# ESDU 71027

Issued September 1971
With Amendment A
September 1974
Re-issued January 2013

# Endurance of high strength steels (in bending)

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## THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item was monitored and guided by the Fatigue Committee. This Committee first met in 1955 and now has the following membership:

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# ENDURANCE OF HIGH STRENGTH STEELS (IN BENDING)

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# ENDURANCE OF HIGH STRENGTH STEELS (IN BENDING)

## 1. NOTATION

| | | | |
|---|---|---|---|
| $f_t$ | tensile strength of material | N/m$^2$ | lbf/in$^2$ |
| $K_t$ | elastic stress concentration factor based on net cross-sectional area | | |
| $N$ | endurance | | |
| $S_a$ | maximum alternating stress based on net cross-sectional area | N/m$^2$ | lbf/in$^2$ |

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

## 2. NOTES

The results of approximately 1100 fatigue tests on plain and notched specimens of a number of types of high strength steel have been analysed to give curves of $K_t S_a / f_t$ against $N$. The data have been grouped according to the type of steel as shown in Table 4.1 and are presented in Figures 1 to 8.

In Figure 9 $S_a$ is plotted against $N$ for various values of $f_t$ to give a correlation of endurance with ultimate tensile strength for low alloy steels only. The curves given in Figure 9 have been obtained by considering all the results shown in Figures 1 to 4, and are not therefore necessarily the best fit for any one particular steel; they do not apply to the stainless or maraging steels of Figures 5 to 8.

All the results were obtained on specimens with $1.0 \le K_t \le 3.2$ tested either as a rotating cantilever (single- or two-point loading) or as a rotating beam (4-point loading), except those results for the austenitic stainless steel DTD 166B (Figure 7) which were obtained on specimens tested in reverse bending.

The diameter at the critical section for most of the specimens was in the range 0.2 to 0.32 in (5.08 to 8.13 mm) though about 60 were bigger, up to 1.0 in (25.4 mm) diameter, and about 10 were smaller, 0.125 in (3.18 mm) diameter. The surface finish was fine turned, ground or polished (normally Centre Line Average Index range 0 to 32 µin (0.813 µm)). No subsequent chemical, thermal or mechanical treatment was applied, except for stress relief *in vacuo* in a few instances.

The values of $f_t$ used in plotting the data points shown were those obtained from control tests on specimens of the same batch of material, whenever available. When such a value was not available an average value taken from the appropriate specification was used.

In each figure a mean curve has been drawn through the results for plain specimens. Test results, whenever available, for notched specimens are plotted on the figures as maximum alternating stress at the notch against endurance. An estimate of the allowable alternating stress at any required endurance in any other notched specimen may be made by treating the mean curve for plain specimens as $K_t S_a / f_t$, that is, using the maximum stress at the notch for the notched specimens. For specimens in the range of sizes on which the figures are based, the extent to which the alternating stress estimated in this way is low may be judged by the difference between the actual notched specimen results and the points from which the mean curve was constructed. For notched specimens larger than those tested the difference between the estimate and



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the results of an actual test is likely to be less. Comparison of the plotted results in order to ascertain the magnitude of any size effect is inadvisable because factors other than size will affect the comparison, for example, surface finish, variation in composition. Conservative estimate of fatigue endurance would be obtained by using a curve through the results lower than the mean curve given.

This Item applies to stress concentrations due simply to change of form and does not relate to stress concentrations forming part of the loading system (for example, interference fits) nor to the fretting that may occur in such cases. Guidance on the latter subject may be obtained from ESDU 90031 "Fretting fatigue".

The fatigue endurance of steels is strongly influenced by surface conditions and treatments which may have a negligible effect on tensile strength. The endurance values may therefore increase or decrease in relation to those indicated by the figures according to the nature of the surface treatment. The fatigue endurance may be reduced by processes that induce a residual tensile stress in the specimen surface, for example, harsh grinding or heavy machining. A reduced fatigue endurance is also associated with surface decarburisation, oxidation and chromium plating. The fatigue endurance may be increased by processes that induce residual compressive stress, for example, shot peening or rolling, and there is evidence to suggest that case hardening, nitriding and grit blasting (before cadmium plating) are beneficial in this respect.

This Item does not cover low strength steels, that is, steels with tensile strengths below below 123 000 lbf/in$^2$ (55 tonf/in$^2$ , 848 MN/m$^2$), which are usually designed to the fatigue limit. Guidance on the fatigue limits that may be assumed for such steels is to be found in ESDU 88008 "Fatigue limit of unnotched steels (related to tensile strength)" and the references given in Section 3 of this Item.

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## 3. REFERENCES AND DERIVATION

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