INTERNATIONAL STANDARD ISO 1099

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Metals — Axial load fatigue testing

Métaux — Essais de fatigue par charge axiale

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FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up has the right to be represented on that Committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

Prior to 1972, the results of the work of the Technical Committees were published as ISO Recommendations; these documents are now in the process of being transformed into International Standards. As part of this process, Technical Committee ISO/TC 17 has reviewed ISO Recommendation R 1099 and found it technically suitable for transformation. International Standard ISO 1099 therefore replaces ISO Recommendation R 1099-1969 to which it is technically identical.

ISO Recommendation R 1099 was approved by the Member Bodies of the following countries :

Australia	India	Romania
Brazil	Israel	South Africa, Rep. of
Canada	Italy	Spain
Colombia	Japan	Switzerland
Czechoslovakia	Korea, Rep. of	Thailand
Denmark	Netherlands	Turkey
Finland	Norway	United Kingdom
Germany	Peru	U.S.A.
Hungary	Poland	U.S.S.R.

The Member Bodies of the following countries expressed disapproval of the Recommendation on technical grounds :

Belgium*
France
New Zealand**
Sweden*

* Subsequently, this Member Body approved the Recommendation.

** Subsequently, this Member Body abstained from voting.

No Member Body disapproved the transformation of ISO/R 1099 into an International Standard.

Metals — Axial load fatigue testing

1 SCOPE

This International Standard specifies the conditions for carrying out axial load fatigue tests on test pieces without deliberately introduced stress concentrations. The tests are carried out at room temperature, in air, the loading applied to the test piece being along the longitudinal axis passing through the centroid of each cross-section.

While the form, preparation and testing of test pieces of circular and rectangular cross-section are described, component testing and other specialized forms of test are not included in this International Standard. Tests on very thin test pieces of rectangular cross-section are not covered by this International Standard.

Results of fatigue tests may be affected by atmospheric conditions, and where controlled conditions are required, sub-clause 2.1 of ISO/R 554 applies.

2 FIELD OF APPLICATION

Tests are made to determine fatigue properties such as the *S/N* curve described in ISO/R 373.

3 REFERENCES

ISO/R 373, *General principles for fatigue testing of metals.*

ISO/R 554, *Standard atmospheres for conditioning and/or testing — Standard reference atmosphere — Specifications.*

4 PRINCIPLE OF TEST

Nominally identical test pieces are mounted in an axial load type fatigue testing machine and subjected to the required loading conditions, which introduce any one of the types of cyclic stress illustrated in figure 3 of ISO/R 373. The test is continued until the test piece fails or until a pre-determined number of stress cycles has been exceeded. (See clause 11.)

NOTE — For definitions of failure, see ISO/R 373.

5 SYMBOLS AND DEFINITIONS

In this International Standard the following symbols (see figures 1 and 2) are used :

Symbol	Definition
D	Diameter of the gripped ends of the test piece if plain, or overall diameter of the threaded ends
d	Diameter of the test piece where the stress is a maximum
L_c	Parallel length
r	Radius[1] at the ends of the test section which starts the transition from the test diameter d or test width b to the diameter D or width B of the gripped ends; or the continuous radius between the gripped ends of the test piece
a	Thickness of test section of test pieces of rectangular cross-section
b	Width of test pieces of rectangular cross-section where the stress is a maximum
B	Width of test pieces of rectangular cross-section at the gripped ends

Further symbols and definitions relating to fatigue testing are given in ISO/R 373.

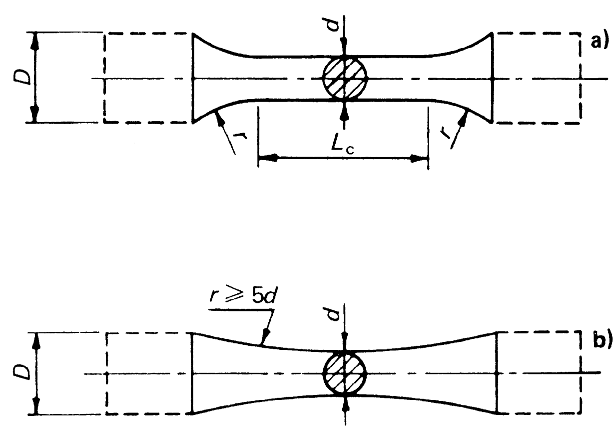

FIGURE 1 — **Test pieces of circular cross-section**

1) This curve need not be a true arc of a circle over the whole of the distance between the end of the test section and the start of the enlarged end for test pieces of the types shown in figures 1a) and 2a).

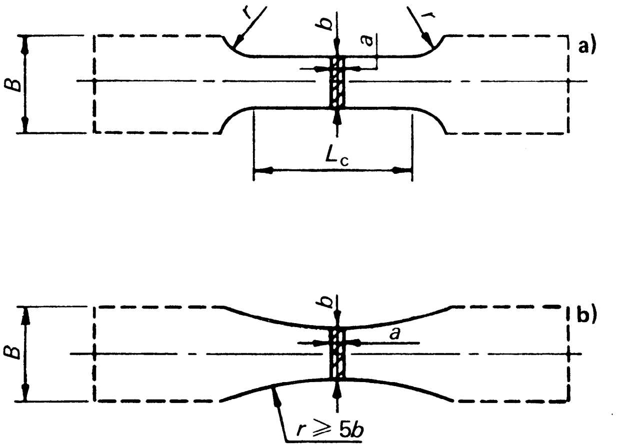

FIGURE 2 — **Test pieces of rectangular cross-section**

6 SHAPE AND SIZE OF TEST PIECE

6.1 Form of test piece

The test piece may be of

a) circular cross-section, with tangentially blending fillets between the test section and the ends (figure 1a), or with a continuous radius between the ends (figure 1b);

b) rectangular cross-section of uniform thickness over the test section with tangentially blending fillets[1] between the test section and the gripped ends (figure 2a), or with a continuous radius between the ends (figure 2b).

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

The gripped ends of the test piece shall be symmetrical about the axis or axes of the reduced test section. With certain types of axial load fatigue testing machines, it is important that the ends of the test pieces shall be machined truly square to the axis or axes of the test section.

For either form of test piece where the test section is formed by a continuous radius, this radius shall be not less than 5*d* or 5*b*.

The type of test piece employed will depend on the information required from the test and the form in which the material is available. If basic fatigue properties of a material are to be determined, it is preferable, where practicable, to use test pieces of circular cross-section. For materials in round bar form, test pieces of circular cross-section are an obvious choice. Test pieces of rectangular cross-section are always used for testing materials in the form of sheet or thin plate. For production material in large sections, for example forgings, either form of test piece may be employed, but it should be noted that the form of the cross-section of the test piece may affect the value of the results obtained from the test.

6.2 Dimensions of test pieces

All the test pieces employed for a fatigue determination shall have the same nominal dimensions.

When fundamental characteristics of a metal from a fatigue point of view are required, the following dimensions and tolerances apply :

6.2.1 *Circular cross-section*

The nominal value of the diameter *d*, where the stress is at a maximum, shall be between 6 mm (0.25 in) and 12,5 mm (0.5 in). Where possible, the tolerance on shape of the cylindrical portion shall be parallel within 0,02 mm (0.001 in).

In the case of test pieces taken from very short samples, a diameter of less than 6 mm may be used to obtain a standard test piece.

For the purpose of calculating the load to be applied to obtain the required stress, the actual minimum diameter of each test piece shall be measured to an accuracy of 0,01 mm (0.000 5 in). Care shall be taken during the measurement of the test piece prior to testing that the surface is not damaged.

NOTE — In tests where the stress cycle runs into compression the ratio L_c/d shall not be greater than 4. It may be necessary to reduce this ratio considerably, to avoid high stresses due to buckling.

6.2.2 *Rectangular cross-section*

Nominal values of the thickness, *a*, and the width, *b*, shall be such that the area of the cross-section where the stress is at a maximum is between 32,2 mm² (0.05 in²) and 645 mm² (1.0 in²). Where possible, the tolerance on shape of the rectangular section shall be parallel within 0,02 mm (0.001 in).

For the purpose of calculating the load to be applied to obtain the required stress, the cross-sectional area shall be calculated from measurement of the appropriate dimensions with a tolerance of not more than ± 0,5 % in each dimension. Care shall be taken during the measurement of the test piece prior to testing that the surface is not damaged.

NOTES

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 of widely varying thicknesses.

2 The tolerance on the measurement permitted for test pieces of rectangular cross-section takes into account the possibility that such

1) With test pieces of rectangular cross-section, 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.

test pieces may be tested with their surfaces in the "as received" condition.

3 In tests where the stress cycle runs into compression the ratio L_c/b shall not be greater than 4. It may be necessary to reduce this ratio considerably to avoid high stresses due to buckling. It may be necessary, also, to consider the ratio of the thickness to the width in relation to buckling stresses.

7 PREPARATION OF TEST PIECE

7.1 Method of machining

It is necessary to ensure that any cutting (for example contour profiling by flame cutting) or machining operation required, either to rough the test piece out from the blank or to machine it to size, does not alter the metallurgical structure or properties of the test piece. All cuts taken in machining should be such as to minimize work-hardening of the surface of the test piece. Grinding may be used, particularly in finishing to size test pieces of the harder steels, but an adequate supply of coolant should be ensured so as to avoid undue heating of the surface. (See sub-clause 4.2 of ISO/R 373.)

Throughout any machining or grinding procedures, the tool or cutter sharpness and setting, the conditions of the wheel and the grinding machine and speeds and feeds should conform to good workshop practice for the material commensurate with the requirements of 7.2, 7.3, 7.4 and 7.5.

7.2 Turning

It is recommended that the following procedure should be adopted :

7.2.1 In rough turning the test piece from a diameter of $x + 5$ mm ($x + 0.2$ in) (x will generally be the diameter, d, plus a suitable allowance for surface finishing) to $x + 0{,}5$ mm ($x + 0.02$ in), a succession of cuts of decreasing depth should be made, the recommended depths of cut being as follows :

1,25 mm (0.05 in)

0,75 mm (0.03 in)

0,25 mm (0.01 in)

7.2.2 From a diameter of $x + 0{,}5$ mm ($x + 0.02$ in) to x, a further succession of cuts of decreasing depth should be made, the recommended depths of cut being as follows :

0,125 mm (0.005 in)

0,075 mm (0.003 in)

0,05 mm (0.002 in)

For these finishing cuts a feed not exceeding 0,06 mm (0.002 5 in) per revolution should be used.

7.3 Milling

This process may be applied in the extraction of test piece blanks from billets or plates and, in the case of test pieces of rectangular cross-section, for machining such blanks to the finished test piece size.

In selecting cutting speeds and feed rates, due regard should 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, while material composition and conditions also influence these values.

7.4 Grinding

For test pieces in material which cannot be readily turned, it is recommended that the finishing operations be carried out by grinding.

The test piece should then be ground to size. A succession of cuts of decreasing depth should be made, the recommended values being as follows :

— 0,030 mm (0.001 2 in) depth of cut to 0,1 mm (0.004 in) oversize;

— 0,005 mm (0.000 2 in) depth of cut to 0,025 mm (0.001 in) oversize;

— 0,002 5 mm (0.000 1 in) depth of cut to size.

7.5 Surface finishing

When the test section has been machined or ground to nominal dimensions, it should be polished either by hand or by machine, using successively finer grades of abrasive papers or cloths. The polishing should generally be in a 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 polishing at the final stage should be mainly longitudinal.

The polishing sequences employed should be such that the finished test section has a surface texture of not rougher than 0,025 μm (centreline average).

7.6 Storage prior to testing

If there is an interval between final preparation and testing of the test pieces they should be examined by appropriate means to ensure that no deterioration of the surface has taken place during the storage period. If there is any deterioration the test piece should be re-polished to remove any surface defects, for example corrosion pits.

With rectangular test pieces it is recommended that burrs and sharp corners be removed. This can normally be done by hand with a fine grade of abrasive paper.

NOTE — The procedures described in 7.2, 7.4 and 7.5 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 (0.02 in) 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 material affected by surface phenomena associated with the heat treatment procedure, such as decarburization, distortion, etc.; the allowance used in practice should be sufficient 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 in the "as received" condition) in which case special conditions would apply.

8 MOUNTING OF TEST PIECE

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.

Care shall be taken to ensure that each test piece is located in the top and bottom grips so that the load is applied axially, and that the intended stress pattern is imposed. With rectangular test pieces it may be important to ensure that the load is evenly distributed over the test piece cross-section. Where test pieces of circular cross-section are screwed at the ends, the tightening sequence of the test piece locking nuts shall be carried out in such a manner that no torsional stresses are imparted to the test piece.

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

9 SPEED OF TESTING

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.

The frequency chosen shall be that which is most suitable for the particular combination of material, test piece and testing machine, having particular regard to the heating which can 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 cycles per minute.

10 APPLICATION OF LOAD

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

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 commencement of testing.

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

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

The mean load and the load range as determined by a suitable method of dynamic calibration shall be known to within 3 % of the maximum load of the cycle or 0,5 % 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 by means of 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 and an International Standard on this subject is in the course of preparation.

11 ENDURANCES

The predetermined number of cycles at which a test is discontinued will generally depend 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 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.

12 TEST REPORT

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

12.1 The material tested, its dimensions, its metallurgical characteristics and the surface condition of the test piece; reference can usually be made to the appropriate International Standard to which the material was produced.

12.2 The type of stress cycle, the mean stress, the stress range and the type of testing machine used.

12.3 The type and nominal dimensions of the test piece.

12.4 The frequency of the stress cycle.

12.5 Where practicable, the temperature of the test piece, if this is significantly higher than that of the test environment.

12.6 The range of relative humidity if this is outside the range of 50 to 70 %. The range of relative humidity shall be measured every day throughout the duration of the test.

12.7 The criterion of the end of the test; i.e. its duration (for example 2×10^6 cycles), or complete failure of the test piece, or some other criterion (see note 1).

12.8 Any deviation from the required conditions during the test.

12.9 Thermal treatment, if any, given to the test piece.

NOTES

1 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.

2 Test results may be presented graphically. Appropriate forms of presentation are illustrated in ISO/R 373.

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