



# ESDU 73002

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## Fatigue of steel spline assemblies under reversed torsion

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## THE PREPARATION OF THIS DATA ITEM

The work on this particular Data Item was monitored and guided by the Stress Analysis and Strength of Components Committee first met in 1964 and now has the following membership:

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The construction and subsequent development of the Data Item was undertaken by

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FATIGUE OF STEEL SPLINE ASSEMBLIES UNDER REVERSED TORSION

CONTENTS

|                              | Page   |
|------------------------------|--------|
| 1. NOTATION                  | 1      |
| 2. GENERAL NOTES             | 1      |
| 3. DISCUSSION OF DATA        | 2      |
| 3.1 Material Factors         | 2      |
| 3.2 Geometric Factors        | 2      |
| 3.3 Spline Surface Condition | 2      |
| 3.4 Other Factors            | 3      |
| 4. DERIVATION                | 3      |
| 5. SPLINE ASSEMBLIES DATA    | 3      |
| FIGURES 1 TO 4               | 5 TO 8 |

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## FATIGUE OF STEEL SPLINE ASSEMBLIES UNDER REVERSED TORSION

### 1. NOTATION

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

|       |                                                                                                                                   |                  |                     |
|-------|-----------------------------------------------------------------------------------------------------------------------------------|------------------|---------------------|
| $a$   | height of male splines                                                                                                            | m                | in                  |
| $f_t$ | tensile strength of shaft material                                                                                                | N/m <sup>2</sup> | lbf/in <sup>2</sup> |
| $K$   | stress concentration factor at root of a male spline on a shaft transmitting torsion, defined by $q_m = Kq$                       |                  |                     |
| $N$   | endurance                                                                                                                         |                  |                     |
| $q$   | nominal shear stress at surface of a plain shaft transmitting torsion and having diameter equal to root diameter of splined shaft | N/m <sup>2</sup> | lbf/in <sup>2</sup> |
| $q_m$ | maximum shear stress at fillet along root of male spline on a shaft transmitting torsion                                          | N/m <sup>2</sup> | lbf/in <sup>2</sup> |
| $r$   | radius of fillet along root of male spline                                                                                        | m                | in                  |

### 2. GENERAL NOTES

This Item presents data on the fatigue strength of steel splines under reversed torsion applied by the female member, the shaft being free from bending or axial loading. The nominal diameter of the splines lies between 1.0 and 1.5 in (25.4 and 38.1 mm). Data on male splines manufactured from eight different steels are provided together with data on the effects of the number of splines, their shape and surface condition.

The largest body of data relates to bottom fitting assemblies having six straight-sided machine-cut splines. The splines conformed to British Standard 2059:1953, fit 1, excepting that, in order to minimise backlash, the tolerances on the spline widths were slightly reduced. The tests were made under alternating torsion of constant amplitude of sinusoidal wave form. Data on both deep and shallow standard splines are included. Figures 1 and 2 present the results of 122 fatigue tests on such assemblies. Figure 1 shows the effect of varying the spline height and root radius. Also shown is the effect of employing an assembly having tapered minor diameters. Four different steels are included on Figure 1. For deep splines, Figure 2 shows the improvements resulting from various surface condition treatments. Figure 3 shows the effect of increasing the number of splines and in addition includes involute forms having 24 splines. Figure 4 shows the effect of surface condition treatments on involute spline forms having 23 or 24 splines. Table 5.1 provides details of the sizes, materials and treatments of all the data groups.

All the fatigue failures initiated at one or more of the roots of the splines of the male member at the point where it entered the female member. The crack, or cracks, then grew on a helical path until rupture occurred. No failures or significant damage to the female splines occurred.

The female components were, in all cases, manufactured from carburised steel to British Standard BSS, En 36 or En 353. Their minimum overall diameter was 2.25 in (57.2 mm).

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