



MCrunch Theory Manual for Version 1.00

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Revised Mon DD, YYYY
for MCrunch v1.00.00

Technical Report
NREL/TP-500-xxxxx
Mon YYYY

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MCrunch User's Guide for Version 1.00

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Introduction

This is just the beginning of a theory manual for MCrunch.

Fatigue Life

We have formulated the fatigue-life calculations to conform to the IEC 61400-1 Edition 3 standard. The algorithm for each channel is as follows:

- 1) Working through the time series, throw out all points between the peaks and valleys.
- 2) Optionally use the racetrack filter (Veers, et al 1989) to eliminate cycles that are smaller than a user-specified fraction of the maximum range of all input files for the given channel.
- 3) Using the method of (Ariduru 2004), generate the raw rainflow cycle counts for each file. This is a modified version of the method of Downing and Socie that works for languages without GOTOs. Closed cycles are given a weight of one, while unclosed cycles are assigned a weight specified by the user. If the user-specified weight is zero, eliminate the cycles.
- 4) Rescale each file's cycles for a user-specified, fixed-load mean, which is the same for all files:

$$CycRange_{FixMean} = CycRange \left(\frac{UltLoad - |MeanLoad|}{UltLoad - |CycMean|} \right)$$

where:

CycRange is the variable-mean load-cycle range.

UltLoad is the ultimate load.

MeanLoad is the fixed-load mean

CycMean is the cycle mean.

- 5) Set up the range bins. The values of the left side of the first bins is zero. The right side of the last bin is a whole multiple of the user-specified bin width that is greater than or equal to the largest, rescaled cycle range in any of the files.
- 6) Allocate the bins for each file and initialize to zeros. For each cycle, determine its bin, then increment the count for its bin by either one or the unclosed cycle weight, as appropriate.
- 7) Determine the highest mean wind speed of all the files. Starting at *WSmin*, generate sufficient wind-speed bins with a width of *WSdel* to contain the highest mean wind speed. Use the Rayleigh distribution with a mean of *RayAverWS* to determine what fraction of time each bin represents (*WSprob*).

- 8) Looping through all the files, use the mean wind speed of each file to determine its wind-speed bin.

- a) Calculate the cycles to failure for each file and load-range bin:

$$Cyc2Fail = \left(\frac{UltLoad - MeanLoad}{BinValue} \right)^m$$

where:

BinValue is the load value at the center of the range bin.

m is the slope of the S/N curve.

- b) Calculate the lifetime cycles for each load-range bin:

$$LifeCycles = WSprob \cdot BinCounts \left(\frac{Lifetime}{WSbinTime} \right)$$

where:

WSprob is the fraction of time each wind-speed bin represents.

BinCounts is the weighted count of cycles.

Lifetime is the hoped for lifetime of the turbine.

WSbinTime is the total time from all the files that contributed to the wind-speed bin..

- c) Accumulate the lifetime damage for all files and load-range bins:

$$Damage = \sum \frac{LifeCycles}{Cyc2Fail}$$

Limitations

MCrunch has the following limitations:

- All files must have the same channel layout.
- Computers must have sufficient virtual memory to contain all the data for a run. All time-series data are stored as four-byte, single-precision fixed-point numbers to save space.
- For aggregate rainflow cycle counting to work, all files must have the same time step.
- Channel names and units strings are limited to 10 characters each and may not contain any white space.

Possible Future Enhancements

- Add Excel output for summary files and extreme event tables.
- Allow default channel names and units if none are supplied.

- Allow processing of a subset of channels from the input data files and permit reordering of channels.
- Include the number of lines/files used in the analyses for all types of analysis.
- For summary statistics, add the aggregate statistics.
- Add ability to read Controls Advanced Research Turbine and Unsteady Aerodynamics Experiment binary files.
- Add cross spectra to the spectral analysis.
- Add polynomial fitting of data, which would be useful for converting BModes mode shapes into FAST-style polynomials.
- Convert AeroDyn-style element files to the WT_Perf style.
- Add probability-weighted DELs.
- For DELs, allow many S/N slopes.
- Add Load Roses.
- Add peak annotation to the PSD plots.
- Add data filtering (low-pass, high-pass, band-pass, and notch filters).
- Add moving averages.
- Add azimuth averaging.
- Add crosstalk removal.
- Add peak and valley listing.
- Add statistical extrapolation.
- Add decimation and averaging.
- Allow output of modified input. This is useful if scales and offsets are used, when only selected channels are used, when channels are reordered, when data are filtered, or when calculated channels are generated.
- Add data interpolation.
- Add an option to have only one file in memory at a time.
- For the Extreme-Events feature, add the ability to generate runners up. That is, the second largest values of a time series.
- Add extreme-value extrapolation. (Moriarty et al. 2004)
- Enable MCrunch to signify that a value of zero for the time column means that no time column is available. This will mean many features will have to be disabled for that run (extreme-value extrapolation, binned rainflow cycle counting, and filtering).
- For the rainflow counting analysis, add an option to specify the number of wind speed bins and hours in each bin. Run MCrunch once to cycle count and scale, with, for example, a list of 25 files (5 ten-minute files in each of 5 wind speed bins). This would speed up the process and enable one to calcu-

late fatigue under different International Electrotechnical Commission wind turbine classes.

- Make it impossible to cycle count the time column.
- Make it impossible to cycle count the same column twice.
- Eliminate the need for the Statistics Toolbox.

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Feedback

If you have problems with MCrunch, please contact Marshall Buhl. If he has time to respond to your needs, he will do so, but please do not expect an immediate response. Please send your comments or bug reports to:

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