

TERMS AND NOTATION FOR FATIGUE ENDURANCE DATA

1. INTRODUCTION

This Item defines the basic terms, notation and forms of presentation of both constant and variable amplitude fatigue endurance data. Terms and notation for statistical analysis of data are presented separately in the Data Items on statistics. The terms defined in this Item are in accordance with those used for the fatigue data presented in DEF STAN 00-932 (Reference 14) and are also broadly consistent with British and American standards.

2. NOTATION

Both SI and British units are quoted.

<i>Symbol</i>	<i>Term</i>	<i>Section giving definition or amplification of term</i>	<i>Units</i>	
D	cumulative damage ratio	6.2		
D_f	cumulative damage ratio at failure	6.2		
f_t	ultimate tensile strength		N/m ²	lbf/in ²
K_f	fatigue strength reduction factor	7.3		
K_t	theoretical elastic stress concentration factor	7.1		
N	endurance	4.1		
n	number of load cycles applied			
R	stress ratio	3.7		
S	stress in general	3.1	N/m ²	lbf/in ²
S_a	alternating stress	3.5	N/m ²	lbf/in ²
$S_{am}(N)$	fatigue strength	4.2.1	N/m ²	lbf/in ²
$S_{am}(\infty)$	fatigue limit	4.2.2	N/m ²	lbf/in ²
S_m	mean stress	3.4	N/m ²	lbf/in ²

Issued November 1970
With Amendments A and B, July 1993

S_{max}	algebraic maximum stress in cycle	3.3	N/m ²	lbf/in ²
S_{min}	algebraic minimum stress in cycle	3.3	N/m ²	lbf/in ²
ΔS	stress range	3.6	N/m ²	lbf/in ²

2.1 Suffixes

1, 2 *etc.* denote various loads under variable amplitude loading

In Data Items on elastic stress concentration factors the suffix 't' in K_t is omitted throughout for simplicity.

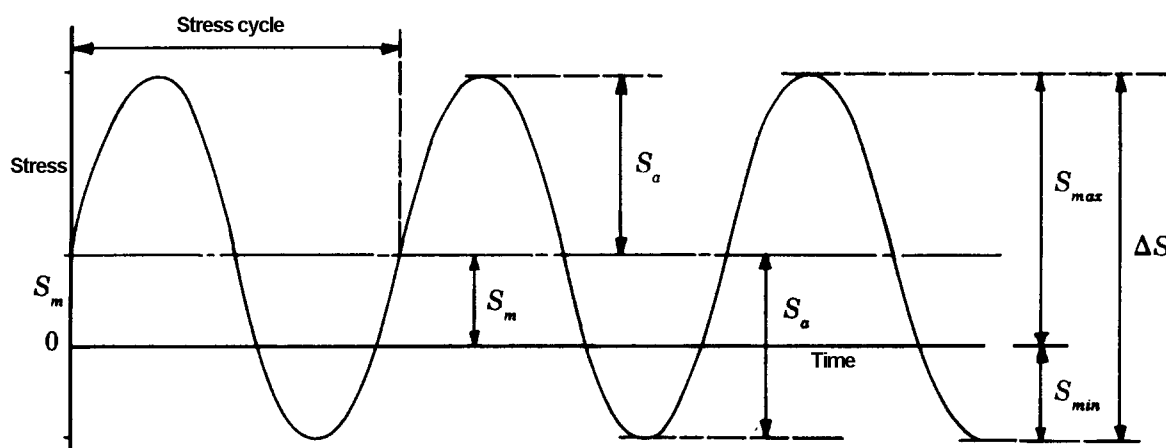
2.2 Sign Convention

Tensile stresses are positive; compressive stresses are negative.

3. FATIGUE UNDER CONSTANT AMPLITUDE LOADING

Service loadings experienced by some engineering components and structures can be represented with sufficient accuracy for most design purposes by stress cycles of constant mean stress and amplitude as illustrated in Sketch 3.1. Appropriate design data for such loadings are obtained from laboratory tests on simple smooth or notched specimens, or on commonly used joints, or sometimes on complete components, machines or structures. Basic data for individual materials in specified environmental conditions are commonly obtained from constant amplitude tests on plain specimens under axial, torsional, bending or rolling-contact loadings.

Symbols and definitions associated with fatigue under constant amplitude conditions are given below. In simple fatigue analysis, where load and stress are directly related, equivalent definitions of mean load, alternating load, *et cetera* are obtained by substituting 'load' for 'stress'. In general, reference to stress in the following sections may be taken to include load and vice-versa but it should be noted that this is not always the case.



Sketch 3.1 Constant amplitude loading

3.1 Stress in General

The notation S , with various suffixes, is used in this Item to denote stress and may refer to a direct stress, shear stress, or equivalent direct stress in different applications. It is also used indiscriminately to denote the stress applied to a component in service, or to the strength of a material or component under given loading conditions. In some Data Items, for example those dealing with stress concentrations, the symbols f , f_e and q are used for direct, equivalent and shear stresses respectively in place of S .

3.2 Stress Cycle

The **stress cycle** under constant amplitude loading is illustrated on Sketch 3.1. It is the smallest section of the stress-time function which is repeated continuously and periodically.

3.3 Maximum and Minimum Stresses, S_{max} and S_{min}

The **maximum stress**, S_{max} , is the highest algebraic value of stress in a cycle. The minimum stress, S_{min} , is the minimum algebraic value of stress in a cycle. Sketch 3.1 shows S_{max} and S_{min} .

3.4 Mean Stress, S_m

The average of the algebraic values of the **maximum and minimum** stress in the cycle, that is,

$$S_m = \frac{1}{2}(S_{max} + S_{min}). \quad (3.1)$$

3.5 Alternating Stress, S_a

The amplitude of the excursion from the **mean stress**. It is one half the difference between the algebraic values of the **maximum and minimum** stress in the cycle, that is,

$$S_a = \frac{1}{2}(S_{max} - S_{min}) = S_{max} - S_m = S_m - S_{min}. \quad (3.2)$$

Under constant amplitude loading, S_a may be considered to be the variable component of the stress and S_m may be considered to be the constant component of the stress.

3.6 Stress Range, ΔS

The difference between the algebraic values of the **maximum and minimum stress** in the cycle, that is,

$$\Delta S = S_{max} - S_{min} = 2S_a. \quad (3.3)$$

3.7 Stress Ratio, R

The ratio of the algebraic **minimum stress** to the algebraic **maximum stress** in the cycle, that is,

$$R = \frac{S_{min}}{S_{max}}. \quad (3.4)$$

The values $R = 0$ and $R = -1$ are commonly used in constant amplitude fatigue testing and are referred to as described below.

(The **stress ratio** is positive when S_{min} and S_{max} are either both tensile or both compressive. It is always clear from the sign of the associated stress values which condition is implied.)

3.7.1 Reversed Stress Cycle

A **stress cycle** with zero **mean stress**.

$$S_m = 0; S_{max} = S_a, S_{min} = -S_a; \text{consequently } R = -1. \quad (3.5)$$

3.7.2 Repeated Tensile Stress Cycle

A **stress cycle** with zero **minimum stress**.

$$S_m = S_a; S_{max} = 2S_a, S_{min} = 0; \text{consequently } R = 0. \quad (3.6)$$

4. PRESENTATION OF FATIGUE ENDURANCE DATA FROM CONSTANT AMPLITUDE TESTS

Fatigue endurance data in Data Items and elsewhere are presented in the following terms.

4.1 Endurance, N

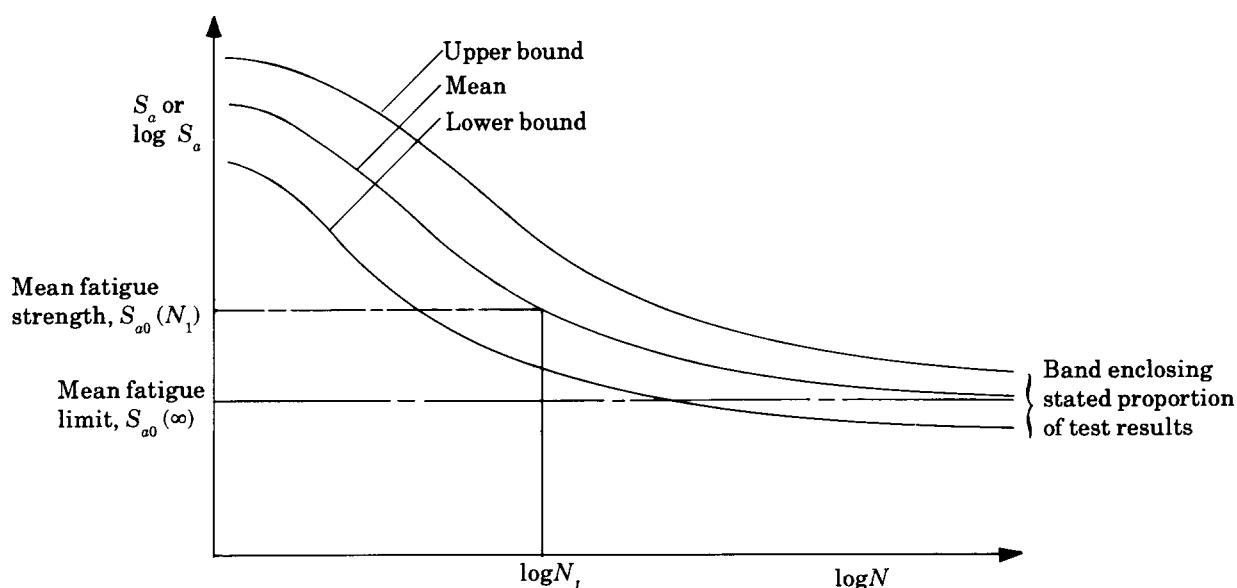
The number of **stress cycles** to failure for tests at constant amplitude.

The graphical presentation of the results of identical or comparable constant amplitude tests is usually made in one of the two standard forms illustrated in Sketches 4.1 and 4.2 and described below.

4.2 The $S-N$ Diagram (Sketch 4.1)

Using the results from a consistent set of tests, the **alternating stress**, S_a , or its logarithm, $\log_{10} S_a$, is plotted against the logarithm of **endurance**, $\log_{10} N$. The plots are referred to as a semi-log plot or a log-log plot respectively. Owing to the scatter inherent in fatigue behaviour, the data are usually accompanied by a best-fit curve, usually referred to as the mean curve. Where a large body of data is available, bands encompassing a proportion of the tests, or bands based on a statistical analysis may accompany the data.

Curves showing the variation in fatigue endurance for different values of **mean stress** or **stress ratio**, R , may be plotted on the same diagram.



Sketch 4.1 S–N diagram

4.2.1 Fatigue Strength, $S_{am}(N)$

The **alternating stress** at a specified **mean stress** that gives rise to an **endurance** N .

In order to distinguish between fatigue strengths at different **mean stresses** and **endurances**, the actual values of **mean stress** and **endurance** may be inserted in place of m and N . For example $S_{a0}(10^4)$ denotes that **alternating stress** which under zero **mean stress** gives rise to an **endurance** of 10 000 cycles. The quantities m and N may often be omitted for brevity.

Because of scatter, the fatigue strength is usually quoted as an average value corresponding to a given **endurance** and occasionally, where sufficient data are available, as a value corresponding to a given probability of failure within N cycles.

4.2.2 Fatigue Limit, $S_{am}(\infty)$

The highest level of alternating stress for a given **mean stress** at which the **endurance** may be regarded as infinite. It should be noted however, that many engineering metals do not exhibit a true fatigue limit within the practical limits of testing.

Because of scatter, the value of a **fatigue limit** is quoted either as an average value from a mean **S–N diagram** or as a lower limit derived from the highest value of S_a for which no failures were obtained in a series of tests. The difference between values obtained by these two methods can be important in interpreting the data for design. Where a fatigue limit has not been shown to exist, $S_{am}(\infty)$ is often taken to be the value of S_{am} at an acceptably high value of N .

4.3 The Alternating Stress – Mean Stress ($S_a - S_m$) Diagram (Sketch 4.2)

This diagram is derived from average **S–N diagrams** for various **mean stresses** and gives contours of constant **endurance**, with **alternating stress** as ordinate and **mean stress** as abscissa. Lines of constant **stress ratio**, R , are straight, radiating from the origin, and are often also plotted on this diagram. The Gerber, Goodman and Soderberg diagrams are particular representations of this type of plot.