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Aerospace series – Test methods for metallic materials – Part 005: Uninterrupted creep and stress-rupture testing

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

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English Version

Aerospace series - Test methods for metallic materials - Part 005: Uninterrupted creep and stress-rupture testing

Série aérospatiale - Méthodes d'essais applicables aux matériaux métalliques - Partie 005 : Essai non interrompu de fluage et essai de rupture par fluage

Luft- und Raumfahrt - Prüfverfahren für metallische Werkstoffe - Teil 005: Kriech- und Zeitstandversuch unter konstanter Zugbeanspruchung

This European Standard was approved by CEN on 23 June 2007.

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This document (EN 2002-005:2007) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

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of an identical text or by endorsement, at the latest by May 2008, and conflicting national standards shall be withdrawn at the latest by May 2008.

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1 Scope

This standard applies to uninterrupted constant-load tensile creep strain and stress-rupture testing of metallic materials governed by aerospace standards. It defines the properties that may need to be determined and the terms used in describing tests and test pieces. It specifies the dimensions of test pieces and the method of testing. The duration of the creep strain and stress-rupture tests complying with this standard shall be less than 10 000 h and at temperatures not exceeding 1 100 °C.

This standard may also apply to metallic materials for test durations exceeding 10 000 h and/or for test temperatures exceeding 1 100 °C providing that previous agreement has been reached between the manufacturer and the purchaser.

2 Normative references

The following referenced documents are indispensable for the application 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 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 7500-1:2004)*

EN ISO 9513, *Metallic materials — Calibration of extensometers used in uniaxial testing (ISO 9513:1999)*

ASTM E 1012-91, *Practice for verification of specimen alignment under tensile loading.* 1)

3 Principle

The test consists in maintaining a test piece at a uniform temperature and subjecting it to a constant tensile force at that temperature in order to determine specified properties.

4 Terms and definitions

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

4.1
test piece
portion of the test sample on which the creep strain or stress-rupture test is carried out (see Figures 1 to 5)

4.2
proportional test piece
these test pieces have an original basis gauge length ($L_o = L_{eo'}$ or $L_{s'}$) which bears a specified relationship to the cross-sectional area

This ensures that comparable values for percentage elongation after rupture (A) are obtained from test pieces of different size but having the same relationship. The relationship $L_o = 5{,}65\sqrt{S_o}$ which for test pieces of circular cross section gives a value of $L_o = 5\ d_o$ has been accepted by international agreement and is preferred in the use of this standard. The relationship is indicated in the symbol for percentage elongation after rupture (A) as a subscript, e.g. $A_{5'}$ representing the ratio L_o/d.

1) Published by American Society for Testing and Materials (ASTM), 1916 Race Street, Philadelphia, PA 19103.

4.3
non-proportional test piece
in cases where the original basis gauge length has not the defined relationship to the cross-sectional area, a subscript shall be used with the symbol for elongation A to indicate the gauge length, i.e. $A_{40\ \text{mm}}$

4.4
gauge length
a length of the test piece on which elongation is measured at any moment during the test

4.5
measurement gauge length (L_m)
the measurement gauge length shall be defined as either the extensometer gauge length L_{eo} for test pieces measured with extensometers gripping the parallel portion of the specimen or small annular ridges, when these are used, or the shoulder gauge length L_s for test pieces where extension is measured between points including the transition radii and/or gripping portions of the test piece

The measurement gauge length (L_m) is to be used only for the numerator in elongation calculations; that is, the change in length of that part of the test piece defined as L_m, whereas the basis gauge length, i.e. $L_{eo'}$ or $L_{s'}$, is to be used for the denominator.

4.6
extensometer gauge length (L_{eo})
where an extensometer is attached directly to the parallel portion of the unloaded test piece, the extensometer gauge length (L_{eo}) is equal to the distance between the points of contact of the extensometer measured at room temperature, and shall also be used as the corresponding basis gauge length

Alternatively, the extensometer may be attached to annular ridges on the parallel portion. In these cases, the basis gauge length to be used as the denominator in the elongation calculations shall be the equivalent gauge length, calculated as shown (see 4.7).

4.7
basis gauge length for elongation calculations ($L_{eo'}$ or $L_{s'}$)
the equivalent gauge length, i.e. the parallel length which would give the same extension, including all loaded portions of the test piece between the measuring points, except the gripped ends

It shall be used as the denominator in all elongation calculations. For stress-rupture test pieces, it is recommended that $L_{eo'}$ or $L_{s'}$ be calculated from the following equation:

$$L_{eo'} \text{ or } L_{s'} = L_c + 2\sum_{i=1}^{k}\left[(d_o/d_i)^{2n} \times L_i\right] = 5{,}65\sqrt{S_o}$$

where:

L_c is the parallel length between the annular ridges or test piece ends, with a diameter d_o, k is the number of sections of length L_i with increasing diameter of d_i at the two transition radii. The correct L_c shall be selected, so that the effective gauge length equals 5,65 $\sqrt{S_o}$. It is recommended to use $n = 6$ as a basis for comparison, although the actual n for many aerospace materials is > 6. This is based on the "power law" creep relationship:

$$\dot{\varepsilon}_\text{p} = \left(\frac{\sigma}{K}\right)^n$$

4.8
shoulder gauge length (L_s)
where the extension is measured at the test piece ends, or between reference marks on the enlarged ends of the test piece, the shoulder gauge length (L_s) shall be denoted

The basis gauge length shall be calculated as in 4.7 and based on room temperature measurements, including all loaded portions of the test piece between the measuring points, except the gripped ends.

4.9
parallel length (L_c)
the length of the parallel portion of the test piece

For some test pieces, L_c will be less than L_m, the applicable original gauge length.

4.10
extension (ΔL_e)
the increase of the extensometer gauge length from the initial length, L_{eo} or $L_{eo'}$, indicated at the test temperature before loading, to a value L_e at a given moment during the test.

4.11
final measurement length after rupture (L_u)
the measure of the applicable gauge length (L_{eu} or L_{su}) after the test piece has ruptured, measured at room temperature

This may include the unstressed test piece ends, if the total length is used as the gauge length.

4.12
percentage elongation after rupture (A)
the permanent increase in length ($L_u - L_m$) of the applicable measurement gauge length, expressed as a percentage of the original applicable basis gauge length ($L_{eo'}$ or $L_{s'}$), for example:

$$A = \frac{L_u - L_{eo'}}{L_{eo'}} \times 100\text{, all measurements being made at room temperature}$$

4.13
percentage extension during testing (A_f)
the increase of the applicable gauge length, at a given time under full load, expressed as a percentage of the original applicable gauge length

The initial plastic strain during loading shall not be included in A_f, just the elongation after attainment of full load (see Figure 6).

4.14
percentage total plastic strain (A_p)
the total plastic extension of the original applicable measurement gauge length (L_{eo} or L_s) inclusive of any plastic extensions during loading (i.e. the total extension excluding elastic extensions), expressed as a percentage of the original applicable basis gauge length (see Figures 6 and 7)

4.15
original section (S_o)
the cross-sectional area of the gauge length of the test piece, determined before testing

4.16
final section (S_u)
the minimum cross-sectional area of the test piece, after rupture

4.17
percentage reduction of area after rupture (Z)
the maximum decrease of the cross-sectional area ($S_o - S_u$) expressed as a percentage of the original cross-sectional area (S_o), i.e. $Z = \frac{S_o - S_u}{S_o} \times 100$

4.18

stress (σ)

the force on the test piece divided by the original cross-sectional area of the parallel portion

It should be noted that the thermal expansion of the test piece during heating increases the effective cross-sectional area. The effective stress is therefore slightly less than σ, which is based on room temperature.

4.19

rupture

complete fracture of the test piece within the original gauge length under constant force and at constant temperature

4.20

time to rupture (t_r)

the total time, at the test temperature and the test force, to the rupture of the test piece (see Figure 7)

4.21

time to specified total plastic strain (t_p)

the total time, at the test temperature and including the portion of the loading time after the loading curve deviates from an extension of the linear-elastic modulus line, until the specified total plastic strain (A_p) is reached (see Figure 6)

4.22

theoretical stress concentration factor (K_t)

the ratio of the greatest in the region of a notch as determined by the theory of elasticity to the corresponding nominal stress

$$K_t = \frac{\sigma_{\text{peak}}}{\sigma_{\text{nom.}}}$$

where

K_t is the theoretical stress concentration factor;

σ_{peak} is the peak stress by notch;

$\sigma_{\text{nom.}}$ is the nominal stress.

5 Symbols and abbreviations

See Table 1 and Figures 1 to 5.