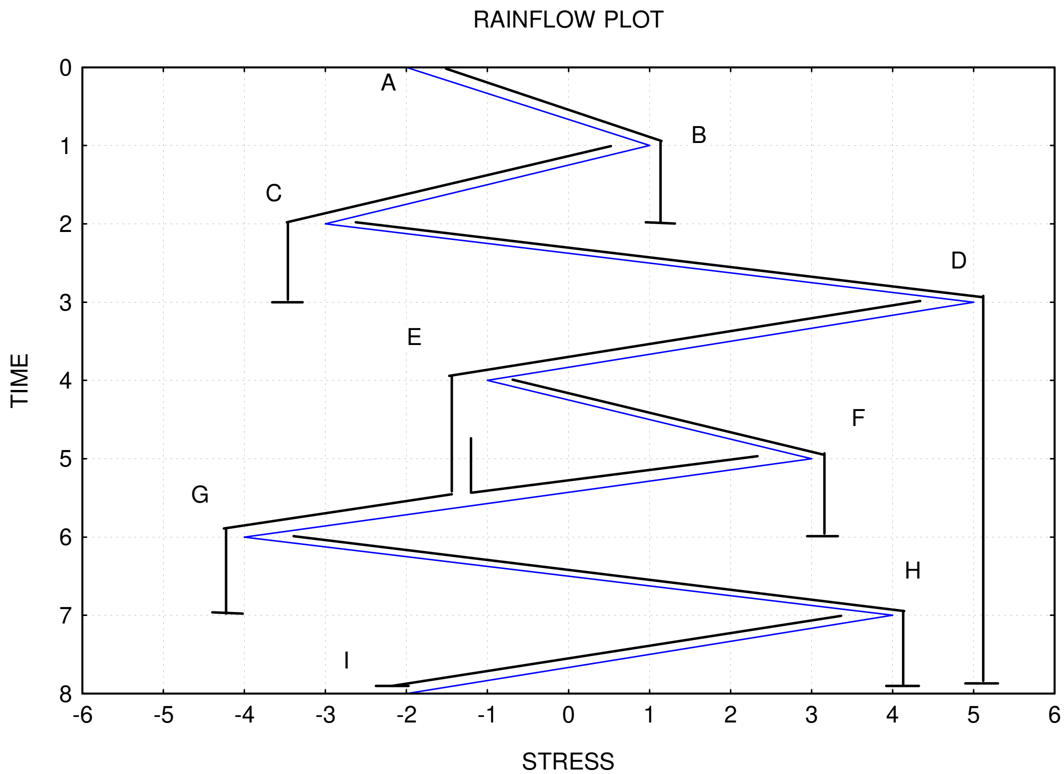

Figure 2.

Table 1. Rainflow Cycles by Path					
Path	Cycles	Stress Range	Peak	Valley	Mean
A-B	0.5	3	1	-2	-0.5
B-C	0.5	4	1	-3	-1
C-D	0.5	8	5	-3	1
D-G	0.5	9	5	-4	0.5
E-F	1.0	4	3	-1	1
G-H	0.5	8	4	-4	0
H-I	0.5	6	4	-2	1

Note that E-F is counted as one cycle because is it considered to contain some of F-G.

Table 2. Rainflow by Bins with Total Cycles		
Stress Range	Total Cycles	Path
10	0	-
9	0.5	D-G
8	1.0	C-D, G-H
7	0	-
6	0.5	H-I
5	0	-
4	1.5	B-C, E-F
3	0.5	A-B
2	0	-
1	0	-

Table 3. Rainflow Paths for Stress Range = 4 Bin						
Path	Cycles	Range	Amplitude	Peak	Valley	Mean
B-C	0.5	4	2	1	-3	-1
E-F	1.0	4	2	3	-1	1

The two paths for Range=4 are shown in Table 3. The amplitude is one-half of the range for each path.

The bin average amplitude is clearly equal to 2. The proper way to calculate the average amplitude is to take the average weighted by the number of cycles.

$$\text{bin ave amp} = \frac{(0.5)(2)+(1.0)(2)}{1.5} = 2 \tag{1}$$

The path mean is the average of the Peak and Valley. The bin mean amplitude is also a weighted average.

$$\text{bin mean amp} = \frac{(0.5)(-1)+(1.0)(1)}{1.5} = 0.333 \tag{2}$$

Table 4. Rainflow Binned Data, NASA Format									
Lower Range	Upper Range	Cycles	Ave Amp	Max Amp	Min Mean	Ave Mean	Max Mean	Min Valley	Max Peak
8.1	9	0.5	4.5	4.5	0.5	0.5	0.5	-4	5
7.2	8.1	1	4	4	0	0.5	1	-4	5
6.3	7.2	0	0	0	0	0	0	0	0
5.4	6.3	0.5	3	3	1	1	1	-2	4
4.5	5.4	0	0	0	0	0	0	0	0
3.6	4.5	1.5	2	2	-1	0.333	1	-3	3
2.7	3.6	0.5	1.5	1.5	-0.5	-0.5	-0.5	-2	1
1.8	2.7	0	0	0	0	0	0	0	0
1.35	1.8	0	0	0	0	0	0	0	0
0.9	1.35	0	0	0	0	0	0	0	0
0.45	0.9	0	0	0	0	0	0	0	0
0.225	0.45	0	0	0	0	0	0	0	0
0	0.225	0	0	0	0	0	0	0	0

The rainflow data is shown in a NASA binned format in Table 4. The bins are grouped in 10% increments for the first eight bins, starting from the highest range. The increment is decreased for the lower bins.

The two paths with Range=4 are given in the sixth bin with limits from 3.6 to 4.5.

Note that binning the data may be unnecessary unless contractually required. A Palmgren-Miner cumulative damage summation can be performed directly on the raw path data shown in Table 1.

Additional Example

Another rainflow example is shown in Appendix A.

References

1. ASTM E 1049-85 (2005) Rainflow Counting Method, 1987.

2. P. Wirsching, T, Paez, K. Ortiz, Random Vibrations Theory and Practice, Dover, New York, 2006.

APPENDIX A

Single Wavelet Example

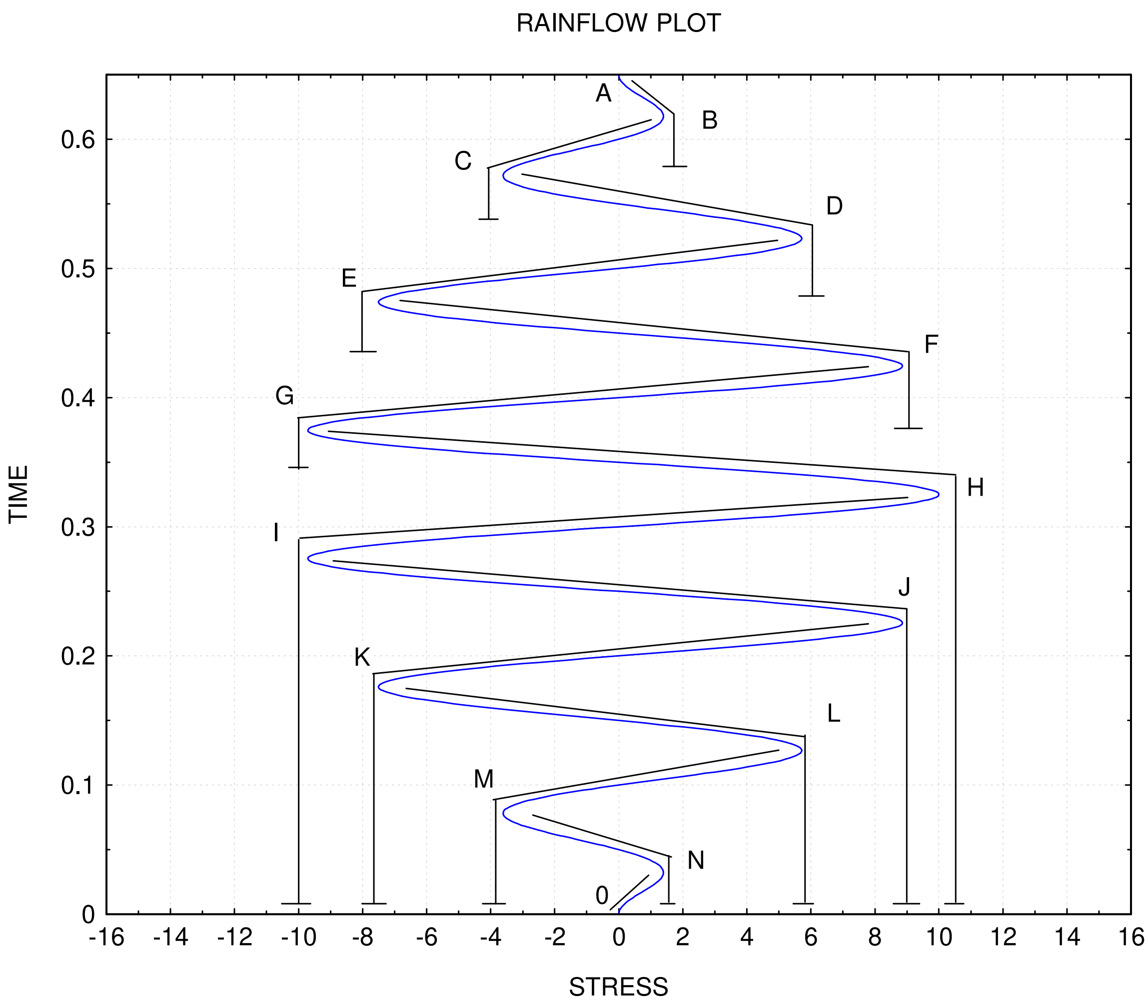

Figure A-1.

Each consecutive segment is a half-cycle in this case.