BS EN 10371:2021



BSI Standards Publication

Metallic materials – Small punch test method

Documents
Document Sharing Hub

Full document details: BS EN 10371:2021

National foreword

This British Standard is the UK implementation of EN 10371:2021.

The UK participation in its preparation was entrusted to Technical Committee ISE/101/1, Uniaxial and Ductility Testing.

A list of organizations represented on this committee can be obtained on request to its committee manager.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

© The British Standards Institution 2021
Published by BSI Standards Limited 2021

ISBN 978 0 539 04168 2

ICS 77.040.10

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2021.

Amendments/corrigenda issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: BS EN 10371:2021

EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 10371

April 2021

ICS 77.040.10

English Version

Metallic materials - Small punch test method

Matériaux métalliques - Méthode d'essai de micro-emboutissage

Metallische Werkstoffe - Small-Punch-Test

This European Standard was approved by CEN on 11 January 2021.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

© 2021 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No. EN 10371:2021 E

Documents
Document Sharing Hub

Full document details: BS EN 10371:2021

Contents

Page

European foreword ... 3
Introduction ... 4
1 Scope ... 5
2 Normative references ... 5
3 Terms and definitions ... 5
4 Symbols and designations ... 9
5 Test piece ... 12
5.1 General ... 12
5.2 Material sampling ... 14
6 Apparatus ... 14
6.1 Testing machine ... 14
6.2 Test environment ... 15
6.3 Applying and measuring force ... 15
6.4 Punch and specimen holder ... 15
6.5 Measuring displacement and/or deflection ... 17
6.6 Measuring test temperature ... 17
7 Small punch test ... 18
7.1 Principle ... 18
7.2 Test procedure ... 18
7.3 Characteristic parameters on the force-deflection curve *F(u)* ... 19
7.4 Test report ... 23
8 Small punch creep test ... 23
8.1 Principle ... 23
8.2 Specificities of apparatus for small punch creep testing ... 24
8.3 Test procedure ... 24
8.4 Characteristics of the deflection-time curve ... 25
8.5 Test report ... 26
Annex A (informative) Determining the compliance of a small punch test rig for displacement measurements ... 27
Annex B (informative) Procedure for temperature control and measurement during small punch testing ... 30
Annex C (informative) Estimation of ultimate tensile strength R_m from small punch testing ... 35
Annex D (informative) Estimation of proof strength $R_{p0,2}$ from small punch testing ... 39
Annex E (informative) Estimation of *DBTT* from small punch testing ... 40
Annex F (informative) Estimation of fracture toughness from small punch testing ... 43
Annex G (informative) Estimation of creep properties from small punch creep testing ... 46
Annex H (informative) Post-test examination of the test piece ... 50
Annex I (informative) Machine readable formats ... 56
Bibliography ... 57

Documents
Document Sharing Hub
Full document details: BS EN 10371:2021

European foreword

This document (EN 10371:2021) has been prepared by Technical Committee CEN/TC 459/SC 1 “Test methods for steel (other than chemical analysis)”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by October 2021, and conflicting national standards shall be withdrawn at the latest by October 2021.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

AVA Documents
Document Sharing Hub

Full document details: BS EN 10371:2021

Introduction

This document describes small punch testing of metallic materials.

While it is recognized that the small punch test technique is not equivalent to uniaxial testing and cannot currently replace uniaxial and fracture mechanics tests with larger specimens, it allows estimation of the values normally obtained using classical standard size uniaxial or fracture mechanics specimens.

The small punch technique is especially useful when only small amounts of material are available as in the case of experimental material batches, or for assessing aging of components where the extraction of classical specimen types would require expensive repairs. Other areas of interest for small punch testing are the characterization of irradiated materials, where small specimens minimize laboratory staff exposure to radiation or the investigation of different zones in welds.

Documents
Document Sharing Hub
Full document details: BS EN 10371:2021

1 Scope

This document specifies the small punch method of testing metallic materials and the estimation of tensile, creep and fracture mechanical material properties from cryogenic up to high temperatures.

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.

EN 60584-1, *Thermocouples - Part 1: EMF specifications and tolerances (IEC 60584 1)*

EN ISO 148-1, *Metallic materials - Charpy pendulum impact test - Part 1: Test method (ISO 148-1)*

EN ISO 204, *Metallic materials - Uniaxial creep testing in tension - Method of test (ISO 204)*

EN ISO 286-2, *Geometrical product specifications (GPS) - ISO code system for tolerances on linear sizes - Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts (ISO 286-2)*

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

EN ISO 6892-2, *Metallic materials - Tensile testing - Part 2: Method of test at elevated temperature (ISO 6892-2)*

EN 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 7500-1)*

EN ISO 7500-2, *Metallic materials - Verification of static uniaxial testing machines - Part 2: Tension creep testing machines - Verification of the applied force (ISO 7500-2)*

EN ISO 9513, *Metallic materials - Calibration of extensometer systems used in uniaxial testing (ISO 9513)*

ISO 2768-1, *General tolerances - Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
punch
single solid rod with a hemispherical tip or a cylindrical rod combined with a ball is used to punch through the centre of the disc shaped test piece

Note 1 to entry: The hemispherical portion of the punch or the ball shall have a sufficient hardness to ensure rigidity so as not to be deformed during the test. Ultra-hard ball-bearing balls can be used for that application. The compliance of the punch will affect the displacement measurement (see 3.5).

AVA Documents Document Sharing Hub

Full document details: BS EN 10371:2021

3.2
test piece
circular, disc shaped piece of the material under investigation

Note 1 to entry: The testing of other geometries is admissible according to this document if the active part of the specimen has a flat cylindrical shape and the clamped area is equal to or larger than that of the specimens included in this document.

3.3
small punch (SP) test
when the punch tip/ball is pushed through the specimen with constant displacement rate of the cross head, $\dot{w}$ and the force, F is measured as a function of deflection, u / displacement, v

Note 1 to entry: The test can be used for estimating tensile and fracture material properties. If displacement is used, consideration of machine compliance is necessary (Annex A).

3.4
small punch creep (SPC) test
when the punch tip/ball is pushed through the specimen under constant force, F and the deflection, u / displacement, v is measured as a function of time

Note 1 to entry: The test can be used for estimating uniaxial creep properties.

3.5
displacement, v of the punch tip
distance by which the punch tip has moved after initial contact with the specimen surface

3.6
crosshead displacement
w
distance by which the cross head has moved after initial contact of the punch tip with the specimen surface

3.7
deflection
u
distance by which the point at the centre of the specimen on the surface opposite to the point of contact between the punch and the specimen has moved after initial contact of the punch tip with the test piece

3.8
creep-deflection curve
***u*(*t*)**
data record of deflection, u as a function of time, t for a given applied force, F from a small punch creep test

Note 1 to entry: The loading period is part of the creep deflection curve. $t = 0$, $F = 0$ (or F = preload) refers to the point in time when loading is started.

Documents
Document Sharing Hub
Full document details: BS EN 10371:2021

3.9
creep-displacement curve
***v*(*t*)**
data record of displacement, v as a function of time, t for a given applied force, F from a small punch creep test

Note 1 to entry: The loading period is part of the creep displacement curve. t=0, F=0 (or F=preload) refers to the point in time when loading is started.

3.10
force-deflection curve
***F*(*u*)**
record of the force, F required to keep the punch moving at constant crosshead displacement rate, $\dot{w}$ as a function of the deflection

3.11
force-displacement curve
***F*(*v*)**
record of the force, F required to keep the punch moving at constant crosshead displacement rate, $\dot{w}$ as a function of the displacement of the punch tip

Note 1 to entry: If the displacement is not measured at the punch tip, but derived from the displacement of the crosshead or at another point along the force line, the displacement signal needs to be corrected for compliance. For details, refer to Annex A.

3.12
ductile to brittle transition temperature
DBTT
temperature where the fracture behaviour of a given material changes from brittle to ductile as defined in EN ISO 148-1

3.13
small punch ductile to brittle transition temperature
T_{SP}
characteristic temperature at which the fracture behaviour in a small punch test changes from brittle to ductile (Annex E)

3.14
small punch energy
E_{SP}
integral of the force-deflection curve up to the deflection at maximum force, u_m

Note 1 to entry: This energy is used for determining T_{SP}. In the case of pop-ins, the integration is carried out up to the first significant pop-in (Annex E).

Note 2 to entry: Instead of deflection, displacement is allowed to be used.

Note 3 to entry: In the case of ductile materials, failure has not yet occurred when the maximum force, F_m is reached. However, limiting the integration to deflection at maximum force, u_m allows harmonized treatment of ductile and brittle failure.

3.15
normalized small punch energy
E_n
E_{SP} normalized by the maximum force F_m

Documents
Document Sharing Hub
Full document details: BS EN 10371:2021

3.16
upper shelf energy
E_{US}
some materials like ferritic/martensitic steels show a distinct transition of $E_{SP}(T)$ from a lower to a higher level at a given temperature, T_{SP}, the higher level of $E_{SP}(T)$ is called upper shelf energy, E_{US}

3.17
lower shelf energy
E_{LS}
some materials like ferritic/martensitic steels show a distinct transition of $E_{SP}(T)$ from a lower to a higher level at a given temperature, T_{SP}, the lower level of $E_{SP}(T)$ is called lower shelf energy, E_{LS}

3.18
pop-in significant for E_{SP} calculation
event during a SP test where the force in the $F(u)$ or $F(v)$ curves drops quasi instantaneously and rises again

Note 1 to entry: A pop-in is indicative for brittle failure.

Note 2 to entry: For calculating $E_{SP,}$ a significant pop-in is defined as a drop of the force by 10% of the maximum force, F_m in the test at any point (Annex E).

3.19
creep rupture time from uniaxial testing
t_u
time to rupture for a test piece maintained at the specified temperature, T and initial stress, R_0 as defined in EN ISO 204

Note 1 to entry: The symbol t_u in a uniaxial creep test may have as superscript the specified temperature in degrees Celsius and as subscript the initial stress, R_0 in mega pascals.

3.20
creep rupture time from small punch testing
t_r
time to rupture for a test piece maintained at the specified temperature, T and constant force F in a small punch creep test

Note 1 to entry: The symbol t_r in a uniaxial creep test may have as superscript the specified temperature in degrees Celsius and as subscript the force, F in newtons.

3.21
proof strength
R_p
proof strength determined from uniaxial tensile testing as defined in EN ISO 6892-1 and EN ISO 6892-2 or estimated from small punch testing (Annex D)

Note 1 to entry: The symbol is followed by a suffix giving the prescribed percentage of strain, for example $R_{p0,2}$.

3.22
yield strength
R_{eL}, R_{eH}
lower and higher yield strength determined from uniaxial tensile testing as defined in EN ISO 6892-1 and EN ISO 6892-2 or estimated from small punch testing (Annex D)

AVA Documents Document Sharing Hub
Full document details: BS EN 10371:2021

3.23
tensile strength
R_m
stress corresponding to maximum force in uniaxial tensile testing as defined in EN ISO 6892-1 and EN ISO 6892-2 or estimated from small punch testing (Annex C)

3.24
plane strain fracture toughness
K_{Ic}
crack-extension resistance under conditions of crack-tip plane-strain, expressed as a critical value of stress intensity factor

3.25
plane strain *J*-integral fracture toughness
J_{Ic}
crack-extension resistance under conditions of crack-tip plane strain, expressed as a critical value of *J*-integral, J_{Ic}

3.26
effective fracture strain
ε_f
natural logarithm of the ratio from the initial specimen thickness h_0 and the thickness after testing close to the fracture surface, h_f (Annex H)

4 Symbols and designations

For the purposes of this document, the following symbols and designations apply.

NOTE This list only includes the most pertinent symbols. Less important symbols that are only used in a specific context are not listed.

Symbol	Unit	Designation	Reference
A_{gt}	%	Total uniform elongation of the uniaxial tensile test	Annex C
A, B	mm	Parameters in the tanh fit of $E_n(T)$	Annex E
A_ε, B_ε	-	Parameters in the tanh-fit of $\varepsilon_f(T)$	Annex E
α	-	Transfer factor between T_{SP} and T_{CVN}: $T_{SP} = \alpha\ T_{CVN}$	Annex E
α_ε	-	Transfer factor between $T_{SP,\varepsilon}$ and T_{CVN}: $T_{SP,\varepsilon} = \alpha_\varepsilon\ T_{CVN}$	Annex E
β_{Rm}	-	Correlation factor for estimation of R_m	Annex C
C	K	Parameter in the tanh fit of $E_n(T)$	Annex E
C_ε	K	Parameter in the tanh-fit of $\varepsilon_f(T)$	Annex E
C_P	mm/N	Compliance of punch and push rod	Annex A
d	mm	Diameter of the punch tip	Clause 6
D	mm	Diameter of the receiving hole (lower die)	Clause 6
$DBTT$	°C, K	Ductile to brittle transition temperature	Annex E

AVA Documents
Document Sharing Hub

Full document details: BS EN 10371:2021

Symbol	Unit	Designation	Reference
D_S	mm	Diameter of the test piece	Clause 5
E_{LS}	mJ	Lower shelf energy	Annex E
EMF	-	Electromotive force	Annex B
E_n	mm	E_{SP} normalised by F_m	Annex E
E_{SP}	mJ	Small punch energy	Annex E
E_{US}	mJ	Upper shelf energy	Annex E
E_{LS}	mJ	Lower shelf energy	Annex E
E_Y	GPa	Young's modulus	Annex A
ε_f	-	Effective fracture strain $\varepsilon_f = \ln(h_0/h_f)$	Annex E
ε_{LS}	-	Effective fracture strain in the lower shelf	Annex E
$\dot{\varepsilon}_{min}$	1/h	Estimated uniaxial minimum strain rate corresponding to minimum deflection rate in a SPC test	Annex G
ε_{US}	-	Effective fracture strain in the upper shelf	Annex E
F	N	Force applied to the specimen	Clause 7, Clause 8
F_e	N	Elastic-plastic transition force in a small punch test	Clause 7, Annex D
F_m	N	Maximum of F during the test	Annex C, Annex E
F_i	N	Force at deflection u_i or displacement v_i, used for estimating R_m	Annex C
h	mm	Thickness of the test piece	Clause 5
h_0	mm	Initial thickness of the test piece (at the beginning of the test)	Clause 5
h_f	mm	Final thickness of the test piece adjacent to the fracture area	Annex E, Annex H
J_{Ic}	N/mm	Plane strain J-integral fracture toughness	Annex F
K_{Ic}	MPa $m^{0,5}$	Plane strain fracture toughness	Annex F
L	mm	Length of the chamfer in the receiving hole	Clause 6
Ψ	N/MPa	Force to stress ratio in SPC	Annex G
r	mm	Radius of the punch tip	Clause 6
R	mm	Radius of the receiving hole (lower die)	Clause 6
R_0	MPa	Initial stress in a uniaxial creep test	Annex G

AVA Documents Document Sharing Hub

Full document details: BS EN 10371:2021

Symbol	Unit	Designation	Reference
R_a	µm	Surface roughness (of the test piece)	Clause 5
R_m	MPa	Ultimate tensile strength	Annex C
R_p	MPa	Proof strength	Annex D
σ	MPa	Equivalent stress	Annex G
T	°C, K	Test temperature	Clause 6, Clause 7, Clause 8, Annex B
T_{CVN}	°C, K	Charpy transition temperature defined at 50 % of upper shelf energy (see EN ISO 148-1)	Annex E
t_r	h	Rupture time of SPC test	Annex G
T_{SP}	°C, K	Ductile to brittle transition temperature as determined from SP testing	Annex E
$T_{SP,\varepsilon}$	°C, K	T_{SP} determined from fracture strain	Annex E
t_u	h	Rupture time in uniaxial creep testing	Annex G
u	mm	Deflection of the specimen	Clause 7, Clause 8
u_e	mm	Deflection at F_e	Annex D
u_i	mm	Characteristic deflection used for estimating R_m	Annex C
u_m	mm	Deflection at F_m	Annex C, Annex E
u_{min}	mm	Deflection at minimum deflection rate $\dot{u}_{min}$ in a SPC test	Annex G
$\dot{u}$	mm/h	Deflection rate	Annex G
$\dot{u}_{min}$	mm/h	Minimum deflection rate in a SPC test	Annex G
u_{p1}	mm	Deflection at first significant pop-in	Annex E
v	mm	Displacement of the ball/punch tip	Clause 7, Clause 8
v_i	mm	Characteristic displacement used for estimating R_m	Annex C
v_{p1}	mm	Displacement at first significant pop-in	Annex E
v_r	mm	Displacement at rupture	Annex G
w	mm	Displacement of the crosshead	Annex A

AVA Documents
Document Sharing Hub

Full document details: BS EN 10371:2021

5 Test piece

5.1 General

The test pieces that should be used are circular discs with a diameter of D_S = 8 mm and an initial thickness of h_0 = 0,5 mm. The use of other specimen shapes is admissible according to this document provided the thickness and surface finish requirements are met and they can be properly clamped.

The use of smaller test pieces (D_S = 3 mm, h_0 = 0,25 mm) is also admissible according to this document. This allows the use of specimens adapted to the size of a TEM specimen holder.

For obtaining macroscopic material properties a representative volume element shall be contained in the specimen thickness. The specimen should contain at least 5 grains in thickness cross-section, but some exceptions can be accepted for coarse-grain, directionally solidified or single crystal materials.

These cases shall be reported accordingly; the recommended correlations for tensile and fracture estimations might not apply.

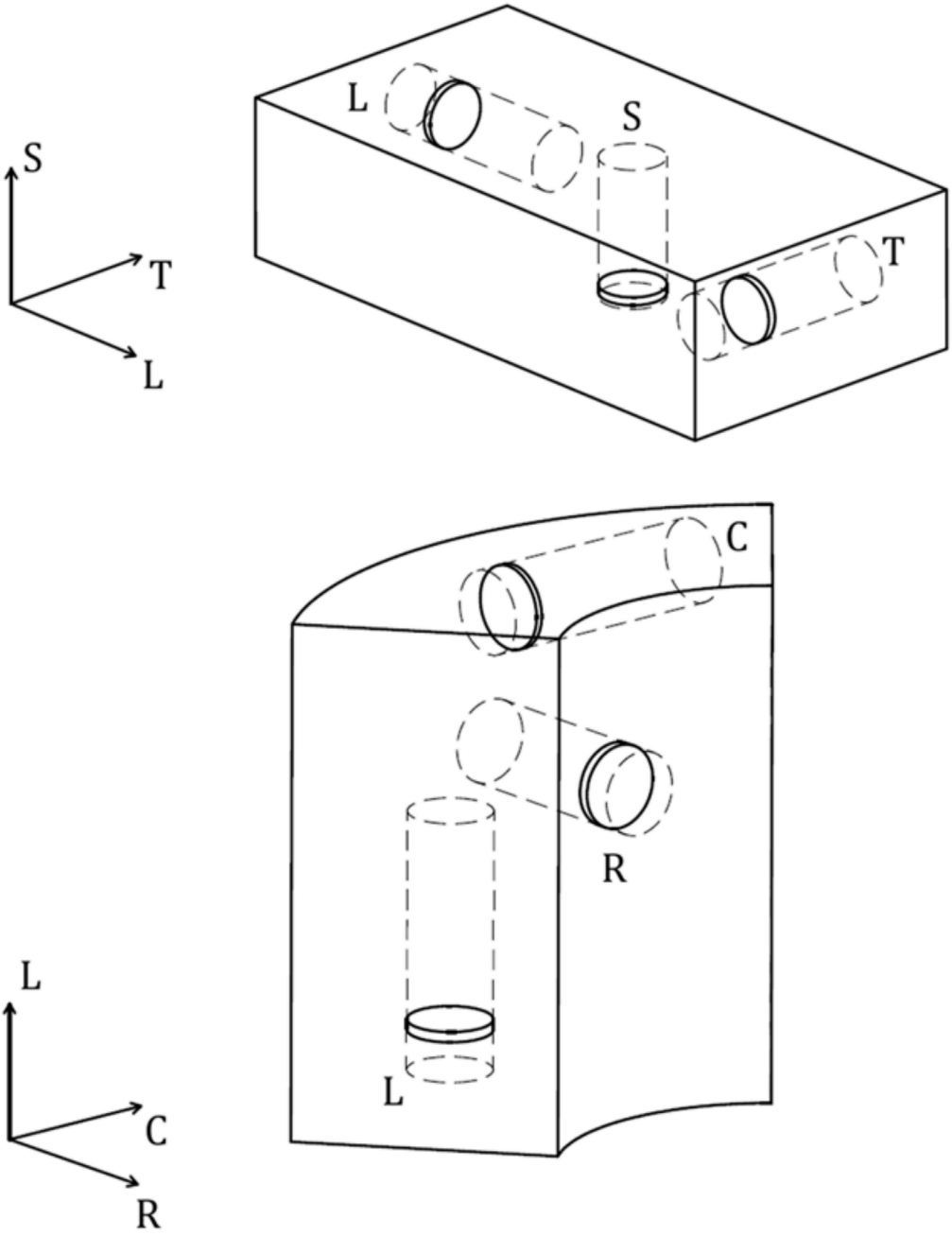
To eliminate the influence of surface damage, the specimen should be machined to a minimal thickness of h_0+0,1 mm and then should be ground from both sides on abrasive paper with a recommended abrasive grit size designation P320 followed by fine grinding (P1200) to reach the final thickness with a tolerance of no more than 1 %. Grinding on both faces shall be done with minimal 0,03 mm material removal from each side of the test piece. Since the test piece is clamped during test, the tolerance of its diameter, D_S is not critical, but it shall not be less than the value indicated in Table 1 to ensure sufficient clamping. The thickness of the test disc specimen shall be measured at four positions around the perimeter at 90° intervals from each other and in the centre. Each measurement shall be within the specifications. The diameter shall be measured in two positions at 90° from each other.

Table 1 — Required test piece dimensions, tolerances and surface roughness

D_S [mm]		h_0 [mm]		Ra [µm]
Ø 8	0	0,50	+0,005	< 0,25
	−0,1		−0,005	
Ø 3	0	0,25	+0,0025	< 0,25
	−0,025		−0,0025	

Orientation of the test piece shall be defined by Figure 1 in the test report.

Documents
Document Sharing Hub
Full document details: BS EN 10371:2021



Key

L longitudinal direction (i.e. rolling direction)

T transverse direction

S short transverse direction

C circumferential direction

R radial direction

NOTE The specimens are classified so that the letter designating the axis falls together with the axis along which the force is applied. Because of the multiaxial stress state, the directions tested in a SP test do not coincide with the force axis.

Figure 1 — Orientation of SP specimen

Documents
Document Sharing Hub

Full document details: BS EN 10371:2021

5.2 Material sampling

A major benefit of the small punch test method is that it enables estimation of actual mechanical properties of operating components or structural materials without affecting their integrity and operational performance. Sampling of the material can be done by a minimally invasive, virtually non-destructive manner. It means that testing material is removed from the component without requirements for its repair due to the small volume of the extracted material that is necessary for the small punch specimen manufacture. Current standardized mechanical tests, on the other hand, require relatively large volumes of material that cannot be extracted from in-service equipment without repair after the material removal.

For the material sampling, existing mechanical or electric discharge machining (EDM) extraction techniques can be used. As a universal system for the sampling of different devices without any significant impact on the component surface and without necessity to repair or modify the component, a Scoop Cutter Sampling technique can be used. The unique hemispherical liquid cooled cutter used in the scoop sampler is able to remove sufficient volume of material without mechanical distortion or thermal degradation of the component. The principle of the sampling by this machine is schematically shown in Figure 2 [1]-[3].

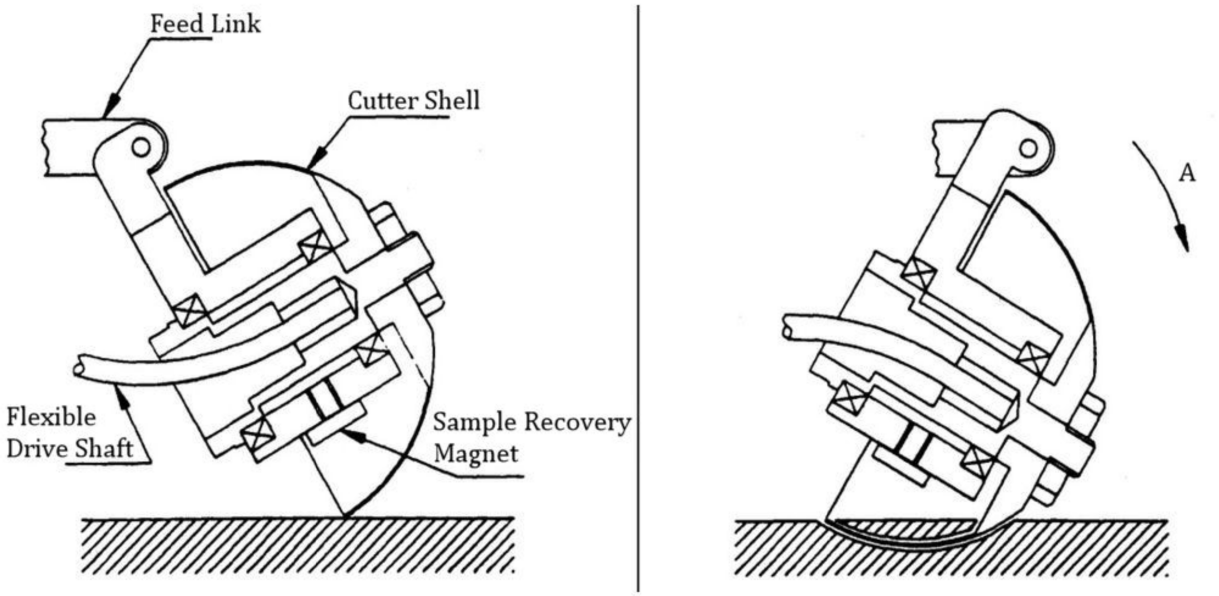


Figure 2 — Schematic view of abrasive-edged spinning cutter [2]

6 Apparatus

6.1 Testing machine

Universal testing machines are often used for SP testing (Clause 7) whereas SPC tests are mainly conducted on test specific dead-weight machines (Clause 8). In both test types, a disc-shaped test piece is clamped between an upper and a lower part of the specimen holder. A hemispherical punch or ball deforms the disc specimen until fracture is indicated by force drop (SP) or sudden rise in deflection/displacement (SPC).

For both test types, the testing machine shall apply a force perpendicular to the surface of the test piece while preventing inadvertent tilting of the punch and misalignment of the specimen. Prior to the test, the machine should be visually examined to ensure that the punch, specimen holder, universal joints and associated equipment are in a good state of repair.

AVA Documents
Document Sharing Hub
Full document details: BS EN 10371:2021

6.2 Test environment

6.2.1 General

When oxidation of the specimen becomes an issue for a given temperature and expected test duration, testing needs to be carried out in inert environment or vacuum.

6.2.2 Heating/cooling system

Small punch tests can be performed in a wide temperature range, i.e. cryogenic to high temperature. In all cases, the measurement of the true test temperature is of great importance (Annex B and Annex G). At cryogenic temperatures attention should be paid to ensure that the deflection/displacement measurement and the true applied force are not affected by ice forming.

6.3 Applying and measuring force

In a SP and SPC test, the force shall be applied smoothly and without shock.

In SP testing (and SPC with force measurement), the force measuring system shall comply with the requirements given in EN ISO 7500-1 class 1 or better. For static dead-weight machines (without force measurement), the requirements are given in EN ISO 7500-2.

It is important to ensure the true force applied on the specimen is known, i.e. the friction losses and similar effects of lead-throughs, pulleys and levers shall be accounted for.

6.4 Punch and specimen holder

Two different types of punching solutions can be used. Both a punch with a hemispherical tip or a ball can be used as shown in Figure 3. The test setup dimensions for the specimen holder that comply with the standard specimen (Table 1) are given in Table 2.

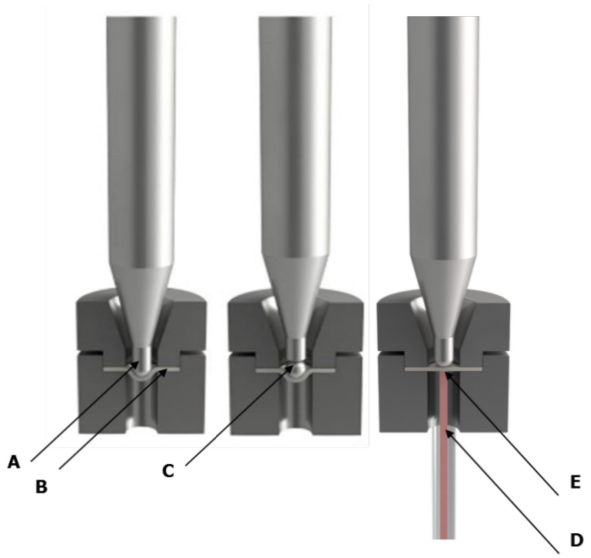
The general tolerance for the manufacture of the specimen holder is tolerance class “f” (fine) in accordance with ISO 2768-1. The receiving hole, the chamfer and the hemispherical punch / balls have a tolerance requirement of H6 according to EN ISO 286-2. An example of a specimen holder is shown in Figure 4.

The specimen holder surfaces shall be plane and perpendicular to the force direction. The surfaces affecting the specimen position and clamping shall be clean and free from oxide build-up, corrosion and dirt. The working surfaces of the upper and lower part of the specimen holder shall have a good oxidation resistance at the test temperatures. The specimen holder itself or a separate fixture shall ensure sufficient clamping, i.e. ensure that the specimen cannot bend upwards. In the case of clamping fixtures with several tightening bolts, it is important to alternate the tightening on opposing sides to avoid uneven clamping. Over-clamping shall be avoided since initial plastic deformation might influence the test result. For better repeatability of clamping a torque wrench should be used to ensure a consistent torsional load.

In high temperature SPC testing oxidation and wear of the punch is a concern, especially if metallic punches are used. It is recommended to frequently check hemispherical punches to ensure that wear has not affected the required tolerances.

AVA Documents
Document Sharing Hub

Full document details: BS EN 10371:2021



Key

A the punch
B the specimen
C the punch-ball
D a ceramic rod for deflection measurement (and temperature E)
E the location where a thermocouple can be integrated into the ceramic deflection rod

Figure 3 — Test set-up and specimen

Table 2 — Required test set-up dimensions

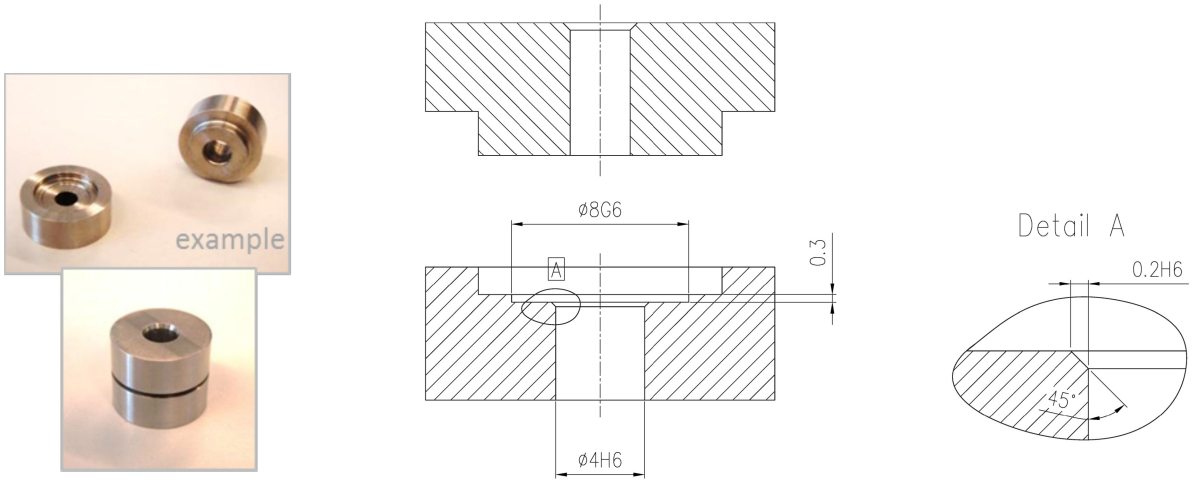
	Required test set-up dimensions for the diameter of the receiving hole	Punch radius	Chamfer length
Test piece	D [mm]	r [mm]	L [mm]
Standard	4	1,25	0,2
Miniature	1,75	0,5	0,2

NOTE Other punch radiuses have historically been used (e.g. 1,0 mm). The use of a differing punch size is acceptable for ensuring consistency during prolonged test campaigns. However, the evaluation of material behaviour in these cases cannot be performed with the correlations given in this document. The use of other punch sizes is discouraged to ensure future comparability of SP and SPC test results.

It is recommended that the material used for the specimen holder should have a similar coefficient of thermal expansion to the test specimen as to minimize stresses from thermal expansion. If there is a marked difference in the thermal expansion coefficient between the punch, disc and specimen holder materials, any effect of thermal loading shall be carefully evaluated.

The shallow recess for fixing the specimen position shall allow for the tolerance of the specimen ($8^{0}_{-0,1}$ see Clause 5) to ensure that the specimen will lie flat and not in a tilted position, e.g. Ø8G6 (see Figure 4b).

Documents
Document Sharing Hub
Full document details: BS EN 10371:2021



(a) **(b)**

Figure 4 — Example of specimen holder (a) and drawing (b)

6.5 Measuring displacement and/or deflection

In SP and SPC tests, the displacement (or deflection) shall be measured using an extensometer, which meets the performance requirements of class 1 or better of EN ISO 9513 or by other means which ensure the same accuracy. The extensometer can be directly in contact with the bottom of the test piece (deflection) and/or attached to the loading rod/punch (displacement). Also, non-contact methods like optical or laser extensometers can be used.

The extensometer shall be calibrated over an appropriate range depending on the expected failure displacement/deflection, for instance 0 mm to 5 mm.

The extensometer shall be calibrated at intervals not exceeding 1 year. If the predicted test duration exceeds the date of the expiry of the calibration certificate, then the extensometer shall be recalibrated prior to commencement of the test.

6.6 Measuring test temperature

The thermocouple(s) defining the test temperature is recommended to be in contact with the specimen. The preferred location is underneath the specimen in the clamped region or measured from below with a thermocouple integrated into the ceramic rod employed for deflection measurement. It is also allowed to have the test temperature sensor located elsewhere in close proximity of the specimen as long as the true specimen temperature can be derived within tolerances. In all cases the temperature should be calibrated against an instrumented SP test specimen as described in Annex B. If a large temperature gradient across the specimen or through the thickness is found, correcting action shall be taken.

The permitted deviations between the indicated temperature, T_i and the specified test temperature, T during a test are given in Table 3.

Documents
Document Sharing Hub
Full document details: BS EN 10371:2021

Table 3 — Permitted deviations between T_i and T

Specified test temperature, T °C	Permitted deviation between T_i and T °C
$T < 600$	±2
$600 < T \leq 800$	±3
$800 < T \leq 1\,000$	±4
$1\,000 < T \leq 1\,100$	±5

For temperatures greater than 1 100°C, the permitted values shall be defined according to target application and in agreement between the parties concerned.

7 Small punch test

7.1 Principle

The test methods of this part of the standard cover the SP test of metallic materials. According to the definition of Clause 3, the SP test shall be performed at a constant displacement rate of the crosshead, $\dot{w}$, of the testing machine. The direct output of the test is the force-deflection curve, $F(u)$ or alternatively the force-displacement curve $F(v)$. Several characteristic parameters can be derived from these curves. Specifically, the elastic-plastic transition force, F_e, the deflection at F_e, u_e (or alternatively the punch tip displacement at F_e, v_e), the maximum force during the test F_m, the deflection at F_m, u_m (or alternatively the punch tip displacement at F_m, v_m), the deflection/displacement at the onset of plastic instability u_i/v_i, the force at the onset of plastic instability, F_i the force at u_i or v_i and the energy up to F_m, E_{SP}, can be obtained from test curves. These parameters, together with post-test examinations of the test pieces (Annex H) are the basis of the correlations that allow the ultimate tensile strength, R_m (Annex C), the proof strength, R_p (Annex D), the ductile to brittle transition temperature, T_{SP} (Annex E) and fracture toughness (Annex F) to be estimated.

7.2 Test procedure

7.2.1 Test piece placement

The test piece shall be clean and be clamped between the upper and lower die of the specimen holder in the testing device following the requirements of 6.4. If the testing temperature is different from room temperature, the test shall be kept at the target temperature at least for 10 min or longer if required by the soaking of the test equipment before starting the test. Temperature should be controlled according to Annex B.

7.2.2 Preload

The SP test starts when the force applied to the specimen increases. From a practical point of view the application of a preload may be useful. The maximum allowable value for this preload is 10 % of F_e.

7.2.3 Displacement rate

The SP test shall be performed by applying a constant displacement rate of the cross head of the testing machine, $\dot{w}$. A displacement rate, $\dot{w}$, of 0,2 mm/min to 2,0 mm/min should be used.

NOTE 0,5 mm/min has been used for testing and establishing material correlations for steels in this document.

Documents
Document Sharing Hub
Full document details: BS EN 10371:2021