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Metallic materials — Fatigue testing — Variable amplitude fatigue testing —

Part 2: Cycle counting and related data reduction methods

Matériaux métalliques — Essais de fatigue — Essais sous amplitude variable —

Partie 2: Méthodes de comptage des cycles et méthodes associées de réduction des données

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Contents

Page

Foreword

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The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 5, *Fatigue testing*.

ISO 12110 consists of the following parts, under the general title *Metallic materials — Fatigue testing — Variable amplitude fatigue testing*:

— *Part 1: General principles, test method and reporting requirements*

— *Part 2: Cycle counting and related data reduction methods*

Metallic materials — Fatigue testing — Variable amplitude fatigue testing —

Part 2:
Cycle counting and related data reduction methods

1 Scope

This part of ISO 12110 presents cycle counting techniques and data reduction methods which are used in variable amplitude fatigue testing.

For each test or test series, cycle counting is mandatory whereas data reduction methods are optional.

This part of ISO 12110 supports ISO 12110-1 which contains the general principles and describes the common requirements about variable amplitude fatigue testing.

In this part of ISO 12110, the term “loading” refers either to force, stress, or strain since the methods presented here are valid for all.

The following issues are not within the scope of this part of ISO 12110 and therefore will not be addressed:

— constant amplitude tests with isolated overloads or underloads;

— large components or structures;

— environmental effects like corrosion, creep, etc. linked to temperature/time interactions leading to frequency and waveform effects;

— multiaxial loading.

NOTE 1 Phasing is of prime importance when dealing with multiaxial tests under either constant or variable amplitude controlled loading.

NOTE 2 Although frequency variations during cycling are not outside of the scope of this part of ISO 12110, the following clauses deal only with constant frequency cycling.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 12110-1, *Metallic materials — Fatigue testing — Variable amplitude fatigue testing — Part 1: General principles, test method and reporting requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12110-1 and the following apply.

3.1
mean crossing
number of times that the load-time history crosses the mean-load level with a positive slope or a negative slope, or both, if specified during a given length of the history

Note 1 to entry: For purposes related to cycle counting, a mean crossing may be defined as a crossing of the reference load level.

3.2
range
algebraic difference between two successive reversals

Note 1 to entry: In variable amplitude loading, range may have a different definition depending on the counting method used. For example, "overall range" is defined by the algebraic difference between the highest peak and the lowest valley (absolute maximum and minimum, respectively) of a given load-time history.

Note 2 to entry: In cycle counting by various methods, it is common to employ ranges between valley and peak loads which are not successive events. In these practices, the definition of "range" is broadened so that events of this type are also included.

3.3
reference load
loading level which is fixed for counting upon which load variations are superimposed

Note 1 to entry: The reference load may be identical to the mean load of the loading time histories, but this is not required.

3.4
reversal
point at which the first derivative of the load-time history changes sign (from + to – or – to +)

Note 1 to entry: Reversals occur at peaks or valleys.

3.5
irregularity factor
characterization of the irregularity of the signal, i.e. number of cycles not crossing the mean value, $I = N_0/N_p$

Note 1 to entry: N_0 is the number of mean crossings.

Note 2 to entry: N_p is the number of peaks.

3.6
mean-load level
mean value of the peak and valley values

4 Cycle counting techniques

4.1 General

Cycle counting is used to summarize irregular load-time histories by providing the number of cycles of various sizes which simulates the real loading of the specimen or component under study.

NOTE The definition of a cycle varies with the cycle counting method used.

Cycle counts can be made for load-time histories of force, stress, strain, deflection, or other loading parameters.

The following subclauses present the following cycle counting methods:

— level-crossing counting;

— peak counting;

— simple range counting;

— range-pair counting;

— Rainflow counting.

4.2 Cycle counting methods

4.2.1 Loading signal sampling

Loading signal recording generally consists of measuring the continuous evolution of the signal versus time (either analog or digital values against time). If the initial loading time history is analog, it needs to be converted into a digital file so that further computer processing of the loading time histories can be accomplished. The operation of digitization consists of sampling the signal that means measuring and recording values at regular time intervals.

The digital signal is representative of the real analog one if the following precautions are taken:

— Filter the output signal to eliminate noise and other disturbances which are not linked to the fatigue process believed to be part of the real loading time histories of the structure.

— The sampling frequency shall be such that every analog loading cycle is represented by at least 20 digital points at least 20 times that of the observed maximum frequency of the real or expected analog signal.

Care shall be taken when filtering the original analog signal. See ISO 12110-1.

4.2.2 Level-crossing counting

4.2.2.1 Results of a level-crossing count are shown in Figure 1. One count is recorded each time the positive sloped portion of the load exceeds a preset level above the reference load, and each time the negative sloped portion of the load exceeds a preset level below the reference load. Reference load crossings are typically counted on the positive sloped portion of the loading time histories. It makes no difference whether positive or negative slope crossings are counted. The distinction is made only to reduce the total number of events by a factor of 2.

4.2.2.2 In practice, restrictions on the level-crossing counts are often specified to eliminate small amplitude variations which can give rise to a large number of counts. This may be accomplished by filtering small load excursions prior to cycle counting. A second method is to make no counts at the reference load and to specify that only one count be made between successive crossings of a secondary lower level associated with each level above the reference load, or a secondary higher level associated with each level below the reference load. Figure 1 b) illustrates this second method. A variation of the second method is to use the same secondary level for all counting levels above the reference load, and another for all levels below the reference load. In this case, the levels are generally not evenly spaced.

4.2.2.3 The most common cycle count for fatigue analysis is derived from the level-crossing count by first constructing the largest possible cycle, followed by the second largest, etc., until all level crossings are used. Reversal points are assumed to occur halfway between levels.

This process is illustrated by Figure 1 c). Note that once this cycle count is obtained, the cycles could be applied in any desired order, and this order could have a secondary effect on the amount of damage. Other methods of deriving a cycle count from the level-crossing count could be used.

4.2.3 Peak counting

4.2.3.1 Peak counting identifies the occurrence of a relative maximum or minimum load value. Peaks above the reference load level are counted, and valleys below the reference load level are counted, as shown in Figure 2 a). Results for peaks and valleys are usually reported separately. A variation of this method is to count all peaks and valleys without regard to the reference load.

4.2.3.2 To eliminate small amplitude loadings, mean-crossing peak counting is often used. Instead of counting all peaks and valleys, only the largest peak or valley between two successive mean crossings is counted, as shown in Figure 2 b).

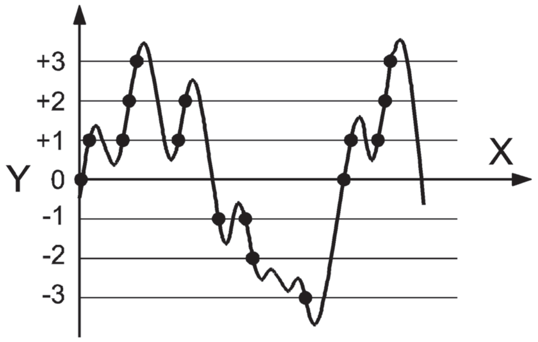
4.2.3.3 The most common cycle count for fatigue analysis is derived from the peak count by first constructing the largest possible cycle, using the highest peak and lowest valley, followed by the second largest cycle, etc., until all peak counts are used. This process is illustrated by Figure 2 c). Note that once this most damaging cycle count is obtained, the cycles could be applied in any desired order, and this order could have a secondary effect on the amount of damage. Alternate methods of deriving a cycle count, such as randomly selecting pairs of peaks and valleys, are sometimes used.

4.2.4 Simple-range counting

4.2.4.1 The method is illustrated in Figure 3. Positive ranges, negative ranges, or both, may be counted with this method. If only positive or only negative ranges are counted, then each is counted as one cycle. If both positive and negative ranges are counted, then each is counted as one-half cycle. Ranges smaller than preset levels are usually eliminated before counting.

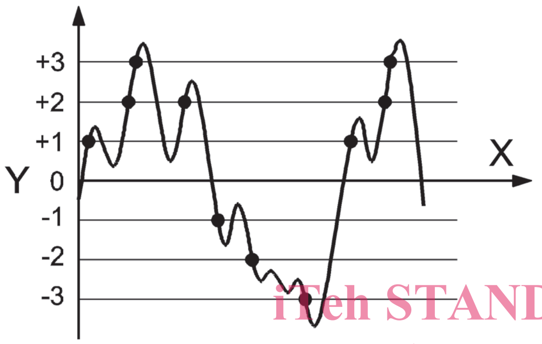
4.2.4.2 It is widely recognized that mean load also affects the measured fatigue results, which is why the mean value of each range is also important and should be counted. This method is called simple range-mean counting.

For the example in Figure 3, the result of a simple range-mean count is given in the table in Figure 3 in the form of a range and mean matrix.



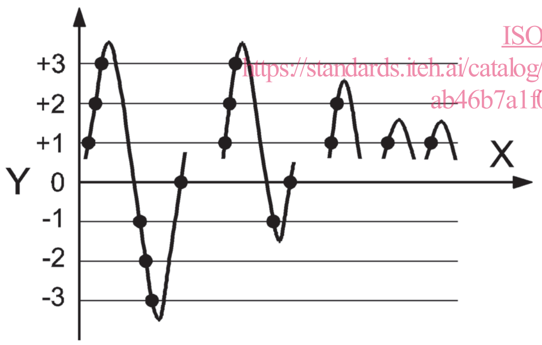
Level	Counts
+3	2
+2	3
+1	5
0	2
-1	2
-2	1
-3	1

a) Level-crossing counting



Level	Counts
+3	2
+2	3
+1	2
0	0
-1	1
-2	1
-3	1

b) Restricted level-crossing counting



Range (levels)	Cycle Counts
7	1
6	0
5	1
4	0
3	0
2	1
1	2

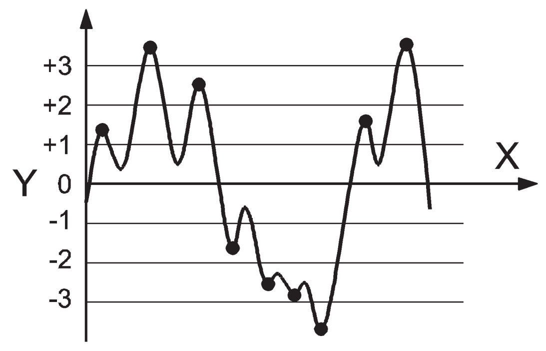
c) Cycles derived from level-crossing count *f (a)*

Key

X time

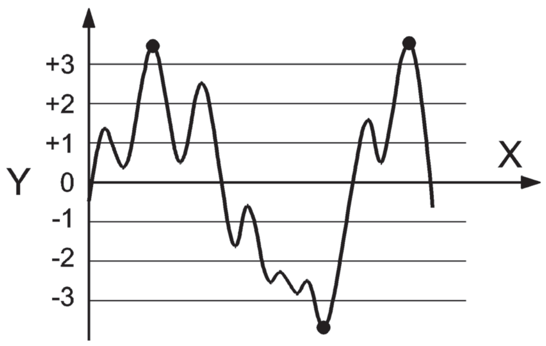
Y load levels

Figure 1 — Level-crossing counting example



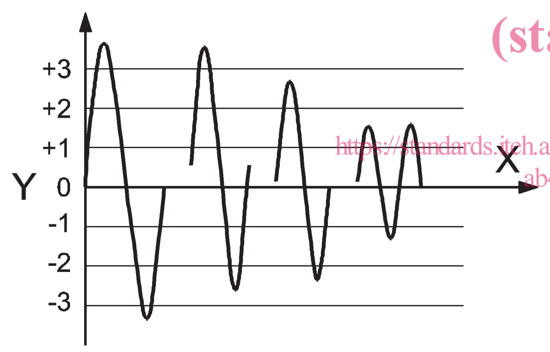
Level	Counts
+3,5	2
+2,5	1
+1,5	2
-1,5	1
-2,5	1
-2,7	1
-3,5	1

a) Peak counting



Level	Counts
+3,5	2
-3,5	1

b) Mean crossing peak counting



Level	Counts
7	1
6,2	1
5	1
3	1,5

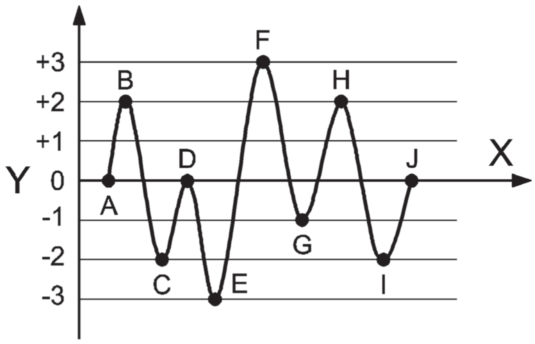
c) Cycles derived from level-crossing count *f (a)*

Key

X time

Y load levels

Figure 2 — Peak counting example



Range (level)	Cycle counts	Events
6	0,5	EF
5	0	
4	1,5	BC-FG-HI
3	1	DE-GH
2	1,5	AB-CD-IJ
1	0	

		Mean (levels)								
		-2	-1,5	-1	-0,5	0	0,5	1	1,5	2
Range (levels)	1									
	2			1				0.5		
	3		0,5				0,5			
	4					1		0,5		
	5									
	6						0,5			

Key

X time

Y load levels

Figure 3 — Simple range counting example — Both positive and negative ranges counted

4.2.5 Rainflow counting

See Annex A.

5 Counting technique selection

There are other cycle counting techniques which are not reported in this part of ISO 12110.

A major problem that has to be solved in each fatigue case (change of loading, of specimen, etc.) is to select which counting method is best adapted for the fatigue situation encountered.

A selection criterion may be narrow or large bandwidth energy spectrum and/or the irregularity factor.

Many choose the Rainflow method. Others use counting methods which are typical of their industrial sector.

In all cases, the selection of the counting method should follow a set of criteria or requirements.

Annex A
(informative)

Rainflow counting

A.1 General

The fatigue behaviour of structures depends on the complex interaction between the nature of the in-service loading, the features of the material, and the geometry of the components.

The Rainflow method is a cycle counting method that permits decomposing the measurements recorded in service using a format adapted to the fatigue analysis of the structures: fatigue life determination and performance of modelling tests.

The Rainflow analysis permits the determination of the level exceedances, their relative ranges, and cycle ranges.

The purpose of the present subclause is to give recommendations and requirements for

— performing the Rainflow cycle counting method, and

— presenting the results of the Rainflow counting.

An example of a loading sequence and the Rainflow analysis of it are presented as a test case to check how to use the Rainflow counting method and as a help for computer programming.

A.2 Preliminary treatment of the loading

A.2.1 General

Before applying the Rainflow method, the loading signal requires a preliminary treatment which consists of extracting peaks and valleys and putting them in classes or levels which had been previously established (see 4.2).

A.2.2 Peak and valley extraction

The Rainflow counting only requires the successive peaks and valleys of the loading which need to be extracted for processing from the sampled signal. The time between the successive peaks and valleys is not part of the process because this part of ISO 12110 is only valid for conducting fatigue tests on materials that yield results which are time or frequency independent. Therefore, environmental and temperature or time interactions are not included in this part of ISO 12110. The fatigue life is expressed in number of cycles or in number of repetitions of the loading sequence.

Figures A.1 and A.2 show the principles of signal sampling and peak and valley extraction from the sampled signal.

