

Indian Standard

METHOD OF
ROTATING BAR BENDING FATIGUE
TESTING OF METALS
(*First Revision*)

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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Indian Standard

METHOD OF ROTATING BAR BENDING FATIGUE TESTING OF METALS (*First Revision*)

0. FOREWORD

0.1 This Indian Standard (First Revision) was adopted by the Indian Standards Institution on 28 February 1985, after the draft finalized by the Methods of Physical Tests Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 This standard was first published in 1969. While reviewing this standard, it was decided to revise this standard with the following main modifications to bring it in line with the International Standard published on this subject:

- a) The scope has been changed to cover test pieces having nominal diameter between 5 and 12.5 mm,
- b) One of the recommended diameter d of the test piece has been changed to 9.5 mm (*see 4.2.1*), and
- c) The minimum speed of testing has been changed to 1 000 cycles per minute (*see 7.1*).

0.3 The failures of metallic products may arise from numerous factors. Fatigue which results from dynamic loads (repeated, periodic, cyclic, etc), is one of them. The types of loading may be in axial tension or compression, cyclic bending (rotation), torsional or vibratory. The variation of loads due to temperature gradients does not fall within the purview of this specification.

0.4 In the preparation of this standard, assistance has been derived from ISO 1143-1975 'Metals — Rotating bar bending fatigue testing' issued by the International Organization for Standardization.

0.5 In reporting the result of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

*Rules for rounding off numerical values (*revised*).

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1. SCOPE

1.1 This standard prescribes the method for carrying out rotating bar bending fatigue tests on test piece having a nominal diameter between 5 and 12.5 mm without deliberately introducing stress concentrations.

2. PRINCIPLE OF TESTS

2.1 The test consists of mounting a test piece as a cantilever, with single point or two-point loading, or as a beam, with four-point loading. The test piece is rotated and subjected to a bending moment. The force giving rise to the bending moment do not rotate. The test is continued until failure occurs or until a predetermined number of stress cycles has been exceeded (*see 9*).

2.2 Results of fatigue test may be affected by atmospheric conditions, and where controlled conditions are required these shall be in accordance with IS : 196-1966*.

3. SYMBOLS USED

3.1 The following symbols have been used in this standard:

<i>Symbols</i>	<i>Description</i>
<i>D</i>	Diameter of the gripped or loaded end of the test piece;
<i>d</i>	Diameter of the test piece where the stress is a maximum; and
<i>r</i>	Radius at the ends of the test section which starts the transition from the test diameter <i>d</i> .

NOTE — This radius need not be a true arc of a circle over the whole of the length between the end of the test section and the start of the enlarged ends for the test pieces shown in Fig. 1, 4 and 5.

4. TEST PIECE

4.1 Form of Test Piece — The test piece shall be:

- a) Cylindrical, with tangentially blended fillets at one or both ends, (*see Fig. 1, 4 and 5*);
- b) Tapered (*see Fig. 2*), or;
- c) Toroidal (*see Fig. 3, 6 and 7*).

In each case the test piece shall be of circular cross-section.

*Atmospheric conditions for testing (*revised*).

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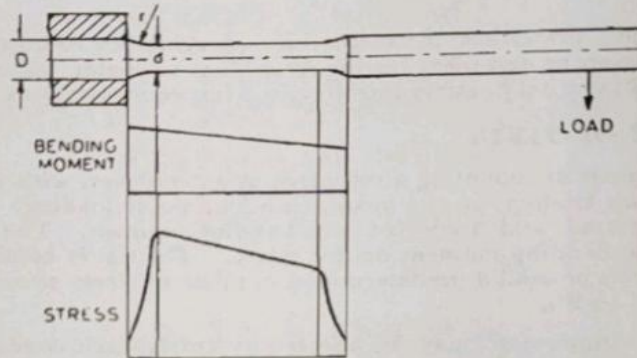


FIG. 1 PARALLEL TEST PIECE, SINGLE-POINT LOADING

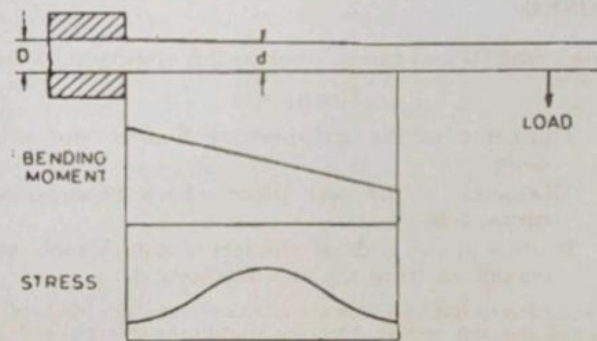


FIG. 2 TAPERED TEST PIECE, SINGLE-POINT LOADING

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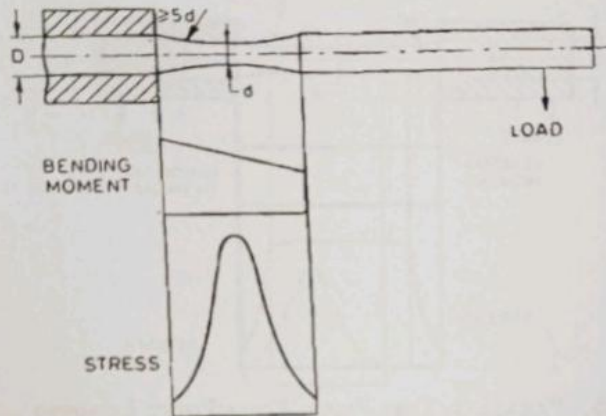


FIG. 3 TOROIDAL TEST PIECE, SINGLE-POINT LOADING

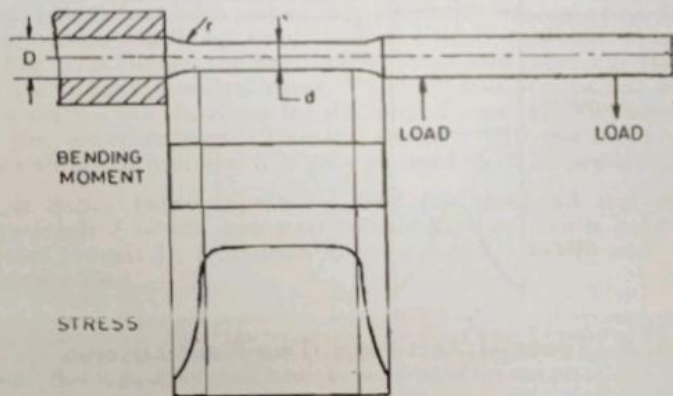


FIG. 4 PARALLEL TEST PIECE, TWO-POINT LOADING

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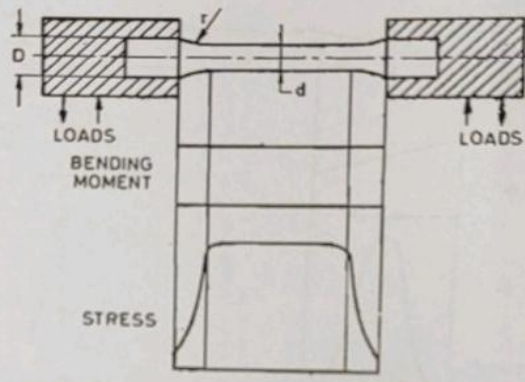


FIG. 5 PARALLEL TEST PIECE, FOUR-POINT LOADING

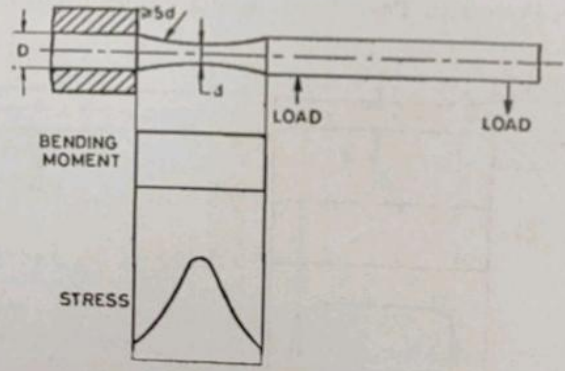


FIG. 6 TOROIDAL TEST PIECE, TWO-POINT LOADING

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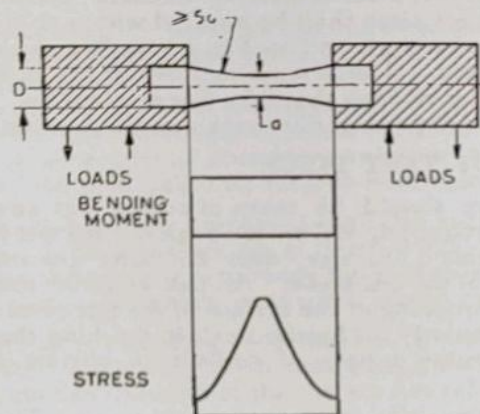


FIG. 7 TOROIDAL TEST PIECE, FOUR-POINT LOADING

4.1.1 The form of the test piece shall depend on the type of loading to be employed. While cylindrical or toroidal test pieces may be loaded as beams, or as cantilevers with either single-point or two-point loading, the tapered test piece shall be used only as a cantilever with single-point loading. Fig. 1 to 7 show the bending moment and nominal stress diagrams for the various practical cases. The volumes of material subjected to high stresses are not the same for different forms of test pieces, and they may not necessarily give identical results. The test piece in which the largest volume of material is highly stressed shall be preferred.

4.1.2 It is found from experience that for threaded test pieces of certain materials (which are particularly hard or brittle) the maintenance ratio of at least 3 : 1 between the threaded section and the test section is desirable.

NOTE — In tests of certain material a combination of high stress and high speed may cause excessive heating of the test piece. This effect may be reduced by subjecting a smaller volume of the material to high stress. If the test piece is cooled, the medium shall be such that it does not react with the material of the test piece.

4.2 Dimensions of Test Piece — All the test pieces employed for a fatigue determination shall have the same nominal diameter, that is, $d \pm 0.05$ mm.

4.2.1 The diameter d shall be between 5 and 12.5 mm. The recommended values of d are 6, 7.5 and 9.5 mm.

4.2.2 For the purpose of calculating the load to be applied to obtain the required stress, the diameter of the test piece shall be measured to an accuracy of 0.01 mm. Care shall be taken that the surface is not damaged during the measurement of the test piece prior to testing.

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4.2.3 For cylindrical test piece subject to constant bending moment (see Fig. 4 and 5) the test piece shall be parallel within 0.025 mm. For other forms of cylindrical test pieces (see Fig. 1) the test section shall be parallel within 0.05 mm. The transition fillets at the ends of the test section shall have a radius not less than $3d$. For toroidal test pieces, the section formed by the continuous radius have a radius not less than $5d$.

5. PREPARATION OF TEST PIECE

5.1 Machining — Care should be taken to ensure that any cutting or machining operation required, either to rough out the test piece out of the blank or to machine it to size, does not alter the metallurgical structure or properties of the test piece. All cuts endured shall be such as to minimize work-hardening of the surface of the test piece. Grinding may be adopted particularly for harder steels in finishing the test pieces to size, ensuring adequate supply of coolant to obviate any undue heating of the surface.

5.1.1 Throughout the turning or grinding procedures the tool sharpness, tool setting, the conditions of the wheel and the grinding machine, and speeds and feeds shall conform to good workshop practice for the material commensurate with the requirements of 5.2 to 5.4.

5.2 Turning — It is recommended that the procedures in 5.2.1 and 5.2.2 be adopted.

5.2.1 In rough turning the test piece from a diameter $x + 5$ mm (x is generally the diameter d plus a suitable allowance for surface finishing) to $x + 0.5$ mm, a succession of cuts of decreasing depth shall be made. The recommended depths of cuts shall be 1.25, 0.75 or 0.25 mm.

5.2.2 From a diameter of $x + 0.5$ mm to x , a further succession of cuts of decreasing depths shall be made. The recommended depths of cuts shall be 0.125, 0.075 or 0.05 mm, using for these finishing cuts. The feed in each case shall not exceed 0.06 mm/rev.

5.3 Grinding — For test pieces in material which cannot be readily turned, it is recommended that the finishing operations are carried out by grinding. Where the strength properties of the material are developed in heat treatment, this heat treatment may be carried out after rough turning to a diameter of $x + 0.5$ mm.

The test piece shall then be ground to size. A succession of cuts of decreasing depth shall be made. The recommended values for depth of cut to oversize are:

Depth of Cut, mm	Oversize, mm
0.030	0.1
0.005	0.025
0.002 5	Nil (to size)

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5.4 Surface Finishing — When the test piece has been turned or ground to diameter x , it shall be polished either by hand or by machine, using successively finer grades of abrasive papers or cloths. Polishing shall generally be in the longitudinal direction, although intermediate stages may be done in any direction to ensure that longitudinal scratches made by the coarser grades of abrasive papers or cloths are removed. The direction of the final polishing stage should mainly be longitudinal.

The polishing sequences employed shall be such that the finished test section has a surface texture of at least $0.025 \mu\text{m CLA}$. It may usually be found satisfactory to arrange the sequence of polishing so that the last paper used is 600 grade waterproof silicon carbide paper.

5.5 Storage Prior to Testing — If there is a time interval between final preparation and testing of the test pieces, they shall be examined to ensure that no deterioration of the surface has taken place during the storage prior. If there is any deterioration, for example, corrosion pits, the test piece shall be repolished to remove any surface defects.

NOTE — The procedures given in 5.2, 5.3 and 5.4 represent standard practice for a wide range of materials. It should not be inferred that they are wholly applicable to all materials and to all heat-treated conditions of these materials. For example, the allowance of 0.5 mm on diameter x , for heat-treatment prior to final grinding to size may not be adequate. The purpose of this allowance is to permit the removal of surface phenomena associated with the heat treatment procedure, such as decarburization or distortion, and the allowance shall be such as to ensure the complete removal of any features associated with such effects.

Some fatigue investigations may be undertaken to study the behaviour of material with particular surface finishes, for example, rough-machined, fine machined, or the testing of material in the 'as-received' condition, in which case special conditions would apply.

6. MOUNTING OF TEST PIECE

6.1 Each test piece shall be mounted in the testing machine in such a manner that stresses at the test section, other than those imposed by the applied load, are avoided.

6.1.1 If the bearings transmitting the load are secured to the test piece by means of slit collets, in certain cases it may be desirable for these to be positioned and fully-tightened before the test piece is mounted in the testing machine, in order to prevent an initial torsional strain being imparted. A similar practice may be necessary if the method of securing is by means of an interference fit.

6.1.2 To avoid vibration during the test, coaxiality of the test piece and the driving shaft of the testing machine shall be maintained within close limits. Permissible tolerances are $\pm 0.025 \text{ mm}$ at the chuck end and $\pm 0.013 \text{ mm}$ at the free end (if there is one) for single-point and some

types of two-point loading testing machines. For other types of rotating bending fatigue testing machines, the tolerance on eccentricity measured at two places along the actual test section shall be ± 0.013 mm. The required degree of coaxiality shall be established before applying any load.

NOTE — The recommendations of the testing machine manufacturer shall be followed when mounting test piece in the machine.

7. SPEED OF TESTING

7.1 It is recommended, that tests are carried out within the speed range 1 000 to 9 000 cycles per minute. However, speeds which cause whirling of the test piece shall be avoided.

8. APPLICATION OF LOAD

8.1 The general procedure for attaining full load running conditions shall be the same for each test piece. The testing machine shall be switched on and the desired speed attained before application of load is commenced. The load shall then be applied incrementally or continuously until the required value is attained without shock and as quickly as is convenient. Small adjustments in operating speed may then be made if a particular frequency is required.

The accuracy of the applied bending moment shall be 1 percent.

9. ENDURANCES

9.1 The predetermined number of cycles at which a test is discontinued depends on the material being tested. The S/N curve for certain materials shows a distinct change in slope after a given number of cycles such that later part of the curve is parallel to the horizontal axis. With other materials the shape of the S/N curve may be a continuous curve which will essentially become asymptotic with the horizontal axis. Where S/N curves of the first type are experienced, it is recommended that the endurance to be used as a basis for the determination be 10^7 cycles and, for the second type 10^8 cycles.

10. TEST REPORT

10.1 In reporting fatigue data, the test conditions shall be clearly defined and the test report shall include the following:

- a) The material tested and its metallurgical conditions. Reference can usually be made to the appropriate Indian Standard to which the material was produced;
- b) Thermal treatment, if any, given to the test piece;
- c) The type, dimensions and surface condition of the test piece and the points of load application;

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- d) The method of stressing and the type of machine used. When calibration of the testing machine does not comply with the appropriate part of this standard, the method used should be indicated;
- e) When practicable, the temperature of the test piece, if this is significantly higher than that of the test environment;
- f) The frequency of the stress cycles;
- g) The range of relative humidity if this is outside the range of 50 to 80 percent. The range of relative humidity should be measured every day throughout the duration of the test;
- h) Any deviation from the required conditions during the test;
- j) The endurance basis of the testing programme, for example, 10^7 cycles; and
- k) Criterion of failure, if other than complete failure of the test piece (*see Note*).

NOTE — In the majority of fatigue determinations the criterion of failure is either the occurrence of a visible fatigue crack or complete fracture. It should be noted, however, that in particular applications other criteria, for example, plastic deformation of the test piece or rate of crack propagation, may be adopted to determine the end of the test.

10.1.1 It is preferable to represent the results of the test graphically in one of the forms of representation given in IS : 5619-1970*.



Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002
Telephones : 3 31 01 31, 3 31 13 75 Telegrams : Manaksanstha
(Common to all Offices)

Regional Offices :

Telephone

*Western : Manakalaya, E9 MIDC, Marol, Andheri (East), 6 32 92 95
BOMBAY 400093

†Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, 36 24 99
Maniktola, CALCUTTA 700054

Southern : C. I. T. Campus, MADRAS 600113 41 24 42

Northern : B69 Phase VII, Industrial Focal Point, 8 73 28
S. A. S. NAGAR 160051 (Punjab)

Branch Offices :

'Pushpak', Nurmohamed Shalkh Marg, Khanpur, { 2 63 48
AHMADABAD 380001 { 2 63 49

'F' Block, Unity Bldg, Narasimharaja Square, 22 48 06
BANGALORE 560002

Gangotri Complex, Bhadrabade Road, T. T. Nagar, 6 27 16
BHOPAL 462003

22E Kalpana Area, BHUBANESHWAR 751014 6 36 27

6-8-56C L. N. Gupta Marg, HYDERABAD 500001 22 10 83

R14 Yudhister Marg, C Scheme, JAIPUR 302008 6 98 32

117/418 B Sarvodaya Nagar, KANPUR 208006 4 72 92

Patliputra Industrial Estate, PATNA 800013 8 23 06

Hantex Bldg (2nd Floor), Rly Station Road, 32 27
TRIVANDRUM 695001

Inspection Office (With Sale Point) :

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