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Varjenje – Metode ocenjevanja nepopolnosti v strukturi kovin

Welding - Methods for assessing imperfections in metallic structures

Schweißen - Verfahren zur Beurteilung von Unregelmäßigkeiten bei metallischen Bauteilen

Soudage - Méthodes d'évaluation des défauts dans les constructions métalliques

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Welding - Methods for assessing imperfections in metallic structures

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Schweißen - Verfahren zur Beurteilung von Unregelmäßigkeiten bei metallischen Bauteilen

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Foreword

This CEN Technical Report (CEN/TR 15235:2005) has been prepared by Technical Committee CEN/TC 121 “Welding”, the secretariat of which is held by DIN.

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Introduction

European provisions for assessing imperfections in metallic structures are needed to meet the requirements of industry. The technology is being applied by many industries for materials selection, design and fabrication and in-service assessment using existing methods. Engineering Critical Assessment (ECA) methods for the assessment of imperfections have received further support by the EC directive 97/23/EC concerning pressure equipment (PED) which permits such methods as an alternative to conventional methods.

The present Technical Report gives guidance to the application of BS 7910 and the European SINTAP Report. Some further documents are also mentioned.

Experience from the application should, in a few years, provide enhanced technology in the subject and eventually permit standardisation at the European level.

Conventional design procedures involve application of mathematical models such as the theory of elasticity. Actions are described by characteristics such as stress and strain. Resistance described by characteristics such as yield stress and ultimate limit stress. The designer has to assure that the resistance of the structure is adequate, using adequate safety factors, partial coefficients, etc. The mathematical models presuppose a homogenous material.

Many failure modes involve cracks. Failure may originate from a crack and/or failure may propagate (slow or fast) as a crack. Application of the conventional theory of elasticity to a structure with a crack leads to a singularity at the crack tip because the stresses approach infinity. To this should be added that a closer study of the fracture processes shows that in-homogeneities such as grain structure and even the atomic structure may influence the mode of fracture. Conventional design procedures can, for these reasons, not be applied in situations where an analysis of the significance of a crack-like imperfection is necessary and they cannot be applied for an analysis of the propagation of fatigue cracks, creep cracks, stress corrosion cracks, etc.

Alternative methods termed fracture mechanics have been developed in order to model the behaviour of structures containing cracks. Fracture mechanics interpret crack driving force and materials resistance by an alternative set of parameters such as stress intensity factor, crack tip opening displacement, etc.

Engineering critical assessments use a combination of conventional design procedures and fracture mechanics calculations, depending on the nature of the imperfection and the likely type of failure. General corrosion results for example in a reduction in cross section and may be analysed by conventional design procedures whereas propagation of fatigue cracks has to be analysed by fracture mechanics methods.

1 Scope

This Technical Report provides guidance on the selection and application of methods for assessing the significance of imperfections in all types of structures and components. The guidance is primarily tailored to welded structures and components in steel or aluminium alloys. Some of the methods may also be applied for other types of metals and for non-welded structures and components.

2 Terms and definitions

For the purposes of this Technical Report, the following definitions apply:

ECA – Engineering Critical Assessment
methods for the assessment of the significance of imperfections for the strength and usability of structures (see also clause 4)

FAD – Failure Assessment Diagram
combines the analysis of the safety against plastic instability and final fracture in a single diagram

3 Symbols and abbreviations

CDF
Crack Driving Force plot

ETM
Engineering Treatment Model

FITNET
European Fitness-for-service Network

HIDA
High Temperature Defect Assessment

SINTAP
Structural Integrity assessment procedures for European industry

The following symbols are used to characterise the local stress-strain field around the crack front. They are (usually with subscripts) used for crack driving force as well as resistance.

K
stress intensity factor

J
a line or surface integral that encloses the crack front from one crack surface to the other

CTOD
Crack Tip Opening Displacement

See the publications listed in the clause "Bibliography" (in particular references [1] and [2]) for further detail.

4 ECA principles

ECA is a designation for methods used for the assessment of the acceptability of imperfections.

Assessment of the acceptability involves consideration of:

a) Legal requirements

Legal requirements and/or provisions in the code(s) for the structure in question or contractual requirements may restrict the acceptance. Mandatory acceptance criteria, to be used for fabrication of new structures may e.g. be specified in the code or contract covering the structure.

b) Contractual requirements

The application of ECA methods should be acceptable to the parties concerned in each particular case.

c) Commercial requirements

Costs and market position may influence the benefits or disadvantages of an application

d) Requirements to fabrication.

A key consideration is maintenance of proper quality control.

5 Safety considerations

5.1 Conventional provisions for acceptance of welded structures

Standards for design and fabrication of welded structures do, as a general rule, include provisions for inspection and testing of the welded joints. The standards usually specify:

a) Acceptance levels for imperfections, normally by reference to a quality level in standards such as EN ISO 5817.

b) Methods for non-destructive testing by reference to the comprehensive system of EN standards for NDT, at least by reference to EN 12062.

c) The amount of testing (100% or examination of only a part of the welds).

d) Procedures for action when non-conformity is detected, typically requirements for repair, re-examination and some supplementary non-destructive testing.

e) Appropriate safety factors.

Conventional non-destructive testing methods involve an element of subjective judgement and the output of the testing is considered to be an evaluation and **not** a measurement (even though figures may be reported). The evaluation has two final outcomes: Accepted or not accepted.

Table 1 — Outcomes of conventional inspections

Result of inspection	**Structure**	
	Safe	*Unsafe*
Accepted	This should be the normal outcome.	Really dangerous situation where a potentially unsafe structure is accepted by mistake, neglect or inefficient inspection procedures. Usually termed customer's and society's risk. Design codes, etc. aim for reduction of this risk to very low levels for critical structures.
Not accepted	This outcome represents an expense due to unnecessary scrapping or repair in order to make the structure formally acceptable. One possible application for ECA (see below) is to document the inherent safety of the structure and thus avoid scrapping or repair. Usually termed producer's risk.	Rejection of an unsafe structure saves the customer and the society from a potential risk. However, it necessitates scrapping or repair in order to make the structure safe and it results in expenses and also a waste of resources.

Experience has shown that the system results in structures characterised by acceptable risks of failure (customer's and society's risk). The actual risk depends on the nature of the structure and on the failure mode. The acceptable risk for sudden, catastrophic failure may be of the order 10^{-6} or even lower for critical structures. The acceptable risk of having substantial fatigue cracks prior to expiration of the stipulated life time of the structure may be much higher, for example of the order 10^{-2}.

5.2 Application of ECA for new products

Application of ECA as a tool for specification of quality criteria for new structures is feasible in theory but difficult in practice. ECA shall not be invoked as an excuse for acceptance of poor workmanship.

Application of ECA involves several requirements:

a) Fracture toughness and other relevant materials data for weld metal, parent metal and heat affected zones have to be determined. This is usually performed as part of the welding procedure qualification. However, strict process control of welding operations is required in order to assure that materials data obtained during procedure testing are truly representative. If not, testing of production test plates may be required.

b) The welds have to be inspected by one or more procedures for non-destructive testing able to:

– Detect all potentially dangerous imperfections.

– Determine the type of the imperfections, at least to distinguish between planar and non-planar imperfections.

– Measure imperfection size, position and orientation.

c) All procedures for non-destructive testing have to be validated on representative samples and the inspection uncertainties determined.

d) Safety factors have to be calculated in order to counteract inspection uncertainties and other uncertainties. This may involve application of advanced probabilistic methods.