

Australian Standard[®]

**DESIGN OF ROTATING STEEL
SHAFTS**

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SHAFTS**

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PREFACE

This edition of this standard was prepared by the Association's Committee on Cranes, to supersede AS 1403—1984.

The 1984 edition included a number of changes that were initiated by teaching institutions with a view to simplifying the standard and enable its use in their curricula. Those changes were as follows:

- (a) A number of definitions were revised, added or detailed, while some definitions were omitted. In conjunction, notations were changed to align with the accepted conventions.
- (b) Table 1 was presented in a completely different form. Instead of providing two general formulas and a note explaining their specific uses, Table 1 provides specific formulas for shaft torques in the first four shafts of a mechanism. It also separated them into driving systems and braking systems and whether the inertia was or was not significant. The establishment of a pattern of formulas was thought to be superior to that of a general formula.
- (c) Data for high tensile steel was included in Appendix A.
- (d) Appendix B, Iterative Method, was added; this addition reflected the wide use of programmable calculators.
- (e) The existing worked example was expanded and two additional worked examples were included. The most possible cases, i.e. driving and braking, moments of inertia of components with rotating and linear motions, and their combinations were covered by examples.
- (f) The appendix covering the corrosion fatigue strength of nickel-containing materials was deleted. However, the deleterious effect of certain conditions was brought to the attention of the user of this standard in Clause 7.2.

Additional changes in this edition are as follows:

- (g) Corrections of a typographical and editorial nature and oversights.
- (h) In Clause 6.3(b), the wall thickness is determined in relation to the minimum calculated diameter of shaft (D), and not the minimum calculated outside diameter of hollow shaft (D_o).

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STANDARDS ASSOCIATION OF AUSTRALIA

Australian Standard
for
DESIGN OF ROTATING STEEL SHAFTS

FOREWORD

The method of design in this standard is the same as that contained in the 1984 issue and is based on calculations for infinite life of the shaft.

It is noted that, as the result of extensive laboratory and/or field tests, shafts of diameters smaller than those resulting from calculations in this standard may be used.

Although the method is not theoretically precise, it gives results which are of sufficient accuracy for practical purposes. The method makes no allowance for corrosive or other abnormal conditions, such as the presence of buckling, 'whipping', cyclic vibration, and similar effects (see Clause 7.2).

In some cases, deflection may be the factor which determines the minimum value of the shaft diameter (see Clause 7.6).

Typical worked examples employing this method of shaft design are given in Appendices D, E and F.

A 'trial' diameter may be necessary in the application of the design method. The value may be assumed on the basis of the designer's previous experience or a simplified version of the method may be used to determine the order of magnitude of the shaft diameter, and the full method then applied to check the selected trial diameter. A convenient quick method of estimating the 'trial' diameter is given in Appendix A, and an iterative method using programmable calculators is provided in Appendix B.

The process of carrying out an accurate and complete analysis of loadings applied to a shaft (see Clause 5) may involve much time and effort, and is warranted where it is desired to keep shaft diameters as small as possible. Where larger diameter shafts can be tolerated, it may be more appropriate to use approximations or to ignore inertia or other effects, but it is important to ensure that, where such inaccuracies are introduced, they result in increased rather than decreased margin of safety and stress-raising characteristics are avoided.

The effect of electric motors with high breakdown torque (also known as pull-out torque) or high locked-rotor torque (also known as starting torque) and the characteristics of motor controllers and torque-limiting devices are outlined in Appendix C.

SPECIFICATION

1 SCOPE. This standard applies to the design of rotating steel shafts which are subjected to torsional, bending and axial-tensile loads either singly or in combination, on the basis of infinite life.

The standard does not apply to shafts specially developed, e.g. those involving extensive laboratory and field testing, heat treatment and like developments, or to shafts for specific applications such as automotive and construction equipment transmissions.

NOTES:

- Particular consideration has to be given to deflections of long shafts where the effects of out-of-balance forces tend to induce 'whipping', and to long shafts which are subject to buckling due to compressive loading (see Foreword).
- The use of this method of shaft design enables justification of the use of shafts of minimal diameter. Where the designer conservatively sizes a shaft, then only those calculations necessary to ensure that the shaft complies with this standard (see Clause 5) are required.

2 REFERENCED DOCUMENTS. The following standards are referred to in this standard:

- AS 1204 Structural Steels—Ordinary Weldable Grades
 AS 1391 Methods for Tensile Testing of Metals
 AS 1654 Limits and Fits for Engineering
 AS B212 Straight Sided Splines
 AS B213 Involute Splines
 AS B265 Involute Serrations
 ISO 14 Straight-sided Splines for Cylindrical Shafts with Internal Centering—Dimensions, Tolerances and Verification
 ISO 4156 Straight Cylindrical Involute Splines, Metric Module, Side Fit—General Use, Dimensions and Inspection
 BS 2059 Straight-sided Splines and Serrations
 BS 4235 Metric Keys and Keyways
 Part 1—Parallel and Taper Keys
 Part 2—Woodruff Key and Keyways

3 DEFINITIONS. For the purpose of this standard, the following definitions apply:

3.1 Applied loading—

3.1.1 Axial loading—force applied to a shaft in the direction of the shaft axis.

3.1.2 Bending loading—bending moment applied to a shaft.

3.1.3 Torsional loading—torque applied to a shaft.

3.2 Equivalent rotational mass moment of inertia of a shaft and its associated components—the linear mass moment of inertia and the rotational mass moment of inertia of the component, related to the rotational full-load speed of the braking or driving medium of the mechanism.

3.3 Stress-raising characteristic—a detail, of a shaft, which induces increased stress in the shaft, e.g. step in diameter, keyway, spline, interference fit with a component on the shaft, transverse hole, annular groove.

NOTE: Stress-raising effects are intensified by machining marks, notching and the like.

4 NOTATION. For the purpose of this standard, the following notation applies:

- D = minimum calculated diameter of shaft at cross-section under consideration, in millimetres (see also Clause 6.2)
 D_a = estimated diameter in iterative method (see Appendix B)
 D_{a-1} = previous estimated diameter in iterative method (see Appendix B)
 D_i = internal diameter of hollow shaft, in millimetres
 D_o = minimum calculated outside diameter of hollow shaft at cross-section under consideration, in millimetres
 e = allowable deviation between successive iterations, expressed as a percentage (see Appendix B, Fig. B1)
 F_R = endurance limit of shaft material in reversed bending during rotation, based on tests of polished steel specimens of diameter between 8 mm and 15 mm, in megapascals
 = $0.45 F_U$, where actual value is not known
 F_S = safety factor
 F_U = tensile strength of shaft material, in megapascals
 F_T = yield strength of shaft material, in megapascals
 I_{ei} = equivalent rotational mass moment of inertia of a shaft and its associated rotating and linear components, in kilogram metres squared
 = $I_{Ri} + I_{Lj}$
 I_{Ri} = equivalent rotational mass moment of inertia of a shaft and its associated rotating components, in kilogram metres squared
 = $I_i \left(\frac{N_1}{N} \right)^2$
 I_{Lj} = equivalent rotational mass moment of inertia of components with linear motion, associated with the shaft under consideration, in kilogram metres squared
 = $m_j \left(\frac{V_j}{2\pi N} \right)^2$
 $I_1, I_2, I_3 \dots I_n$ = rotational mass moment of inertia at first, second, third ... n th shafts and its components rotating at $N_1, N_2, N_3 \dots N_n$ revolutions per second, in kilogram metres squared
 i = number defining the rotational motion component under consideration (1, 2, 3, ... n)
 j = number defining the linear motion component under consideration (1, 2, 3 ... k)
 k = total number of components with linear motion
 K = stress-raising factor (see Clause 8.2):
 for a stepped shaft, see Fig. 4
 for a shaft fitted with rolling-element bearing, see Fig. 5