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*Indian Standard*  
METHOD OF AXIAL LOAD FATIGUE  
TESTING OF STEEL

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INDIAN STANDARDS INSTITUTION  
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# *Indian Standard*

## METHOD OF AXIAL LOAD FATIGUE TESTING OF STEEL

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# *Indian Standard*

## METHOD OF AXIAL LOAD FATIGUE TESTING OF STEEL

### 0. FOREWORD

**0.1** This Indian Standard was adopted by the Indian Standards Institution on 21 April 1969, after the draft finalized by the Methods of Physical Tests Sectional Committee had been approved by the Structural and Metals Division Council.

**0.2** 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 standard.

**0.3** In the preparation of this standard the details in Draft ISO Recommendation No. 1351 'Axial load fatigue testing' issued by International Organization for Standardization have been considered.

**0.4** 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\*.

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### 1. SCOPE

**1.1** This standard prescribes the method for axial load fatigue test on test pieces without any features involving stress concentrations.

**1.2** This standard does not apply to the fatigue testing of components, thin sheets and strips.

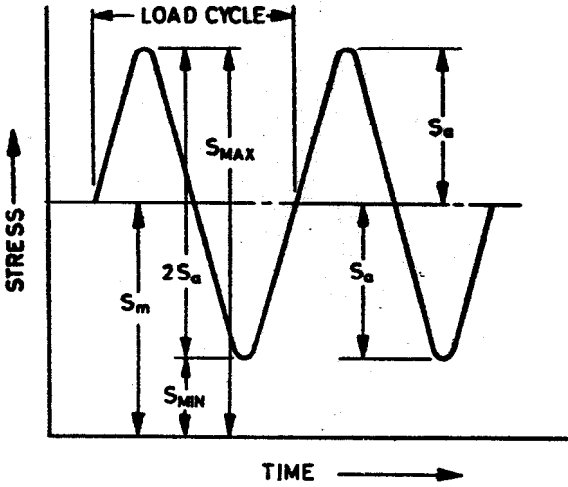
### 2. PRINCIPLE OF TEST

**2.1** Test pieces of identical dimensions indicated herein are used in the types of cyclic stresses illustrated in Fig. 1 (A) and 1 (B). The tests are carried out either to failure, or to a predetermined or specified endurance limit.

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

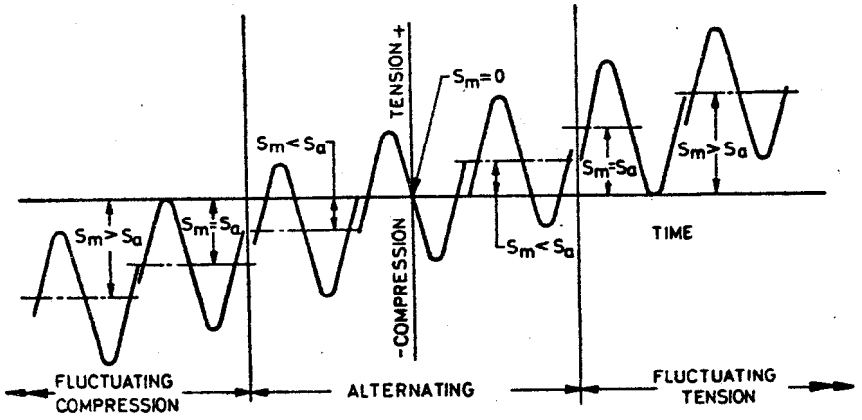
\*Rules for rounding off numerical values (*revised*).

†Specification for atmospheric conditions for testing (*revised*).



I A Stress — Time Curve to Indicate Various Stresses in Stress Cycles

$S_m$  = mean stress                       $S_a$  = stress amplitude  
 $S_{max}$  = maximum stress               $S_{min}$  = minimum stress



I B Types of Cyclic Stresses

Alternating stress : Stress varies from + to -ve through zero  
 Fluctuating stress : Stress varies from + to zero or from -ve to zero over a range

FIG. 1 STRESSES

### 3. SYMBOLS USED AND THEIR INTERPRETATION

3.1 The following symbols have been used in this standard:

<i>Symbols</i>	<i>Interpretation</i>
( see Fig. 2 and 3 )	
<i>D</i>	The diameter of the grip ends of the test piece ( plane or threaded )
<i>d</i>	The diameter of the test piece where the stress is a maximum
<i>L<sub>c</sub></i>	Parallel length
<i>r</i>	*The radius at the ends of the test section which starts the transition from the test diameter <i>d</i> to the end diameter <i>D</i> , or the continuous radius between the grip ends
<i>a</i>	Thickness of rectangular test section
<i>b</i>	Width of test pieces of rectangular cross-section where the stress is a maximum
<i>B</i>	Width of rectangular test pieces at the grip ends

### 4. TEST PIECE

4.1 **Forms of Test Piece** — The test piece shall be of:

- a) Circular cross-section, with tangential blending of fillets between the test section and the ends ( Fig. 2A ), or with a continuous radius between the ends ( Fig. 2B ); or
- b) Rectangular cross-section of uniform thickness over the test section with tangential blending of fillets between the test section and the ends ( Fig. 3A ), or with a continuous radius between the ends ( Fig. 3B ).

NOTE — With rectangular cross-section test pieces, it may be required to reduce the test section in both width and thickness. If this is necessary, then blending fillets will be required in both the width and thickness directions.

4.1.1 The ends of the test piece shall be of a form to suit the type of machine used and the material being tested.

4.1.2 The grip ends of the test piece should be symmetrical about the axis or axes of the reduced test section with certain types of axial load fatigue testing machines, it is necessary that the ends of the test pieces are machined truly square to the axis or axes of the test section.

\*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 end for test pieces of the types shown in Fig. 2A and 3A.

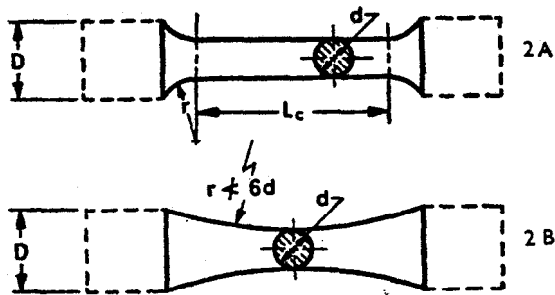


FIG. 2 TEST PIECES OF CIRCULAR CROSS-SECTION

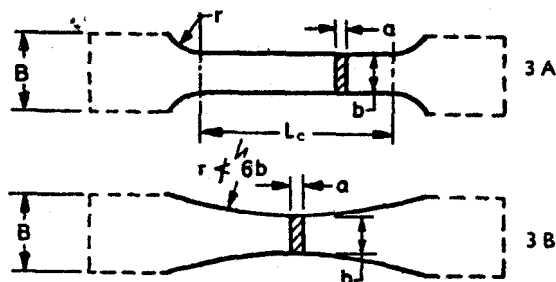


FIG. 3 TEST PIECES OF RECTANGULAR CROSS-SECTION

**4.1.3** In the case of circular and rectangular cross-section test pieces, the continuous radius of the test section should not be less than  $6d$  or  $6b$ , respectively.

**4.1.4** The forms of the test pieces rectangular or circular cross-sections depend upon the nature of particulars required from the tests and naturally the form in which the material is available. Where fundamental fatigue properties are desired, test pieces of circular cross-section are recommended obviously (when materials are available in circular cross-section, test pieces are of circular cross-section). Rectangular cross-section test pieces, naturally, are used for testing sheets or thin plate materials. Production pieces and forgings are usually tested (as far as possible) in circular cross-section since the results obtainable would be more reliable.

**4.2 Dimensions of Test Pieces** — All the test pieces employed for a fatigue determination shall have the same nominal dimensions. When basic fatigue data are required, the following dimensions and tolerances should apply:

a) *Circular Cross-Section* — The nominal value of the diameter  $d$ , where

the stress is at a maximum, shall be between 6 and 12.5 mm. In case of parallel test section, a tolerance in parallelism less than 0.02 mm is permissible.

For the purpose of reckoning the load to be applied to the test piece to obtain the required stress, diameter should be measured accurately up to 0.01 mm ensuring that the smooth surface is not damaged in such measurement.

NOTE — In alternating stress cycles (tension-compression) the ratio  $L_c : d$  should not be greater than 4. To avoid high buckling stress, it is preferable to reduce this ratio as much as possible.

- b) *Rectangular Cross-Section* — Nominal values of the thickness  $a$  and the width  $b$  should be such that the area of the cross-section where the stress is at a maximum is between 30 and 640 mm<sup>2</sup>. The tolerance limit for parallelism, where applicable, is 0.02 mm maximum.

The error in the measurement of dimensions for arriving at area of cross-section should not exceed  $\pm 0.5$  percent in computing the load from the stipulated stress. Care should be taken to avoid any surface damage in the process.

NOTE 1 — A larger range of cross-sectional area is permitted for test pieces of rectangular cross-section than for test pieces of circular cross-section, as the rectangular form is frequently used for obtaining data on sheet and plate material of widely varying thicknesses.

NOTE 2 — The error of measurement permitted for test pieces of rectangular cross-section should take into account the possibility that such test pieces may be tested with their surfaces in the 'as received' condition.

NOTE 3 — In alternating stress cycles (tension-compression) the ratio  $L_c : b$  should not be greater than 4. To avoid high buckling stress, it is preferable to reduce the ratio, as much as possible, while also considering the effect of the ratio of thickness to width of the section.

## 5. PREPARATION OF TEST PIECE

**5.1 Machining** — Care should be taken to ensure that any cutting or machining operation required, either to rough cut 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 machining or grinding procedures, the tool or cutter sharpness and setting, the conditions of the wheel and the grinding machine and speeds and feeds, shall conform to good workshop practice for the material without any overheating effects or introduction of points of stress concentration.



**5.2 Turning** — The following procedure shall be adopted:

- a) In rough turning the test piece from a diameter  $x+5$  mm ( $x$  will generally be 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 and 0.25 mm.
- b) From a diameter of  $x+0.5$  mm to  $x$ , a further succession of cuts of decreasing depth shall be made. The recommended depths of cuts shall be 0.125, 0.075 and 0.05 mm using for these finishing cuts a feed not exceeding 0.06 mm/rev.

**5.3 Milling** — is adopted for the preparation of test piece blanks from billets or plates, and in the case of rectangular cross-section test pieces, for machining such blanks to the finished test piece size.

**5.3.1** In selecting cutting speeds and feed rates, due regard shall be paid to the test piece material and, for finishing cuts, to the quality of the surface finish required.

**NOTE** — It is not practicable to recommend a set procedure for milling. Cutting speeds and depths of cut differ for plain milling and face milling, whilst material composition and conditions also influence the said operations.

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

**5.4.1** The test piece shall then be ground to size. A succession of cuts of decreasing depth shall be made. The recommended depths of cuts shall be the following:

<i>Depth of cut, mm</i>	<i>Overize, mm</i>
0.030	0.1
0.005	0.025
0.002 5	Nil ( cut to size )

**5.5 Surface Finishing** — When the test section has been machined or ground to nominal dimensions, it shall be polished either by hand or by machine, using successively finer grades of paper or cloth based abrasives. The polishing is generally carried out in the longitudinal direction, (although intermediate polishing may be in any direction) to ensure that longitudinal scratches made by the coarser grades of abrasive papers, or cloths, are obliterated. The direction of the final polishing stage shall mainly be longitudinal.

**5.5.1** The polishing sequences employed shall be such that the finished test section has a surface texture of at least 0.025 microns CLA. It will usually be found satisfactory to arrange the sequence of polishing, so that the last paper used is 600 grade waterproof silicon carbide paper.

**5.6 Storage Prior to Testing** — If there is an interval between final preparation and testing of the test pieces, they shall be examined to ensure that no deterioration of the surface has occurred in storage. If there is any deterioration the test piece shall be repolished to remove any surface defects, such as corrosion pits.

**NOTE 1** — The procedures laid down in 5.3, 5.4, 5.5 and 5.5.1 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, distortion, etc, 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.

**NOTE 2** — With rectangular test pieces burrs and sharp corners should be removed. This may normally be done by hand with a fine grade of abrasive paper.

## **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.

**6.2** The test piece should be so mounted in the grips that the load applied is axial and the intended stress pattern is assured. In the case of rectangular test pieces it should be ensured that the load applied is evenly distributed over the test piece cross-section. In the case of circular cross-section test pieces which are screwed at the ends, the tightening sequence of the test piece locking nuts should be such as to avoid torsional strains in the test piece.

**NOTE** — The recommendations of the testing machine manufacturer should be followed in mounting test pieces into the machine.

## **7. SPEED OF TESTING**

**7.0** The frequency of the stress cycle will depend upon the type of testing machine employed, and in many cases upon the stiffness of the test piece.

**7.1** The testing speed shall be that which is most suitable for the particular combination of material, form of test piece and testing machine with due

regard to the effect of heating which may occur due to rapid dissipation of strain energy in the test piece.

NOTE — The frequency range of axial load fatigue testing machines in common use is approximately 250 to 18 000 c/min.

## 8. APPLICATION OF LOAD

8.1 The general procedure for attaining full load running conditions shall be the same for each test piece. The load shall be applied axially.

8.2 If the frequencies are determined from the dynamic characteristics of the test piece and testing machine combination, it may be necessary to measure the stiffness of the test piece before testing.

8.3 In general, the application of the mean load is followed by an adjustment of the fluctuating load.

8.4 Where testing machines operate on the resonance principle, care shall be taken to adjust the running speed so as not to exceed the required load.

8.5 During the early stages of the test the load shall be frequently checked to ensure that the required conditions are maintained. The load maintaining devices and the test pieces fracture cut-off switches should then be adjusted and set.

8.6 At frequent intervals throughout the test period, the load shall be monitored to ascertain that the load conditions have not changed.

8.7 The mean load and the load range as determined by a suitable method of dynamic calibration shall be known to within 3 percent of the maximum load of the cycle or 0.5 percent of the maximum load of the machine, whichever is the greater.

NOTE — Some users of axial load fatigue testing machines rely entirely on static calibration using elastic proving devices. This does not take account of the dynamic response of the testing machine dynamometer, which may be appreciably different from the static behaviour; a dynamic calibration is to be preferred. It is not considered feasible at the present time to attempt to standardize a method, but techniques involving the oscillation or reciprocation of masses, such as those depending on the rotation of a mirror, are not recommended since errors introduced by inertia of the masses may be significant.

## 9. ENDURANCE

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 of slope in a given number of cycles such that the latter 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 eventually become asymptotic to 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  $10^7$  c and, for the second type,  $10^8$  c.

## 10. TEST REPORT

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

- a) The material tested and its metallurgical condition;
- b) Thermal treatment, if any, given to the test piece;
- c) The type and dimensions of the test piece;
- d) The type of stress cycle, the mean stress, the stress range and the type of testing machine used;
- e) Where practicable the temperature of the test piece, if this is significantly higher than that of the test environment;
- f) Frequency of the stress cycle;
- 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 test programme (namely,  $10^7$  c): and
- k) Criterion of failure, if other than complete failure of the test piece (see Note 1).

**NOTE 1** — In the majority of fatigue determinations of the criterion of failure is either the occurrence of visible fatigue cracks 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.

**NOTE 2** — It is preferable to represent the results of the tests graphically.

# INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

## Base Units

Quantity	Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

## Supplementary Units

Quantity	Unit	Symbol
Plane angle	radian	rad
Solid angle	steradian	sr

## Derived Units

Quantity	Unit	Symbol	Conversion
Force	newton	N	1 N = 1 kg·m/s <sup>2</sup>
Energy	joule	J	1 J = 1 N·m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V·s
Flux density	tesla	T	1 T = 1 Wb/m <sup>2</sup>
Frequency	hertz	Hz	1 Hz = 1 c/s (s <sup>-1</sup> )
Electric conductance	siemens	S	1 S = 1 A/V
Pressure, stress	pascal	Pa	1 Pa = 1 N/m <sup>2</sup>

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