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Metallic materials — Tensile testing —

Part 5: Specification for testing miniaturised test pieces

Matériaux métalliques — Essais de traction —

Partie 5: Spécifications pour l'utilisation d'éprouvettes d'essai miniaturisées

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Foreword

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This document was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 1, *Uniaxial testing*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 459/SC 1, *Test methods for steel (other than chemical analysis)*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 6892 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The knowledge of the local strength properties and local flow curves of formed component areas becomes increasingly important for different applications. However, their determination by tensile testing is often restricted because of the possible test piece geometry, the availability of suitable testing equipment and the comparability with the results of the standard tensile tests. By using adjusted test piece geometries, suitable test piece preparation, adapted clamping and extensometer systems and finally an adjusted test procedure tensile test can be performed which gives reproducible and comparable test results.

In this document suggestions are given to perform tensile tests on miniaturised test pieces. It describes the state of the art of testing using adjusted standard testing equipment.

It is pointed out that the experimental effort (test piece preparation, adjustment and alignment of the testing equipment and also the fine motor skills) is higher than for testing of typical standard test piece geometries.

Metallic materials — Tensile testing —

Part 5:
Specification for testing miniaturised test pieces

1 Scope

This document provides specifications for testing miniaturised metallic test pieces where not enough material is available for test pieces according to ISO 6892-1.

The guidelines in this document are not intended to replace the requirements of the standard method described in ISO 6892-1.

This document refers to conventionally manufactured materials.

NOTE 1 Additional information regarding testing of additively manufactured materials are given in ISO/ASTM 52909[5].

NOTE 2 Further information on the performance of miniaturised test pieces in tensile testing and the comparability of respective results is available in References [8] to [14].

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

ISO 9513, *Metallic materials — Calibration of extensometers used in uniaxial testing*

3 Terms and definitions

For the purposes of this document, the terms, definitions and symbols given in ISO 6892-1 apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 Principle

The test involves straining a test piece by tensile force, typically to fracture, for the determination of mechanical properties in accordance with ISO 6892-1.

This document shall only be applied in cases where not enough material is available for test pieces in accordance with ISO 6892-1.

Caution should be taken at the determination of the elongation after fracture. Because of small test pieces the factor of proportionality can be different. If so, the determined values for elongation after fracture cannot be comparable (see Figure 3). The reduction of area might also be affected by the size of the cross-section.

The test shall be carried out at room temperature between 10 °C and 35 °C, unless otherwise specified.

Room temperature tests under controlled conditions shall be carried out at a temperature of 23 °C ± 5 °C.

NOTE If the aim of the test is testing at elevated or low temperature as specified before, additional information can be found in ISO 6892-2[1] or ISO 6892-3[2], respectively. There can be interactions at elevated or low temperatures, e.g. oxidation and its influence on material properties.

5 Test piece

5.1 Test piece design and adaptation

It is necessary to adapt the shape and dimensions of the test pieces to the shape and dimensions of the metallic product from which the test pieces are taken. The gripped ends shall be adapted to the available clamping system, whereby a very precise axial clamping is essential to get suitable testing results (for verification of the complete test see Clause 10). Several form fitting systems are appropriate, e.g. thread, shoulder or pin connection (Figures 1 and 2). If force clamping systems are used, procedures shall be implemented to avoid any axial compression of the sample e.g. by using modified clamp jaws or sample heads.

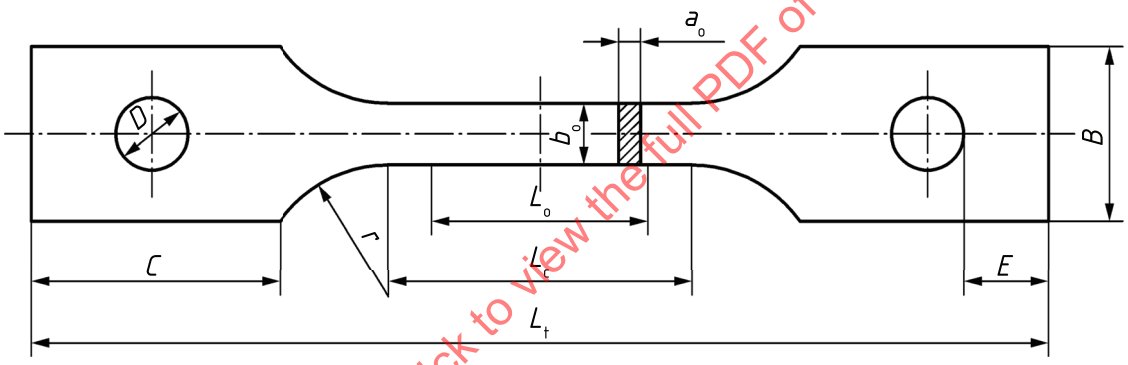


Figure 1 — Schematic illustration of a flat test piece and of the dimensions, gripping by pins[1][2]

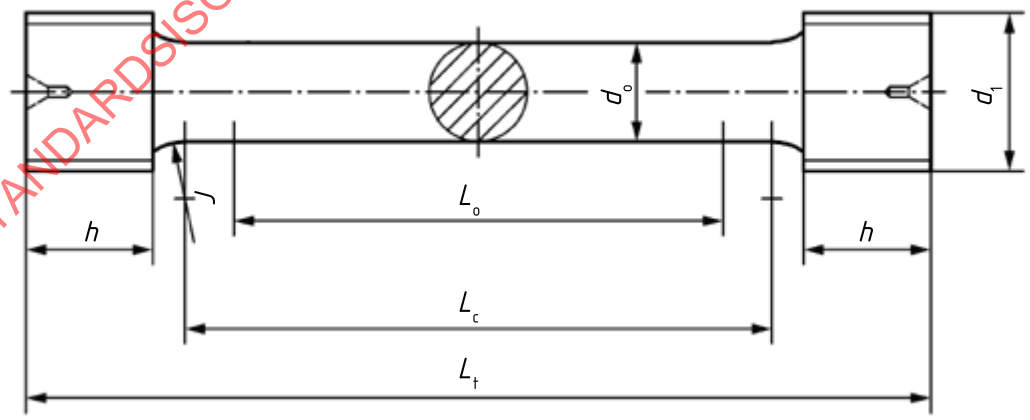


Figure 2 — Schematic illustration of a round test piece and of the dimensions[7]

5.2 Test piece preparation methods and parameters

The miniaturised test pieces can be produced e.g. by turning, milling, water jet cutting, or grinding. It is especially important to minimise work hardening and warming during production of the test piece. The use of k = 5,65 is preferable. Because of dimensional restrictions (extensometer gauge length, L_e, original gauge length, $L_{0,}$ original cross-sectional area of the parallel length, S_0), it is often not possible to use a test piece geometry with coefficient of proportionality k = 5,65. This means that the test results determined after A_g cannot be compared to values obtained from standard test pieces. For a given test piece geometry, the resultant coefficient of proportionality k is calculated by Formula (1)

$$k = L_o \times (S_o)^{-0,5} \quad (1)$$

If the extension at fracture is determined by an extensometer, L_o is equal to L_e.

A defined relation of L_c/b_o or L_c/d_o should be used for comparison purposes. To avoid any influence of the shoulders, the ratio of L_c/b_o for flat test pieces should be 5 or larger, the ratio of L_c/d_o for round test pieces should be 6 or larger (see Tables 1 and 2).

Table 1 gives examples for test pieces for pin gripping systems. In this table resulting coefficients of proportionality k are given for test piece thicknesses of 1,0 mm and 0,29 mm. The thickness a_o of the test piece should not exceed the width b_o.

Table 1 — Examples and dimensions of flat test pieces
(Form A to Form C, see Reference [15])

Dimensions in millimetres

Test piece form	L_t	B	b_o	L_c	L_o	C	D	E	r	$\frac{L_c}{b_o}$	$\frac{L_o}{b_o}$	k	
												a_o=1,0 mm	a_o=0,29 mm
Form A	23	4,0	1,25	7,5	5	6	2	2	2	6	4	4,47	8,30
Form B	32	6,0	2,0	12	10	8	3	3	2	6	5	7,07	13,13
Form C	35	6,5	2,5	15	10	8	3	3	2	6	4	6,32	11,74
Form D	70	12	5	28	20	16	---	---	5	5,6	4	8,94	16,61

NOTE 1 Form D test pieces can also be tested using force clamping systems. In this case the hole in the grip-end of the test piece is not necessary.

NOTE 2 Form D test piece also fulfils the ISO 6892-1 specifications regarding the gauge length.

Table 2 gives examples of round test pieces for threaded gripping systems.

Table 2 — Examples and dimensions of round test pieces for threaded gripping systems[16]

Dimensions in millimetres

Test piece form	L_t	d_1[a]	d_o	L_c	L_o	r	h	$\frac{L_c}{d_o}$	$\frac{L_o}{d_o}$	k
Form P	32	M 5	3,0	18	15,0	2,5	5	6	5	5,65
Form Q	29	M 5	2,5	15	12,5	2	5	6	5	5,65
Form R	26	M 4	2,0	12	10,0	2	5	6	5	5,65

[a] For some materials, larger thread dimensions may be used to avoid failure in the grip end.

NOTE Form P test piece also fulfils the ISO 6892-1 specifications regarding the gauge length.

Due to the small dimensions of the test piece, modified tolerances of the test piece compared to ISO 6892-1 shall be applied. Typically, the dimension tolerances should be scaled from ISO 6892-1 tolerances, e.g.

— for flat test pieces: tolerance for a_o and b_o: ≤0,01 mm or 0,5 %, whatever is larger,

— for round test pieces: tolerance for d_o: ≤0,015 mm or 0,7 %, whatever is larger.

6 Determination of the original cross-sectional area

All measuring devices used for the determination of the original cross-sectional area shall be calibrated with traceability to the SI system.

The relevant dimensions should be measured with an accuracy better than 0,5 %.

7 Test equipment

7.1 Method of gripping and alignment

The method of gripping and the alignment are important for the accuracy and determination of the properties. Helpful information about alignment can be found in ASTM E1012[6] and in ISO 23788[3]. For verification of the complete test see Clause 10.

7.2 Force-measuring system

The force-measuring system of the testing machine shall be in accordance with ISO 7500-1, class 1, or better in the relevant evaluation range.

7.3 Extensometer

Due to the small extensometer gauge length L_e and the small measured extensions, the extensometer shall be in accordance with ISO 9513, class 0,5, or better in the relevant evaluation range.

8 Procedure

8.1 In order to attain reproducible strain rates without creating unrealisable demands on the testing system, tests shall be performed in accordance with ISO 6892-1, Method A.

8.2 In some cases, it is easier to control the strain rate in open loop, Method A2, rather than in closed loop, Method A1. All other testing parameters (e.g. pre-load, data sampling frequency) should be adapted to the special testing situation of miniaturised test pieces.

9 Evaluation of the test

The evaluation of the test shall be done in accordance to ISO 6892-1.

10 Verification of the test procedure

The fulfilment of all requirements specified in this document shall be documented and evidence provided upon request. In addition, verification tests shall be carried out to prove that correct test results are obtained with the used test setup. For this, a homogeneous material shall be selected and both full size and miniaturised test pieces shall be manufactured and tested. The selected verification material should exhibit similar strength and deformation properties to the later on tested material. The test results shall be compared.

To minimize the influence of the material inhomogeneity, both full size and miniaturised test pieces should be machined out of the same product (e.g. sheet, wire, ...) in the same orientation.

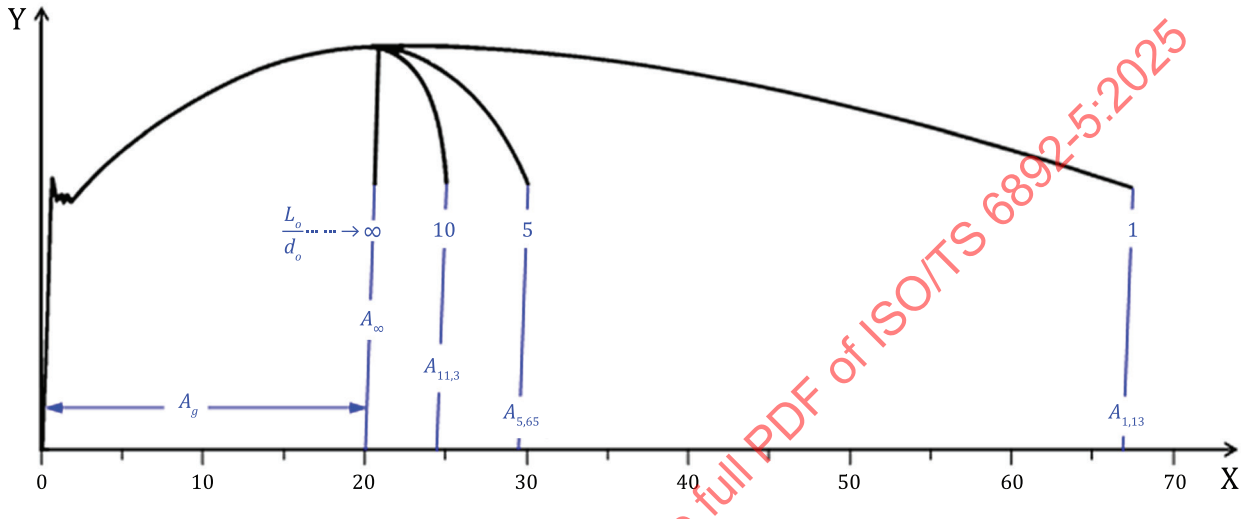
In case of flat test pieces, the thickness of the test pieces shall not be machined.

For comparison of the results, the slope of the elastic portion of the stress-strain curve is a good indicator for checking the performance of the complete system. On 5 tests in sequence during the verification, the slope of the elastic portion of the stress-strain curve shall be evaluated to see if it agrees with nominal values obtained during full size testing within ±20 % for all five tests.

If the results of miniaturised test pieces are to be compared to the results of full-size test pieces using this technical specification, then the verification shall require that the average of all properties to be determined shall agree within 5 %.

11 Comparability of the test results with results from standard tensile test pieces

Differences will occur for the test results percentage elongation after fracture A and percentage total extension at fracture A_t if test pieces with different coefficients of proportionality k are used. Figure 3 displays schematically the correlation between the percentage elongation after fracture A and the coefficient of proportionality k. The figure cannot be used for any conversion of absolute values.



Key

X e in %

Y R in MPa

Figure 3 — Schematic illustration of the correlation between the percentage elongation after fracture A and the coefficient of proportionality k[17]

Differences for stress values R (respectively in the stress/strain curve), for tensile strength values R_m and their possible causes were published in Reference [16] for mild steel grades. For these properties lower stress values were always found for the larger standard test pieces. The cause of this effect was justified with a larger temperature increase of the standard test pieces during the plastic deformation than for miniaturised test pieces and that in consequence of higher temperatures the strength values decrease. The increase of temperature was measured with miniaturised thermocouples fixed on the test piece surface. For aluminium alloys no increase of temperature was measured for miniaturised and standard test pieces and out of this no different stress values R and tensile strength values R_m were found.

Deviations of test results can also occur, if the diameter or width and thickness of the test piece are less than 5 times the grain size.

12 Test report

The test report shall contain at least the following information:

a) reference to this document, i.e. ISO/TS 6892-5:2025;

b) identification of the test piece;

c) specified material, if known;