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Metallic materials — Steel — Method of test for the determination of brittle crack arrest toughness, K_{ca}

Matériaux métalliques — Acier — Méthode d'essai pour déterminer la ténacité à la rupture fragile, K_{ca}

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Contents

Page

Foreword ..... **v**

Introduction ..... **vi**

1 Scope **1**

2 Normative references **1**

3 Terms and definitions **1**

4 Symbols **2**

5 Test equipment **3**
5.1 General 3
5.2 Testing machine 3
5.2.1 Force implementation 3
5.2.2 Calibration of the load cell 3
5.2.3 Force measurement 4
5.2.4 Method for force transfer to integrated test piece 4
5.2.5 Loading direction 4
5.2.6 Distance between the loading pins 4
5.3 Impact equipment 4
5.3.1 Impact methods 4
5.3.2 Impact energy calculation 6
5.3.3 Reaction force receivers 6

6 Test pieces **7**
6.1 Test piece configurations 7
6.2 Configurations of extension plates and tab plates 9
6.2.1 General 9
6.2.2 Extension plates 11
6.2.3 Tab plates 11
6.3 Welding of test piece and extension plates 11

7 Test methods **12**
7.1 Temperature control method 12
7.1.1 Determination of temperature gradient 12
7.1.2 Method of temperature control and monitoring 13
7.2 Crack initiation methods 14

8 Test procedures **15**
8.1 Pretest procedures 15
8.2 Impacting procedures 16
8.3 Post-test operations 16
8.4 Observation of fracture surfaces 17

9 Determination of arrest toughness **22**
9.1 Validation of arrested crack 22
9.2 Assessment of impact energy 23
9.3 Calculation of arrest toughness 24

10 Reporting **24**

Annex A (informative) **Devices and method for controlling and monitoring the temperature of test pieces** **28**

Annex B (normative) **Method for obtaining K_{ca} at a specific temperature** **31**

Annex C (normative) **Calculation of stress intensity factors for a curved crack** **33**

Annex D (informative) **Double tension type arrest test** **34**

Annex E (informative) **Duplex type arrest test** **37**

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Annex F (informative) **Dynamic measurement methods** **40**
Bibliography **44**

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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 4, *Fatigue, fracture and toughness testing*.

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.

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Introduction

This document provides a test method for determining the crack arrest toughness of steels. Experimental methods of crack propagation and arrest are documented in Reference [1] Among these, ASTM E1221[2] is a test method to evaluate lower bound crack arrest toughness, K_{Ia}, under plane strain conditions. On the other hand, crack arrest testing methods using wide plates were developed in the 1950s[3] and have been used for assessing the crack arrest capabilities of cryogenic tanks[3] and pressure vessels[4][5][6]. In recent years, these methods have been extensively used for evaluating the crack arrest toughness of ship steels[7].

The wide plate crack arrest test is intended to evaluate the arrest toughness, K_{ca}, of steel plate at its thickness of actual use and not the lower bound arrest toughness, K_{Ia}. However, the relationship between the two arrest toughness values has been investigated[4][6]. It was shown that K_{Ia} and K_{ca} values agreed at lower bound of K_{ca}. Moreover, the wide plate crack arrest tests were shown to evaluate the arrest toughness at a higher temperature range at which K_{Ia} evaluation is impossible. The theoretical background of crack arrest toughness testing with a temperature gradient is described in References [8] and [9].

This document provides a test method for the determination of brittle crack arrest toughness of steel by using wide plates with a temperature gradient.

The test method can be summarized as follows: after setting a temperature gradient across the width of a test piece and applying uniform stress to the test piece, the test piece is struck to initiate a brittle crack from a mechanical notch in either edge of the test piece and cause crack arrest after propagating in the width direction (temperature gradient type arrest testing). Annex A describes typical devices and a method of setting the temperature gradient on the piece. Using the stress intensity factor, the arrest toughness, K_{ca}, is calculated from the applied stress and the arrest crack length. This value is the arrest toughness at the temperature at the point of crack arrest (arrest temperature). To determine K_{ca} at a specific temperature, such as the design temperature of a structure, the method specified in Annex B is applicable.

The method described in Annex C can be used to determine the stress intensity factor for a curved crack, in order to check the validity of a crack propagation path.

As a method for initiating a brittle crack, a secondary loading mechanism can be used (see Annex D). The arrest characteristics of the test piece can also be evaluated by welding a crack starter plate to the test plate in the width direction to enable a brittle crack initiated from the mechanical notch at the edge of the test piece to propagate in the crack running plate and observing the propagation behaviour of the crack immediately after entering the test plate (see Annex E).

The method explained in Annex F can be used to determine the dynamic behaviour of crack propagation and measure the dynamic strain of a test piece.

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Metallic materials — Steel — Method of test for the determination of brittle crack arrest toughness, K_{ca}

1 Scope

This document specifies a test method for the determination of brittle crack arrest toughness.

It is applicable to ferritic steel base metals exhibiting ductile to brittle transition behaviour. Applicable materials are rolled steel plates. It is intended for materials with a tensile strength of 950 MPa or less and a test piece thickness of 200 mm or less. The range of arrest temperatures is between –196 °C and +100 °C. This document can be applied to flat rolled steel plates but not to flattened steel pipes because the flattening can cause changes in arrest toughness.

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 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*

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:

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

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

3.1
brittle fracture
fracture with predominantly cleavage

3.2
arrest
sudden halt of a propagating *brittle crack* (3.4)

3.3
arrest toughness
materials resistance against *brittle crack* (3.4) propagation expressed in terms of stress intensity factor

3.4
brittle crack
crack propagating at approximately 300 m/s or more due to a *brittle fracture* (3.1)

3.5
arrest temperature
temperature at the point where a *brittle crack* (3.4) is arrested in the temperature gradient type *arrest toughness* (3.3) test

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3.6
test piece
flat steel plate in which *arrest toughness* (3.3) is to be evaluated

3.7
tab plate
thick end inserted for transferring force from a testing machine

3.8
extension plate
flat plate welded between the *test piece* (3.6) and *tab plates* (3.7)

3.9
integrated test piece
weld assembly of *test piece* (3.6), *extension plates* (3.8) and *tab plates* (3.7)

3.10
loading pin
pin used for the transfer of the force from the testing machine into the *integrated test piece* (3.9)

3.11
distance between loading pins
distance between the centres of the *loading pins* (3.10) inserted into the holes of the *tab plates* (3.7)

3.12
impact energy
energy applied to a wedge placed on a notch formed at the edge of a *test piece* (3.6) to initiate a *brittle crack* (3.4)

3.13
crack branching
case when two or more cracks form during initiation or propagation of a *brittle crack* (3.4)

Note 1 to entry: Secondary cracks that are not a main crack are called branch cracks.

3.14
main crack
crack with the longest propagation length when *crack branching* (3.13) occurs

3.15
shear lip
fracture surface generated by ductile fracture adjacent to the front and back surfaces of a steel plate

3.16
stretch zone
plastic deformation at tip of the arrested crack front

4 Symbols

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

Table 1 — Symbols used in this document

Symbol	Unit	Designation
a_{ca}	mm	Arrest crack length
B	mm	Test piece thickness
B_{ex}	mm	Extension plate thickness
[a] 0,031 6 MPa $m^{1/2}$ = 1 N $mm^{-3/2}$ =0,031 6 MN $m^{-3/2}$.		

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