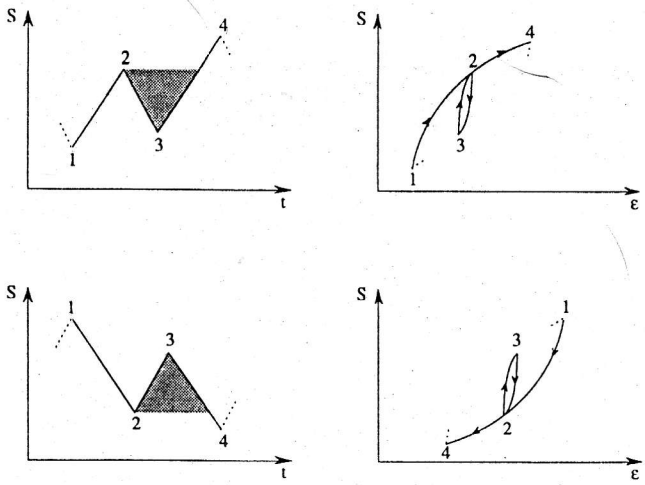

Figure 1 Principle of cycle extraction

range is less than or equal to its two adjacent ranges ΔS_1 and ΔS_3) then:

1. the cycle represented by its extreme values S_2 and S_3 is extracted;
2. the two points S_2 and S_3 are discarded;
3. the two remaining parts of the sequence are connected to each other.

If not, then the following point is considered and the same test is applied, using points 2, 3, 4 and the new point.

The comparison of ranges instead of the relative levels of the different points simplifies the algorithm. The procedure is repeated until the last point of the sequence is reached. Once achieved, the remaining points constitute what is called the residue. Its maximum number of points cannot exceed $2k - 1$, where k is the number of possible levels. The results of the counting can be stored in a matrix giving the mean value, the range and the number of cycles.

Algorithm

The initial data are the consecutive values S_i ($1 \leq i \leq N$) of the peaks and valleys of the sequence. The rules of the algorithm are given in *Figure 2*.

Use and treatment of the residue

The residue appears as a sequence for which the ranges of the successive transitions first increase and then decrease. The widest transition has the maximum and minimum values of the sequence as extrema.

Two treatments of the residue are possible depending on the final use: (1) decomposition into cycles for fatigue life prediction; and (2) storage of the residue for a sequence reconstruction. The following sections describe these two treatments.

Decomposition of the residue into cycles. Fatigue life prediction requires stress or strain cycles. For this

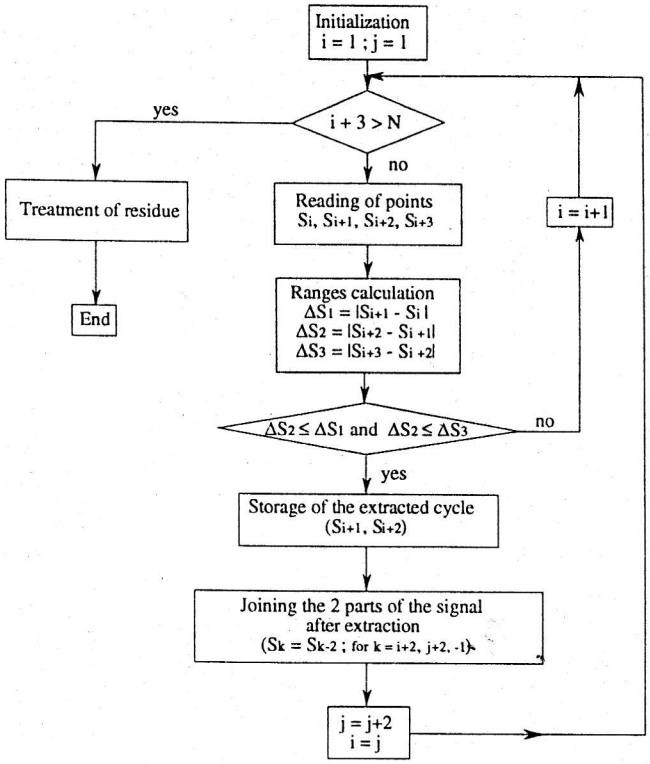

Figure 2 Proposed rainflow algorithm

purpose it is necessary also to extract cycles from the residue. The technique adopted is to add the residue to itself and apply the previous rainflow technique to the sequence composed of two residues. The property of this procedure is that the final residue is identical to the first one. This can be expressed as:

$$[\text{residue}] + [\text{residue}] \rightarrow [\text{residue}] + \{\text{cycles}\}$$

The advantage of this technique is that the same procedure is applied as before. The whole sequence is decomposed into cycles in this way. Some care has to be taken in joining the two residues, depending on their initial and final relative values and slopes[11].

An example will serve to describe the procedure. The sequence is composed of 24 peaks and valleys, as listed in *Table 1*. *Figure 3* shows the extraction of cycles from this sequence and its residue.

Reconstruction of a loading sequence. The residue is kept as it appears at the end of the first treatment (that is, it is not decomposed into cycles). The reconstruction is based on the principle that the new sequence must present the same rainflow counting result as the previous sequence. The two loadings can be considered as equivalent in terms of their identical rainflow decomposition, even if their respective points do not occur in the same order. The main interest of the reconstruction of the sequence is to provide a loading in which some cycles can be omitted or

Table 1 Example sequence (see *Figure 3*)

Point	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Load	4	7	2	10	5	9	3	4	2	12	5	11	1	4	3	10	6	12	4	8	1	9	4	6