



# Fatigue strength of keyed assemblies

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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. This Committee first met in 1964 and now has the following membership:

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## FATIGUE STRENGTH OF KEYED ASSEMBLIES

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## FATIGUE STRENGTH OF KEYED ASSEMBLIES

### 1. INTRODUCTION

This Item provides information on the fatigue strength analysis of keyed assemblies. Very few data concerning fatigue strength were found to be available. The majority of information found concerned stress analysis and where applicable this has been included in the form of stress concentration factors that give the magnitude of the stress fields in the areas where fatigue cracks initiate. Included are the stress concentrations present at a keyway, both in bending, and for a non-shrink fit assembly where torque is transmitted by the key. The factors upon which the stress concentrations and distributions depend and others that influence fatigue strength are discussed.

### 2. NOTATION

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

|       |                                                                                                                                                          |                  |                     |
|-------|----------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|---------------------|
| $b$   | keyway width                                                                                                                                             | m                | in                  |
| $D$   | shaft outside diameter                                                                                                                                   | m                | in                  |
| $f_t$ | tensile strength of shaft material                                                                                                                       | N/m <sup>2</sup> | lbf/in <sup>2</sup> |
| $K_b$ | stress concentration factor defined as direct stress in keyway divided by maximum nominal bending stress in plain shaft subjected to same bending moment |                  |                     |
| $K_t$ | shear stress concentration factor defined as shear stress in keyway divided by nominal shear stress at surface of a plain shaft subjected to same torque |                  |                     |
| $N$   | endurance                                                                                                                                                |                  |                     |
| $q_a$ | amplitude of alternating shear stress at surface of a plain solid shaft of diameter $D$                                                                  | N/m <sup>2</sup> | lbf/in <sup>2</sup> |
| $S_a$ | amplitude of alternating direct stress at surface of a plain solid shaft of diameter $D$                                                                 | N/m <sup>2</sup> | lbf/in <sup>2</sup> |
| $t$   | keyway depth in shaft measured from shaft outside diameter (see Table 12.1)                                                                              | m                | in                  |
| $r$   | keyway fillet radius (see Table 12.1)                                                                                                                    | m                | in                  |

### 3. SHAFT TYPES

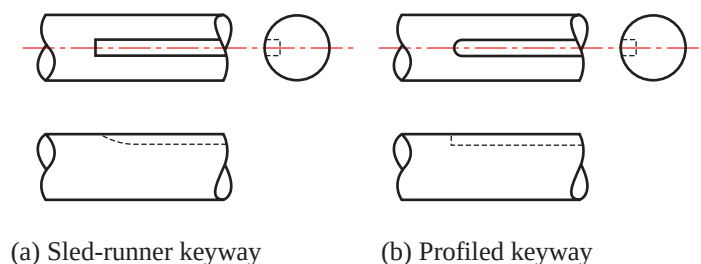
This Item concerns keyways and keys as fitted to parallel shafts and hub bores. In the case of tapered shafts and bores, torque applied to the assembly is transmitted almost entirely by friction between the conical faces and the key and keyway will be taking very little torsional loading.

## 4. LOADING TYPES

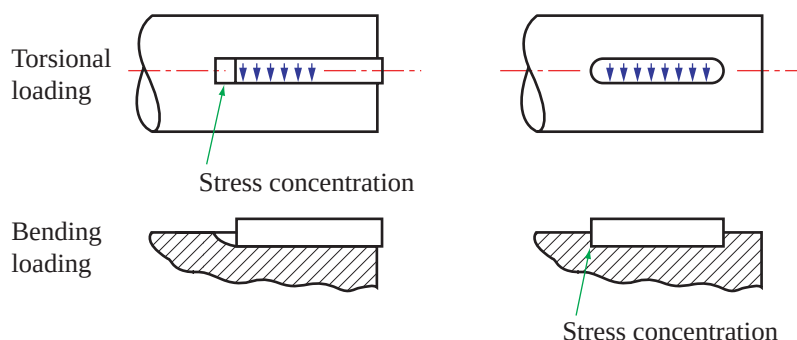
The shaft of a keyed assembly can experience basically two types of loading in service, either torsional or bending. The two types are often combined, as in the case of an overhanging, rotating shaft with a keyed pulley transmitting torque. Loading cycles can be further complicated, from a fatigue viewpoint, since in the case cited the bending cycles will often be far greater in number than those due to torsion.

## 5. KEYWAY TYPES

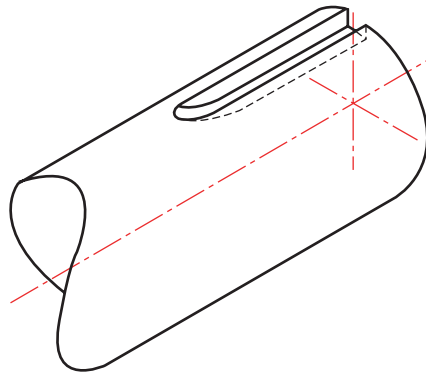
Two types of keyway, for which data are available, are in common use; the sled-runner type, as cut with an ordinary milling cutter of the same width as the keyway, as shown in Sketch 5.1a, and the profiled type, as cut with an end-mill of the same diameter as the keyway width, as shown in Sketch 5.1b. It has been found that the shapes of the key and keyway ends are important factors in determining resistance to fatigue failure. It can be deduced from Sketch 5.2 that under bending loading the contour of the sled runner keyway provides a smoother change in cross-sectional-area at the end of the keyway than does the profiled keyway and hence produces a lower stress concentration. However, under torsional loading the profiled keyway, because of its rounded end, provides a smoother contour for the load path and hence a lower stress concentration than does the sled-runner type. A combination of the two types could be devised to resist both types of loading, as shown in Sketch 5.3, by machining with an end-mill and using a progressive run-out of depth at the keyway end. This can easily be achieved if numerically controlled machine tools are used. This keyway end type has been shown to provide an improved stress distribution (see Derivation 9). Chamferring or radiusing the ends of the key was also found to give beneficial effects.



Sketch 5.1

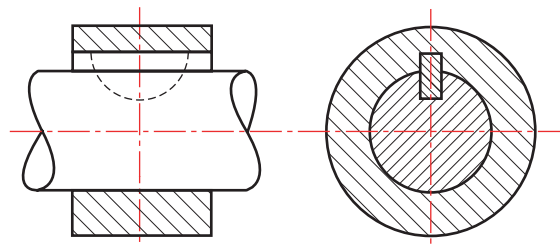


Sketch 5.2



**Sketch 5.3**

A further type of key, for which data do not appear to be available, is the Woodruff type, as shown in Sketch 5.4.



**Sketch 5.4**

This type is often used in tapered shaft assemblies purely for angular location purposes, the torque being transmitted by friction at the shaft taper. An advantage of this type of keyway is that it is relatively easy to machine and the key has the ability to rotate due to its circular base and thus find its own seating.

## 6. EFFECT OF FIT OF THE COMPONENTS

The behaviour of the keyed assembly under load is affected by the fit of its components. For example, if interference is present between the shaft and the hub then all, or a large part, of the applied torque can be transmitted by friction, with the key and keyway taking very little load.