INTERNATIONAL STANDARD

ISO 20032

Second edition
2013-08-01

Method for evaluation of tensile properties of metallic superplastic materials

Méthode de détermination des caractéristiques de traction des matériaux métalliques superplastiques

Reference number
ISO 20032:2013(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 2, *Ductility testing*.

This second edition cancels and replaces the first edition (ISO 20032:2007) of which it constitutes a minor revision.

Introduction

Superplastic forming requires the characterization of metallic superplastic materials. The tensile test specified in this International Standard permits the evaluation of superplastic properties, such as superplastic elongation, flow stress, strain rate sensitivity exponent (m-value), stress-strain relation and flow stress-strain rate relation.

Method for evaluation of tensile properties of metallic superplastic materials

1 Scope

This International Standard specifies a method for evaluating the tensile properties of metallic superplastic materials which exhibit what is called “Fine-Grained Superplasticity”, without significant work-hardening or dynamic microstructure evolution, by means of a tensile test at constant cross-head velocity, for flat-form test pieces, without an extensometer attached.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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 6892-2, *Metallic materials — Tensile testing — Part 2: Method of test at elevated temperature*

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

ISO 80000-1, *Quantities and units — Part 1: General*

IEC 60584-1, *Thermocouples — Part 1: Reference tables*

IEC 60584-2, *Thermocouples — Part 2: Tolerances*

3 Symbols, terms and definitions

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

Table 1 — Symbols, terms and definitions

Symbol	Term	Definition	Unit
Superplasticity			
—	Superplastic state	Deformation conditions on onset of superplasticity and its continuation	—
Test piece			
—	R-type test piece	Test piece that has the shape of a conventional tensile test piece without its parallel portion	—
—	R portion	Principal portion of the R-type test piece to be elongated, which has an arc-like shape between grips	—
b	Width of parallel-sided portion or minimum width of the R portion	Original width of parallel-sided portion of the S-type test piece or original minimum width of the R portion of the R-type test piece	mm
$b_o[i]$	Original width in division, *i*, of the R portion	Original width in a specific division, *i*, of the R portion	mm
$b[i]$	Width in division, *i*, of the R portion	Width in a specific division, *i*, of the R portion after the interrupted test	mm
A	Superplastic elongation	Elongation after fracture in a superplastic state	%
B_g	Grip portion width	Width of grip portion of the S- or R-type test piece	mm
L_o	Original gauge length	Original distance between gauge marks measured by appropriate apparatus with an accuracy of at least 1 % of the distance or 0,01 mm, whichever is greater	mm
L_u	Final gauge length after fracture	Final distance between gauge marks measured after fracture with fracture surfaces placed together with care, so that the centre line of either fracture surface is on a single straight line	mm
L_c	Parallel length	Original length of parallel portion of the S-type test piece	mm
L_t	Total length of test piece	Original total length of test piece	mm
L_g	Grip portion length	Length of grip portion of test piece	mm
L_R	R portion length	Original length of the R portion	mm
ΔL_R	Elongation of the R portion	Increase in the R portion length at any moment during the test	mm
R	Radius of fillet or R portion radius	Original radius of fillet of the S-type test pieces or original R portion radius of the R-type test piece	mm
S_o	Original cross-sectional area of test piece in the reduced section	Original cross-sectional area of a test piece measured by an appropriate apparatus with an accuracy of ±2 % or better	mm^2
$S_o[i]$	Original cross-sectional area in division, *i*, of the R portion	Original cross-sectional area in a specific division, *i*, of the R portion	mm^2
$S[i]$	Cross-sectional area in division, *i*, of the R portion	Cross-sectional area in a specific division, *i*, of the R portion after the interrupted test	mm^2
t	Thickness of test piece	Thickness of the S- or R-type test piece	mm
$t_o[i]$	Original thickness in division, *i*, of the R portion	Original thickness in a specific division, *i*, of the R portion	mm

Table 1 *(continued)*

Symbol	Term	Definition	Unit
$t[i]$	Thickness in division, *i*, of the R portion	Thickness in a specific division, *i*, of the R portion after the interrupted test	mm
Force			
F_{10}	10 % deformation force	Force at 10 % nominal strain	N
Stress			
K	*K* value	A constant-with-stress dimension, which is defined by Formula (5)	MPa
σ_{10}	10 % flow stress	True stress when 10 % nominal strain is achieved	MPa
σ_f	Flow stress	True stress during superplastic deformation	MPa
σ_N	Nominal stress	A load during deformation divided by the minimum area of the original cross-section in the R portion, which is defined for the R-type test piece	MPa
$\sigma[i]$	True stress	A load during deformation divided by the cross-sectional area in a specific division, *i*, of the R portion, which is defined for the R-type test piece	MPa
Strain			
$\varepsilon[i]$	True strain	True strain given by deformation in a specific division, *i*, of the R portion	—
Period			
τ_{inter}	Period required for interrupted test	Period required from the time when the axial force starts to increase linearly against strain in the elastic deformation stage, until elongation of the R portion, ΔL_R, reaches 3 mm	s
Strain rate and *m*-value			
$\dot{\varepsilon}_N$	Nominal strain rate	Crosshead velocity divided by the original parallel length, L_c for the S-type test piece, and divided by the original gauge length, L_o for the R-type test piece	s^{-1}
$\dot{\varepsilon}$	True strain rate	Increment of true strain per unit time	s^{-1}
$\dot{\varepsilon}[i]$	True strain rate during deformation	True strain rate during deformation in a specific division, *i*, of the R portion	s^{-1}
m	*m*-value	Index representing the strain-rate sensitivity of flow stress in superplastic materials	—

4 Principle

The test consists of straining a test piece by a tensile force, for the purpose of determining the superplastic properties, such as superplastic elongation (A), flow stress (σ_f) and strain-rate sensitivity exponent (*m*-value).

The tensile testing is carried out at elevated temperatures and strain rates.

An S-type test piece is employed to evaluate mechanical properties for general superplastic materials, or at an early stage of deformation.

Due to the limitation of furnace length, S-type test pieces are more suitable for lower-strain superplastic testing. R-type test pieces are more suitable for higher-strain superplastic testing, as most of the strain is developed in a small section at the centre of the specimen.