Standardization of the rainflow counting method for fatigue analysis

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The rainflow procedure is a cycle-counting method that makes it possible to store service measurements in a form suitable for fatigue analysis of structures: fatigue life prediction and simulation testing. A consultation has been conducted by the authors with different industries (automobile, aircraft, energy and steel) to obtain a consensus on a proposed rainflow methodology and its use for fatigue analysis. An AFNOR document, resulting from this work, has been edited for describing the rainflow procedure, the standardized presentation of results and the reconstruction of a loading sequence from a rainflow matrix. This paper presents the methodology used and its application for combining different sequences.

(Keywords: rainflow cycle counting method; reconstruction; fatigue analysis)

The fatigue behaviour of structures depends on the interaction between loading sequence, material characteristics and component geometry. There is now wide consensus on the use of rainflow method both for analysing variable-amplitude loadings and for simulating reconstructed sequences[1–6]. Although the basic principles of the technique are well known, their practical applications vary widely[4–6]. Furthermore, the corresponding terminology may be confusing, as the same terms are often employed for different meanings or procedures. Previous standards developed and validated several years ago[7,8] do not comply with actual recognized industrial practice[9,10].

These reasons led the authors to realize an overview of the matter to optimize the procedures (such as the treatment of the residue) and the application to fatigue analysis and testing development (reconstruction and combination of different sequences). A consultation was then conducted with different industries (automobile, aircraft, energy and steel) to obtain a consensus on the proposed rainflow methodology and its use for fatigue analysis[11].

Fatigue analysis requires a decomposition of the loading sequence into elementary cycles characterized by their mean value and amplitude. The rainflow method is a cycle-counting technique that makes it possible to store service measurements in a form suitable for fatigue analysis of structures: fatigue life prediction and simulation testing. Rainflow counting results can give level crossing counting results and allow a reconstruction of a possibly different sequence which contains exactly the same cycles as the original sequence.

PROCEDURE FOR CYCLE COUNTING BY THE RAINFLOW METHOD

Preliminary treatment of the sequence

Application of the rainflow method and storage of its results require a preliminary treatment of the loading, which consists of sampling, extraction of extrema, and finally quantification of the values into classes.

Service measurements generally consist of the monitoring of a continuous variable over time (an analogue signal). Treatment of the sequence by computer requires discrete digital values, sampled in a way that adequately represents the real evolution of the variable. The rainflow counting method needs only the successive extrema of the loading sequence, which have to be extracted from the sampled sequence.

To store the results, and for speed of analysis, it may be necessary to quantify the possible values. In practice, the total range of the sequence is divided into k classes of constant-width interval or steps, and all the values (peaks or valleys) located in a given class are replaced by a representative value of this class (the mean value is usually chosen). Standard practice in industry is to take the number of classes equal to 64.[9,10]

Principle of cycle extraction

The principle of the extraction of a cycle uses four successive points (1, 2, 3 and 4 in *Figure 1*).

This can be illustrated as follows. S represents a stress, and the cycle appears as a closed loop in stress–strain space. *Figure 1* shows the two possible types of cycle that can occur. Three consecutive ranges are determined: $\Delta S_1 = |S_2 - S_1|$, $\Delta S_2 = |S_3 - S_2|$ and $\Delta S_3 = |S_4 - S_3|$. If $\Delta S_2 \leq \Delta S_1$ and $\Delta S_2 \leq \Delta S_3$ (ΔS_2

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