SIST

SLOVENSKI STANDARD
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Lepila - Preskusne metode za ocenjevanje dolgoroļ ne trdnosti vezanih kovinskih struktur

Structural adhesives - Test methods for assessing long term durability of bonded metallic structures

Strukturklebstoffe - Prüfverfahren zur Bewertung der Langzeitbeständigkeit geklebter metallischer Strukturen

Adhésifs structuraux - Méthodes d'essai pour évaluer la durabilité a long terme des structures métalliques collées

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Structural adhesives - Test methods for assessing long term durability of bonded metallic structures

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Strukturklebstoffe - Prüfverfahren zur Bewertung der Langzeitbeständigkeit geklebter metallischer Strukturen

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Foreword

This document (EN 15190:2007) has been prepared by Technical Committee CEN/TC 193 “Adhesives”, the secretariat of which is held by AENOR.

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of an identical text or by endorsement, at the latest by February 2008, and conflicting national standards shall be withdrawn at the latest by February 2008.

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

Safety statement

Persons using this document should be familiar with the normal laboratory practice, if applicable. This document does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices and to ensure compliance with any regulatory conditions

Introduction

Susceptibility to fatigue crack growth under hot humid conditions is one of the major concerns for the durability assessment of bonded metallic joints. Knowledge of the long-term durability of bonded joints is useful for product development and material selection. Furthermore, it has been shown that the relationship between cyclic mode I strain energy release rate and crack growth rate is independent of geometry and load application. This allows the materials characterisation data measured from RDCB testing to be applied directly to other joined metallic structures, and therefore the data are useful for establishing design allowable criteria used in their life assessment.

1 Scope

1.1 This standard specifies test procedures for determining the long-term durability of an adhesive system subjected to environmental and fatigue loads. The procedures are based upon measurement of the crack growth rate and the resistance to crack propagation through the adhesive layer in double cantilever beam type specimens under an applied mode I opening cycling loading.

1.2 The test specimens consist of rectangular metal substrates bonded together with a pre-starter crack in the bondline. For testing joints consisting of relatively thin sheets of metallic substrates the specimen needs to be structurally reinforced by adding layers of compatible material to the back of each adherend substrate in order to prevent permanent deformation, usually referred to as reinforced double cantilever beam (RDCB) test specimen.

1.3 For brevity, the standard relates to testing RDCB specimens, which are essentially more complex in manufacturing than standard double cantilever beam (DCB) specimens. However, the standard allows also for use of single substrate double cantilever beam specimens when the substrate material is available in sufficient thickness.

1.4 The test method has been proven to be particularly sensitive in finding weaknesses within certain adhesive systems and is recommended as a scientific tool to study adhesion properties. This test method may be used to determine:

- The fatigue crack growth rate as a function of the mode I strain energy release rate;
- The threshold values for negligible crack growth;
- The effects of other environmental factors (temperature and/or humidity cycling);
- The mode I (peel or crack opening) failure mode of the adhesive joint (cohesive, interfacial, near-surface …).

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 923:2005, *Adhesives – Terms and definitions*

EN 13887, *Structural Adhesives - Guidelines for surface preparation of metals and plastics prior to adhesive bonding*

EN ISO 9142, *Adhesives - Guide to the selection of standard laboratory ageing conditions for testing bonded joints (ISO 9142:2003)*

ISO 15024, *Fibre-reinforced plastic composites — Determination of mode I interlaminar fracture toughness,* G_{Ic}*, for unidirectionally reinforced materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 923:2005 and the following apply.

3.1

mode I crack opening

crack opening mode due to a load applied perpendicular to the plane of crack growth using a reinforced double cantilever beam specimen as shown in Figure 1

3.2

number of fatigue cycles, *N* (cycles)

cycle count during a fatigue test

3.3

crack length, *a* (mm)

crack length measured from the loading point to the crack tip

3.4

initial crack length, a_o (mm)

manufactured crack length before the test

3.5

fatigue crack growth rate, d*a*/d*N* (mm/cycle)

increase of the crack length per fatigue cycle

3.6

strain energy release rate, *G* (J/m^2)

loss of strain energy, d*U*, in the test specimen per unit of specimen width for an infinitesimal increase in crack length, d*a*, for a crack growing under a constant displacement. In mathematical form,

$$G = \frac{1\,000}{b}\frac{\mathrm{d}U}{\mathrm{d}a} \qquad (1)$$

where:

U total elastic strain energy in the test specimen (mJ)

b specimen width (mm)

a crack length (mm)

3.7

displacement, δ (mm)

distance between the load points

3.8

fatigue loading ratio, *R*

ratio of the minimum load to the peak load within a load cycle

3.9

maximum mode I cyclic strain energy release rate, $G_{(\mathrm{Imax})}$ (J/m^2)

value of *G* at peak load during the fatigue cycle

3.10

strain energy release rate threshold, G_{th} (J/m^2)

value of *G* at which fatigue crack growth becomes negligible (approach zero). This is typically at measured crack growth rates between 10^{-6}mm/cycle and 10^{-7} mm/cycle.

3.11

peak load, $P_{\max}$ (N)

maximum load applied during a dynamic load cycle

3.12

compliance, *C* (mm/N)

displacement divided by load during the loading cycle applied to the RDCB specimen, at a given crack length

3.13

maximum displacement, δ_{max}(mm)

maximum test piece displacement at the peak load, i.e. P_{max} x *C*, for any given crack length

3.14

compliance calibration constant, *m* ($mm^{-2/3}$. $N^{-1/3}$)

slope of the linear fit relationship between the cube root of the test piece compliance, *C* (y-axis) and crack length, *a* (x-axis)

3.15

compliance calibration constant, Δ (mm)

x-axis intercept, determined from the extrapolation of the linear fit (between $C^{1/3}$ and *a*) to the point where $C^{1/3}$ equals zero

3.16

test piece width, *b* (mm)

4-point average of test piece width, measured along the length of the RDCB test piece

3.17

Paris Law constants, *A* and *B*

for the Paris Law relationship: da/dN = $A(G)^B$ applied to the log-log plot of $G_{(Imax)}$ versus d*a*/d*N*

3.18

projected 'threshold', $G|_{10^{-6}}$ (J/m^2)

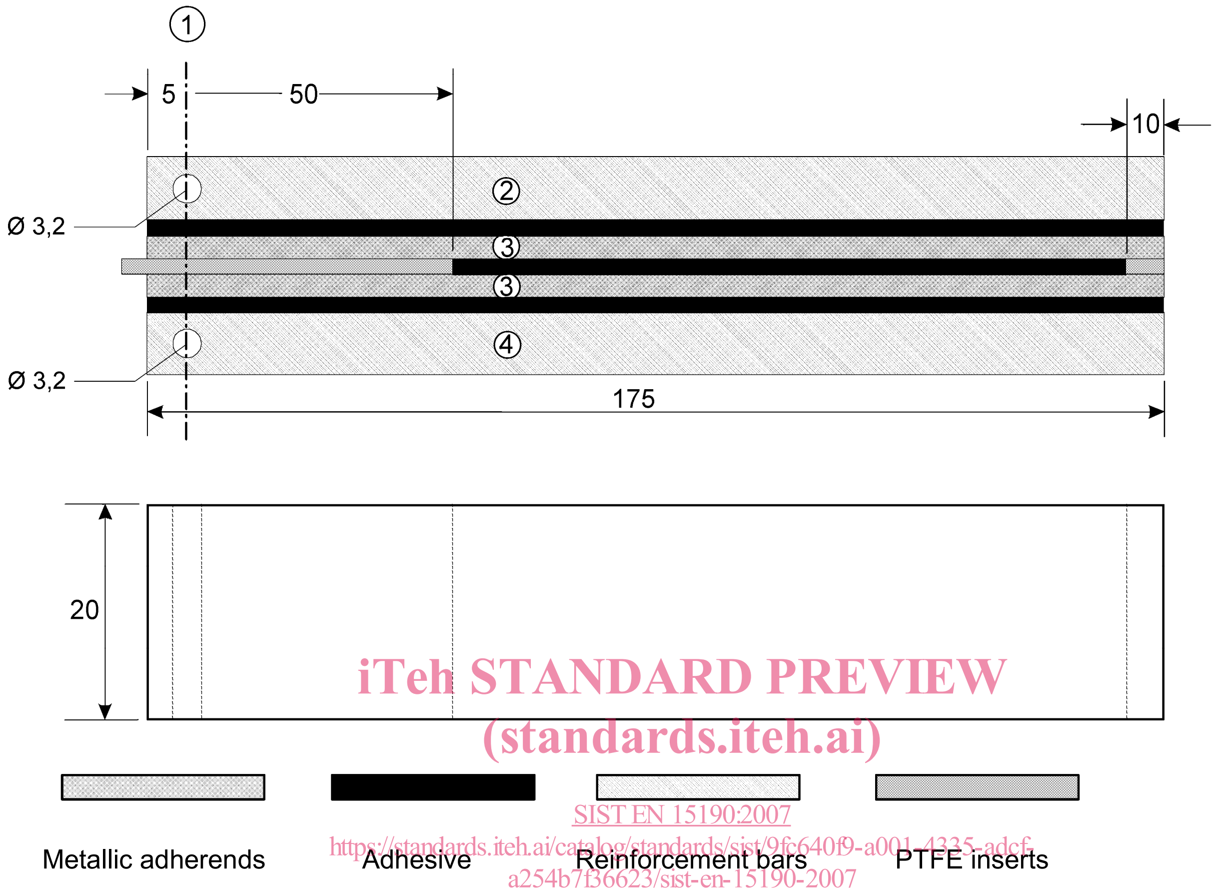
projected value of $G_{I(max)}$ at a crack growth rate of 10^{-6} mm/cycle, using the Paris Law relationship: d*a*/d*N* = AG^B

3.19

projected 'threshold', $G|_{10^{-7}}$ (J/m^2)

projected value of G_{Imax} at a crack growth rate of 10^{-7} mm/cycle, using the Paris Law relationship: d*a*/d*N* = AG^B

Dimensions in millimetres



NOTE The 3,2 mm diameter holes are for the use with 3 mm pins to apply the load

Key

1 Centre line

2 Reinforcement

3 Substrate (thickness as required)

4 Reinforcement

Figure 1 — RDCB Specimen dimensions and configuration

4 Principle

4.1 A reinforced double cantilever beam (RDCB) test specimen (see Figure 1) is tested to determine a compliance relationship with the crack length, the rate of crack growth at ambient and elevated temperature and the effect of imposing a hostile environment. For the fatigue characterisation the RDCB is cycled between a minimum and maximum displacement, δ_{min}, and δ_{max}, at a specified frequency. For linear elasticity and small deflections the displacement ratio, $\delta_{min}/\delta_{max}$, is identical to the fatigue loading ratio, R. The rate of growth of the crack per fatigue cycle is recorded along with the corresponding mode I cyclic strain energy release rate, for example the maximum value, $G_{(Imax)}$. The test is run until the crack growth rate reduces to a slow rate or nominally a threshold value, G_{th}. The test is conducted at ambient temperature, elevated temperature, and both elevated temperature and humidity to determine any degradation in wet adhesion. Combinations of environmental factors can also be applied, to determine their effects on either crack growth behaviour or crack initiation.

4.2 This method can serve the following purposes:

To measure adhesion properties and reveal the presence of weak-boundary layers.

To compare quantitatively the relative values of fatigue crack growth rate for different adhesive systems, including failure mode.

To compare quantitatively the effects of different adhesive systems on the wet adhesion durability.

To develop criteria for predicting the crack growth extent in damage tolerance and durability analyses.

5 Apparatus and materials

5.1 Fatigue tensile-testing machine capable of producing crack growth in the specimen under a sinusoidal displacement producing a tensile force between 10 % and 80 % of the full-scale range of the force transducer. This should be capable of running unattended for long periods during a 10 million cycle test with maintained accuracy. Good alignment must be present in the load train to enable accurate positioning of loading forks around the RDCB test piece. Rotational freedom, via the use of threaded bars and universal joints, also help with the fitting of the loading pins through the loading fork-test piece assembly.

NOTE For efficiency in testing time, the cross head of this machine should enable more than one specimen to be fitted and tested concurrently. The force behaviour of each specimen will be monitored individually by using individual force transducers.

5.2 Force transducer one for each specimen capable of measuring the force applied to the specimen with an accuracy of ±1 N. The transducers shall be able to withstand any applied environmental conditions without any change in their characteristics. A minimum capacity of 500 N is recommended.

5.3 Displacement transducer for the test machine capable of measuring displacement to an accuracy of 1 %, and including two places of decimal.

5.4 Environmental chamber fitted to the fatigue machine shall be used for test conditions other than room ± 5 % following EN ISO 9142.

5.5 Data-logging equipment to continuously record the displacement and the applied load, for each specimen, from the start of application of the load until the end of the test.

NOTE It is recommended that computer based logging systems are used which log directly to disc for conversion into results after or during the test.

5.6 RDCB manufacturing equipment to enable the production of identical RDCB specimens.

NOTE As well as adhesive and adherends, the following list of equipment is recommended: - heated press, plaque mould, reinforcement material, heated adhesive applicator, cutting device (abrasive wheel saw, water jet, band saw with milling machine to finish).

5.7 Micrometer, having an accuracy of better than 0,1 mm, to measure the external dimensions of the RDCB.

5.8 Optical measuring microscope, having an accuracy of better than 0,01 mm, to measure the thickness of the adhesive layers and (if necessary) the crack length in the adhesive bond.

5.9 Non-adhesive film, a film of the thickness of the desired bondline thickness to be used to form the initial crack length. Example films include polytetrafluroethylene (PTFE).

5.10 Cleaning agents , for cleaning the metals prior to bonding such as heptane and acetone.