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Supersedes ESDU 69001

Fatigue strength of external and internal steel screw threads under axial loading. (Standard forms not greater than 1.0 inch diameter)

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THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item, which supersedes ESDU 69001, was monitored and guided by the Stress Analysis and Strength of Components Committee which has the following membership:

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The Item was also accepted for inclusion in the Fatigue – Endurance Data Series by the Fatigue Committee which has the following membership:

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FATIGUE STRENGTH OF EXTERNAL AND INTERNAL STEEL SCREW THREADS UNDER AXIAL LOADING (STANDARD FORMS NOT GREATER THAN 1.0 INCH DIAMETER)

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FATIGUE STRENGTH OF EXTERNAL AND INTERNAL STEEL SCREW THREADS UNDER AXIAL LOADING (STANDARD FORMS NOT GREATER THAN 1.0 INCH DIAMETER)

1. INTRODUCTION

The behaviour of threaded components under alternating or pulsating loads has been examined over many years. Investigators have established that a large number of factors influence the behaviour of screwed items under fatigue conditions. Material properties, heat treatment, design of assembly and method of manufacture of the threads all significantly affect the life of the threaded component subjected to fatigue loads. To a smaller extent the steady pre-load (or mean stress) and the behaviour of internally threaded components have been investigated. This Item examines the data available and gives guidance to designers for a wide range of manufacturing and operating conditions. It should be noted that the data in this Item do not apply to stud threads at the block end.

The method of manufacture of the thread dominates its fatigue strength. Because of this the relatively minor variations in fatigue strength resulting from differences in form among the various standard threads investigated (Sketch 6.1) are undetectable. Thus, for practical design against fatigue, the primary consideration is the method of manufacture.

2. NOTATION

D	nominal diameter of thread	m	in
D_1	external diameter of cylindrical nut (internal threads)	m	in
f_t	tensile strength of material	N/m ²	lbf/in ²
N	endurance		
R	ratio of minimum stress to maximum stress $R = \left[\frac{S_m - S_a}{S_m + S_a} \right]$		
S_a	* alternating stress (half stress range)	N/m ²	lbf/in ²
S_m	* mean stress	N/m ²	lbf/in ²

* Based on core area for external threads and on the area $\pi(D_1^2 - D^2)/4$ for internal threads.

Both SI and British units are quoted but any coherent system of units may be used.

3. EXTERNALLY THREADED COMPONENTS

Table 6.1 presents the ranges of the experimental variables for which data are available. The various methods of thread manufacture used for the screw threads investigated are given in Table 6.2. The data given are the results of analysing about 1500 fatigue tests by a number of different investigators. The tests all resulted in core failures of solid low-alloy steel screw threads, from which it has been possible to present the curves of S_a/f_t against N shown in Figures 1 and 2.

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The tests were designed to represent standard nut and bolt assemblies. The thread specimens tested were fitted with steel nuts which were of standard thickness (nut thickness greater than $0.75D$). The nut materials were, in all cases, of lower tensile strength than the materials of the associated male threaded members. The results were derived from failures in the threaded portion of the bolt. All failures occurred just inside the nut close to the loaded face. Some results of tests of specimens unbroken at the completion of loading are also plotted and these are clearly distinguished. All tests were carried out at room temperature under an alternating tensile load. Care was taken to maintain axially of loading during the tests, thus eliminating bending stresses. About 50 per cent of the threaded specimens tested were cadmium plated.

When using this Item to determine the fatigue strength of a low alloy steel bolt it should be noted that the data relate solely to the fatigue strengths of the threaded portions. The endurance of other parts, such as the head fillet, waisted shank or thread run-out, may be significant and should be determined separately.

Figure 1 shows a mean line and a scatter band including 90 per cent of the results. In Figure 2 the data are in three groups and a mean line and scatter band are shown for each. These bands have been drawn so that 5 per cent of the results lie above the band and 5 per cent lie below. The widths of the bands are influenced by experimental variations between the testing laboratories and by the availability of data throughout the endurance range considered. In Figure 1 the band is shown as a broken line below 10^5 cycles because of the relatively few data points in this region all of which relate to one method of manufacture.

3.1 Effect of Method of Manufacture

The method of manufacture of the thread, as defined in Table 6.2, has a major effect on the endurance of a steel screw thread. The endurance of threads made by grinding from fully heat-treated material (Method B) is similar to that of threads made by cutting from fully heat treated material (Method A), as can be seen in Figure 1. In Method C, where threads are rolled and then heat treated, relief of residual stress and surface decarburisation of the steel nullify the beneficial effects of form rolling the thread; the resulting fatigue performance is consequently markedly inferior to that of threads made by Methods D and E, as is shown in Figure 2. When thread form-rolling follows the heat treatment, as in Method D, the favourable residual compressive stresses are retained and despite the effect of surface decarburisation the long endurance shown in Figure 2 are obtained. In Method E, in which the decarburised layer caused by heat treatment is removed by grinding before the thread rolling process, an even higher fatigue strength at long endurance is achieved.

3.2 Effect of Tensile Strength

As is shown in Table 6.1, a wide range of ultimate tensile strengths was evident in the samples under test. From inspection of the data no obvious relationship exists between fatigue strength and tensile strength at high endurance. For endurance less than 10^5 cycles the higher values of S_a/f_t in the bands are frequently associated with lower values of f_t .

3.3 Effect of Size

Within the range covered by the tests no consistent pattern showing the effect of specimen size could be detected. However, ESDU 68045* shows that the larger screw threads (1.5 in up to 5.0 in diameter) exhibit a lower fatigue performance than the smaller ones so that a similar, though not so pronounced, effect may be expected among threads less than 1.0 inch diameter.

* ESDU 68045 "Fatigue strength of large steel screw threads under axial loading".