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Tensile testing systems — Determination of *K*-value

Systèmes d'essai de traction — Détermination de la valeur K

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FOREWORD

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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.

International Standard ISO 2573 was developed by Technical Committee ISO/TC 17, *Steel*, and was circulated to the member bodies in July 1976. Subsequently, responsibility for this document was transferred to ISO/TC 164, *Mechanical testing of metals*, which was set up in 1975.

The document has been approved by the member bodies of the following countries :

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Tensile testing systems — Determination of K-value

0 INTRODUCTION *

0.1 The International Standards (see clause 2) for the tensile testing of steel include a requirement that the strain rate during yielding should be controlled when an upper yield stress is to be measured. Some tensile testing systems are so constructed that a predetermined strain rate can be imposed on the test piece. Other systems include ancillary equipment such that the strain rate can be measured directly and its control may therefore be possible.

0.2 A number of tensile systems are used, however, in which there is no possibility of directly maintaining the strain rate. With some of these systems an indirect method has to be employed, this requiring a knowledge of the K-value of the system, namely the apparent elastic compliance of the system (deflection per unit force), determined from a tensile test performed in accordance with clause 8. In order to determine a K-value, it is necessary to perform an actual tensile test using the required method of gripping, measurements made during the course of this test enabling the K-value to be calculated.

0.3 A necessary condition for the method of determining the K-value of a tensile testing machine, as is described below, is an almost constant speed of the moving grip (see clause 7), whilst measurements are made according to 8.1.5. This ensures that the rate of increase of force in the elastic range of deformation of the test piece remains constant.

The following types of machines comply with this requirement :

a) machines provided with position control;

b) machines with mechanical driving systems, provided that there is no drop in speed once the driving velocity is set and the force is increased;

c) some machines with hydraulic driving systems with very slight leakage of oil.

However, if the conditions in clause 7 are given up, it is also possible to test some of the remaining machines concerning their compliance (K-value).

If the machines are equipped with a pace setter or a recording device, a constant speed of the moving grip can be attained up to the limit between the elastic and the plastic range of the test piece by suitable control of the driving system.

Using hydraulic machines with a ground piston, it is therefore permitted to compensate for the leakage of oil by opening the control valve more.

1 SCOPE AND FIELD OF APPLICATION

This International Standard specifies the method of determining the mechanical characteristic known as the K-value, of tensile testing systems having an essentially constant extension rate when force is increased (used for the determination of yield stresses in accordance with relevant ISO publications).

2 REFERENCES

ISO 82, *Steel — Tensile testing.*

ISO 86, *Steel — Tensile testing of sheet and strip less than 3 mm and not less than 0,5 mm thick.*

ISO 89, *Steel — Tensile testing of wire.*

ISO/R 147, *Load calibration of testing machines for tensile testing of steel.*

ISO 375, *Steel — Tensile testing of tubes.*

3 PRINCIPLE

Using a suitable test piece mounted in the testing system, measurements are made of its extension rate during elastic loading and during yield when the force remains sensibly constant. The ratio of these two extension rates is used to calculate the *K*-value for the system for the particular test condition.

The determination is carried out at ambient temperature.

4 SYMBOLS AND DEFINITIONS

For the purpose of this International Standard, the following symbols and definitions apply. Other symbols and definitions relating to tensile testing are given in the relevant ISO publications.

4.1 Symbols

The symbols used are as follows :

Symbol	Designation
L_c	Parallel length of test piece
S_o	Original cross-sectional area of the gauge length
v	Extension rate of the parallel length of the test piece
v_e	Extension rate during elastic extension
v_p	Extension rate during yielding at constant force
E	Modulus of elasticity
K	The *K*-value of a tensile testing system under particular test conditions

4.2 Definitions

4.2.1 testing system : The tensile testing machine, including the whole of the mechanical system for applying and measuring the force on the test piece. It includes the framework of the machine, the straining mechanism (driving system) the force-measurement device, the grips and attachments by which the test piece is held and their position, the test piece excluding its parallel portion and, possibly, the position of the piston.

4.2.2 test piece : The piece of steel, inserted into the machine to complete the system, used in the determination of *K*. (It may be of conventional form or specially prepared — see 5.2.)

4.2.3 parallel length of test piece (L_c) : The length of the parallel reduced central portion of a test piece, measured before a determination of *K*, over which yield occurs.

4.2.4 original cross-sectional area of the gauge length (S_o) : The cross-sectional area of the parallel length, L_c, measured prior to a determination of *K*.

4.2.5 extension rate (v) : The rate of increase of the parallel length of the test piece. In particular, distinction is made between the extension rate during elastic extension (v_e) and extension rate during yielding at constant force (v_p); see also 8.2.

4.2.6 operative elastic range : The range in which extension of the test piece is linearly proportional to the force applied.

4.2.7 *K*-value (K) : The apparent elastic compliance of a testing system (deflection per unit force) determined from a tensile test performed in accordance with clause 8.

NOTE — *K*-values depend on the construction of the testing system (see 4.2.1) and may also depend on other variables such as the force, and the range of forces applied.

5 TEST PIECES FOR DETERMINING *K*

5.1 The material selected for the determination of *K* shall be one which exhibits a sharp transition from elastic to plastic extension at essentially constant force (see figure 1). This characteristic may be obtained by using a test piece of material which shows the yield phenomenon [figure 1 (1)] or by using a suitably cold-worked test piece [figure 1 (2)]. If the test piece is cold-worked by pulling in the testing machine, it shall be unloaded and repositioned in the grips before determining *K*.

5.2 Form of test piece

5.2.1 The tensile test piece, prepared from the selected material, may be in the form of a conventional test piece (see relevant ISO publications). Test pieces should preferably be of geometry, size (except for the parallel length) and gripping arrangements nearly equal to those for which control of strain rate is required in subsequent testing. However, the longest parallel length for which a suitable type of extensometer is available shall be selected; see also 5.2.2. The cross-sectional area of the reduced portion shall be such that yield will occur at the required force.

5.2.2 It is preferable to allow for the attachment of an extensometer which spans the reduced portion and is connected to the test piece at the unreduced ends. In any case, the extensometer shall span at least 80 % of the parallel length.

6 PRELIMINARY CHECKS

6.1 The procedure described in clauses 7 and 8 shall not be commenced unless the testing machine complies with the appropriate grading given in ISO/R 147 and is in good working order.

6.2 The machine shall be operated in accordance with the manufacturer's instructions.

7 DETERMINATION OF CONSTANCY OF RATE OF INCREASE OF FORCE IN EACH FORCE RANGE

7.1 Mount an elastic test piece in the testing system; to ensure that the test piece is firmly gripped, apply and remove a force at least as great as that to be used in the determination.

NOTES

1 The elastic test piece may be a tensile test piece of steel having a larger diameter or higher yield strength than usual for the force range or a test piece of normal size which is first loaded until appreciable work-hardening has occurred and then unloaded. Such a test piece may be used repeatedly.

2 In universal testing machines, the determination may be carried out in compression using either the compression platens themselves or a block of steel as the elastic member. The K-value determined in compression cannot be used for the traction test as the gripping of the test piece is not taken into account. In this case it is only the coefficient of elasticity of the bed-plate of the machine that is at issue.

7.2 For determining the constancy of rate of increase of force of the testing system, two series of measurements of force against time are required. Make these series at the rates of force application which will be used in the subsequent determination of K; see clause 8. In each case, once the controls have been set, do not alter them until the measurements have been completed. For each series of measurements, prepare a graph of force against time; see figure 2. The difference in rate of increase of force measured at 80 % and 105 % respectively of the expected yield force to be used in the determination of K shall not be greater than ± 20 % of the mean of the two rates. This may be determined from the formula

$$\tan \alpha_1 - \tan \alpha_2 \leqslant 0{,}2 \frac{(\tan \alpha_1 + \tan \alpha_2)}{2}$$

where α_1 and α_2 are the angles shown in figure 2.

7.3 If the requirements in 7.2 are not met within a particular force range, then a K-value cannot be determined for that range.

8 DETERMINATION OF K-VALUES

8.1 Procedure

Provided that the conditions specified in 7.2 are met, determine the K-values for the force ranges under consideration as follows :

8.1.1 Measure the dimensions of the test piece to be used for the determination including the length of the whole of the parallel portion. Fit the test piece in the testing machine in accordance with the normal testing procedure.

8.1.2 The deviation from true displacement of the extensometer used, including any ancillary electronic or autographic equipment, shall not exceed 0,01 mm for displacements up to and including 0,5 mm and shall be not greater than 2 % of the recorded value for displacements above 0,5 mm.

8.1.3 Determine two values of K for each force range, one at approximately 20 % and the other at approximately 65 % of the maximum force that can be applied to each range to be used in subsequent testing (see figure 2).

8.1.4 Produce, for each determination of K, a force-extension diagram at the time at which the determination is made. Do not alter the controls of the testing system after the curve becomes linear.

8.1.5 At the same time as the force-extension diagram is produced (see 8.1.4), take sufficient extension readings with respect to time during the upper third of the operative elastic range and during subsequent plastic extension to enable a graph of total extensometer reading against time to be plotted accurately.

8.2 Calculation of K

8.2.1 On the graph obtained (see 8.1.5), fit two straight lines, one covering at least the upper third of the operative elastic range (figure 3, slope A) and the other covering the range during which yielding occurs and the force remains sensibly constant (figure 3, slope B). Irregular changes at the start of the test and both immediately before and immediately after yielding may be ignored. Determine the slopes of the two lines in any convenient units (for example millimetres per second, unit of extensometer reading per second). The ratio of the slope associated with yield to the slope associated with elastic loading is equal to the ratio v_p/v_e (see 4.2.5).

8.2.2 Calculate the K-value of the testing system from the following equation :

$$K = \frac{L_c (v_p/v_e - 1)}{E S_o}$$

NOTES

1 The value of K will be in millimetres per newton where L_c is expressed in millimetres, S_o is expressed in square millimetres, E is expressed in newtons per square millimetre and v_p/v_e is a ratio.

2 The value of the modulus of elasticity of the test material, E, which appears in the equation may be taken from published typical values. It need not be accurately determined for the particular material being used.

9 ASSESSMENT OF K

9.1 The average of the determinations in the force ranges under consideration shall be regarded as the K-value of the testing system provided that no individual determination differs from the average by more than ± 50 %. If an individual determination differs from the average by more than ± 50 %, K-values for the individual ranges as determined in 8.1 shall be stated. The mean of the two K-values determined in an individual range is then regarded as the K-value for that range, provided that the individual determinations do not differ by more than ± 50 % from their mean. If they differ by more than ± 50 % in the range under consideration, a K-value for that range cannot be stated.

9.2 Since the *K*-value for wedge grips is always greater than for positive grips, the value obtained for wedge grips may, if desired, be used for subsequent tests when positive gripping arrangements are employed. When wedge grips are used, it will be found that, depending on the size of the test piece, the value of *K* increases markedly below certain minimum force levels. In such cases, for the determination of yield stresses at low forces, it is permissible to use the *K*-value determined in accordance with clause 8.

NOTE — It is acknowledged that the actual *K*-value at very low forces may be considerably greater than at higher forces. However, since the cross-sectional area of the test piece is correspondingly small, the two effects tend to cancel each other and thus the stressing rates specified in the relevant ISO publications are unlikely to be exceeded.

10 RE-TESTING

10.1 Subsequent checks of the *K*-value shall be made, for example during periodic inspection and/or verification of the testing system.

10.2 For testing systems where the *K*-value is known to be reasonably constant over the ranges of forces which are applied in the determination of yield stresses, the check may consist of a single determination using only one of the force ranges. For this check, wedge grips may be used if these were employed in the determination of *K*; see also 9.2.

10.3 Provided that the check described in 10.2 gives a value of *K* which is within ± 50 % of the value established by 9.2, the *K*-value of the testing system may be regarded as unchanged. If the check gives a value outside these limits, a redetermination of *K* shall be carried out; see clause 8.

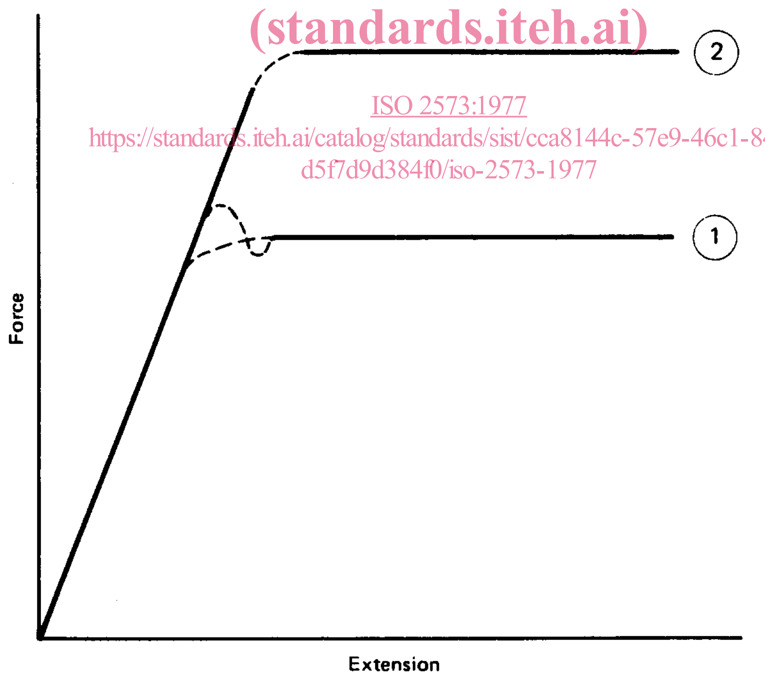

FIGURE 1 — **Typical force-extension diagrams for test-piece material**

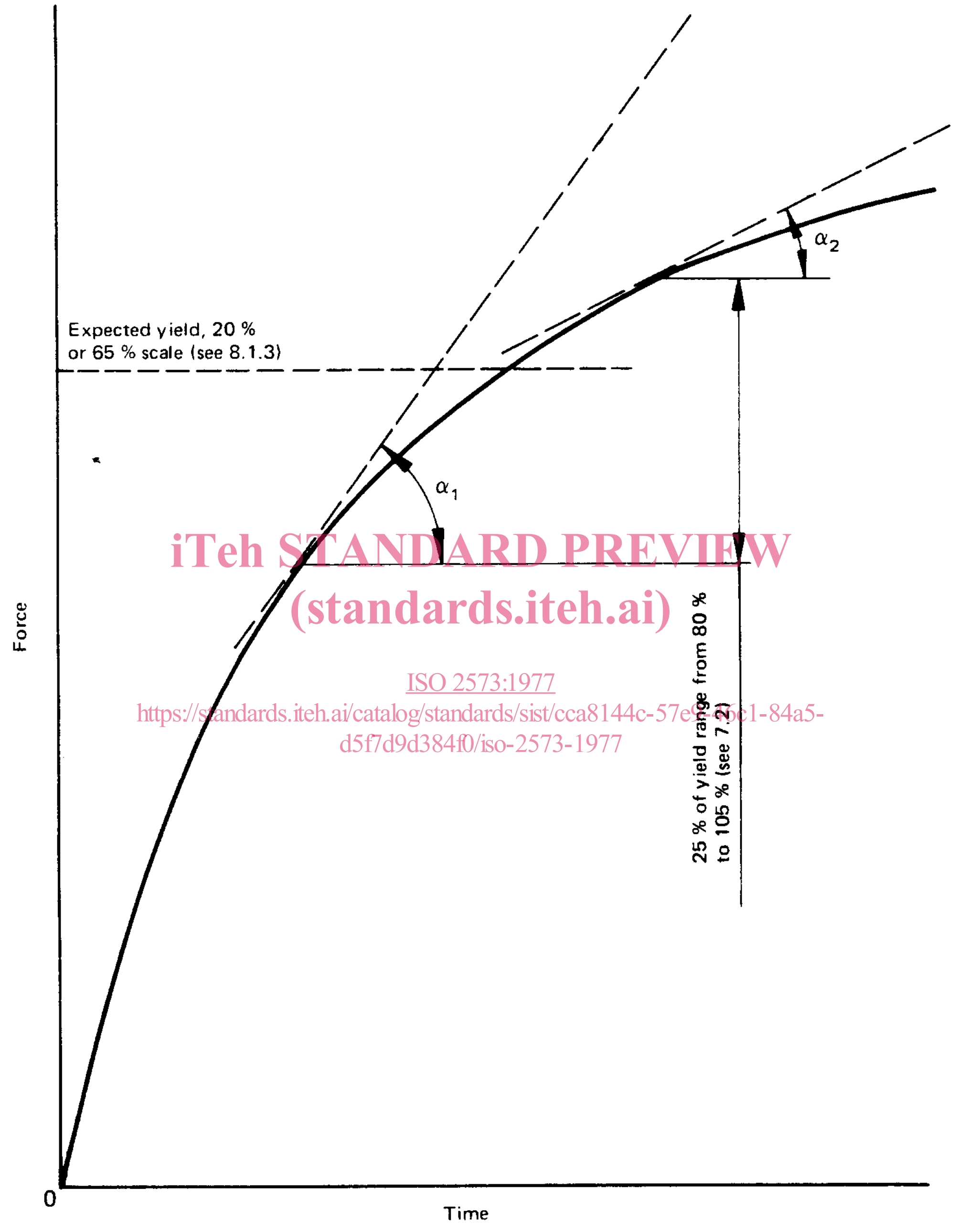

FIGURE 2 — **Example of graph for determining constancy of rate of increase of force in each force range**

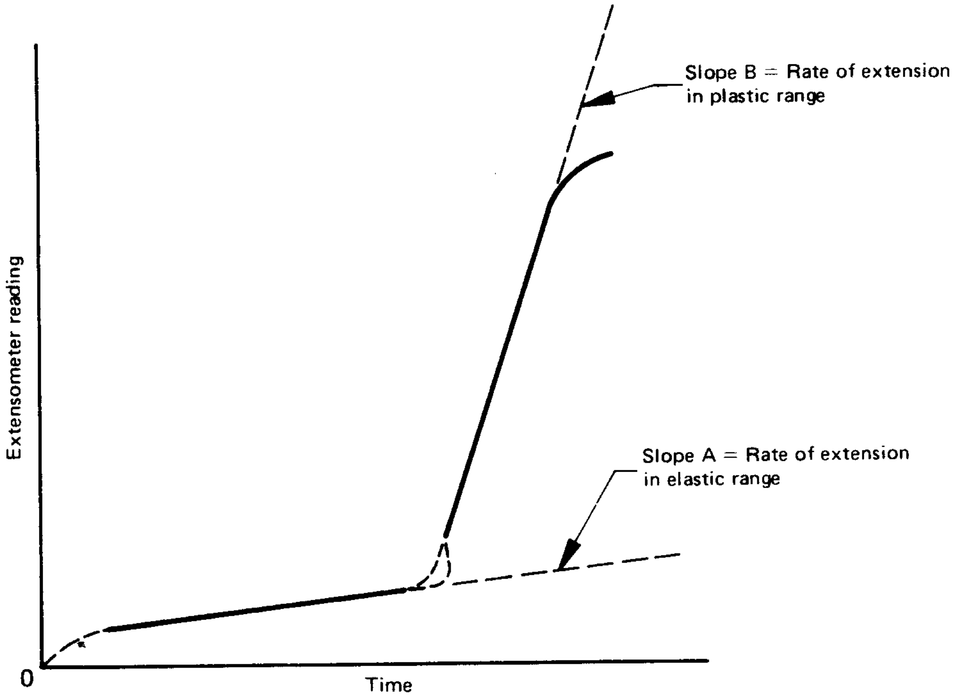

FIGURE 3 — Graph from which ratio v_p/v_e is determined