BS 7910:2013

BSI Standards Publication

Guide to methods for assessing the acceptability of flaws in metallic structures

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Publishing and copyright information

Published by BSI Standards Limited 2013

ISBN 978 0 580 74334 4

ICS 25.160.40

The following BSI references relate to the work on this standard:

Committee reference WEE/37
Draft for comment 12/30241229 DC

Publication history

First published December 1999
Second edition, July 2005
Third (present) edition, December 2013

Amendments issued since publication

Date	Text affected

Contents

List of tables

Summary of pages

This document comprises a front cover, an inside front cover, pages i to x, pages 1 to 466, an inside back cover and a back cover.

Foreword

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 December 2013. It was prepared by Technical Committee WEE/37 *Acceptance levels for flaws in welds.* A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 7910:2005 (incorporating Amendment No.1), which is withdrawn.

Information about this document

This is a full revision of the standard, and introduces the following principal changes that reflect advances in structural integrity technology, in particular elements of the European FITNET procedure [1] and [2] and the UK nuclear industry's R6 procedure [3].

- In Clause **7** the fracture assessment "Levels" 1-3 have been replaced by "Options" 1-3 and the definitions changed substantially so that the new hierarchy of Options is in line with that used in the R6 procedure. The Level I fracture assessment procedure and the simplified implementation thereof (given in Annex N of BS 7910:2005) have been deleted.
- Annex S of BS 7910:2005 on appropriate numerical integration techniques for fatigue life estimation has been deleted.
- Annex U of BS 7910:2005, which gave worked examples to demonstrate high temperature assessment, has been deleted.
- Crack driving force is expressed in terms of K_I only. The materials toughness, K_{mat}, can be derived from K_{Ic}, CTOD or *J*-integral or Charpy test data.
- A procedure for incorporating weld strength mis-match has been included in Annex I for selected geometries.
- A procedure for incorporating crack tip constraint effects has been included in Annex N.
- New rules for flaw interaction criteria have been introduced in Clause **7**.
- Clause **8**, Clause **9** and Clause **10** have been rewritten to take into account new sources of information on environmental fatigue crack growth, creep crack growth and environmentally assisted cracking (EAC).
- Annex P now includes reference stress solutions and limit load solutions for both homogeneous and strength mis-matched structures.
- A new informative annex on the reliability of various non-destructive testing (NDT) techniques has been added as Annex T.
- Annex Q has been rewritten to facilitate the use of non-linear stress distributions for residual stress fields.
- The corrosion assessment annex (Annex G) has been renamed *Assessment of locally thinned areas (LTAs)* and substantially expanded to cover geometries other than straight pipes, e.g. elbows and spheres.

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

As a guide this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification or a code of practice and claims of compliance cannot be made to it.

Presentational conventions

The guidance in this standard is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

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Introduction

Where it is necessary to examine critically the integrity of new or existing structures by the use of non-destructive testing (NDT) methods, acceptance levels are required for any flaws that might be revealed. These often already exist as quality control levels (for example in a construction code); however, in this British Standard the derivation of acceptance levels for flaws is based upon the principle of fitness-for-service.

By this principle a structure is considered to be adequate for its purpose, provided the conditions to cause failure are not reached. A distinction has to be made between acceptance based on quality control and acceptance based on fitness-for-service.

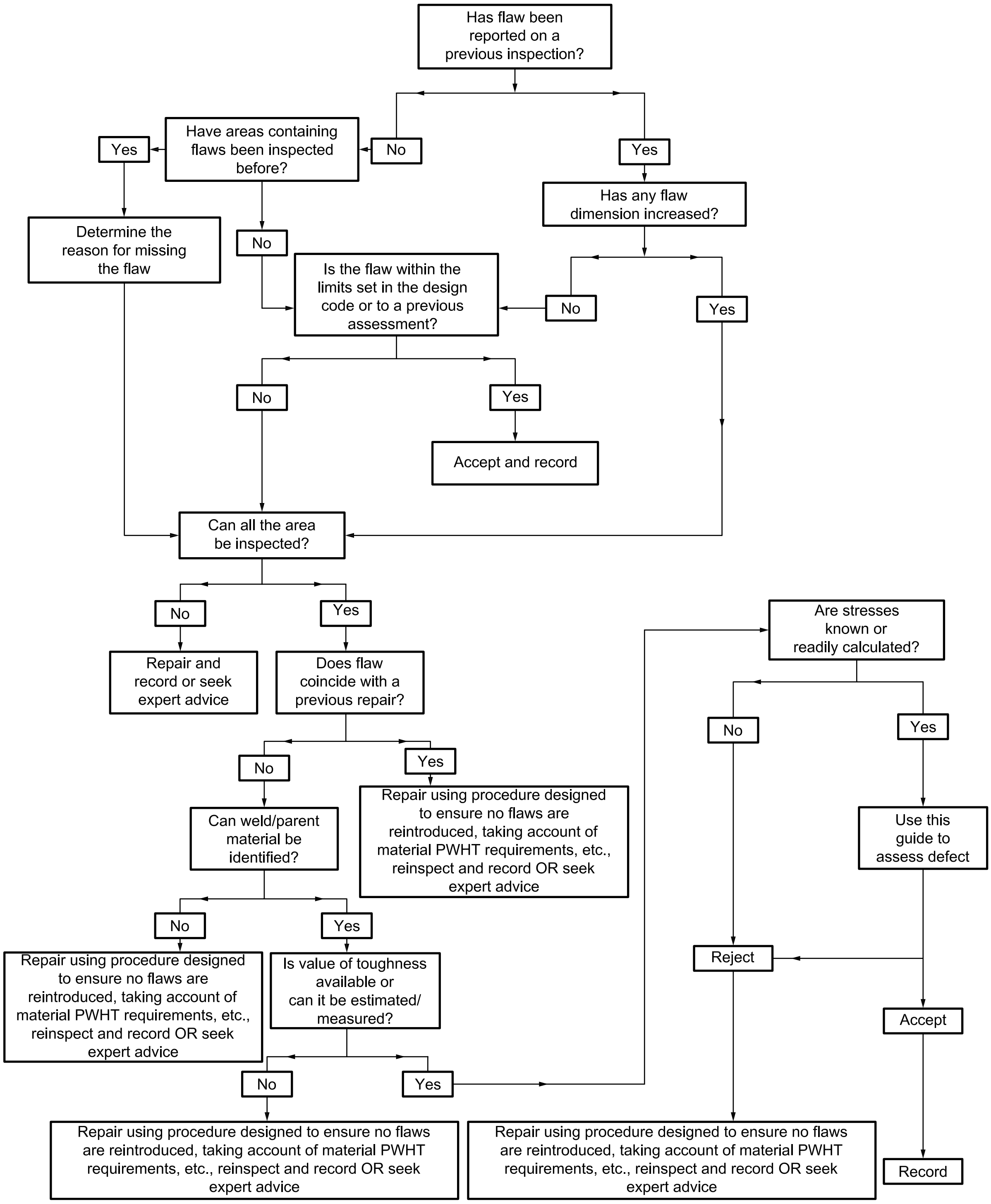
Quality control levels are usually both arbitrary and conservative, but are of considerable value in the monitoring and maintenance of quality during production. Flaws that are less severe than such quality control levels as given, for example, in current construction codes, are acceptable without further consideration. If flaws are more severe than the quality control levels, rejection is not necessarily automatic. Decisions on whether rejection, down rating and/or repairs are required may be based on fitness-for-service, either in the light of previously documented experience with similar material, stress and environmental combinations or on the basis of an engineering critical assessment (ECA) (see Figure 1). It is with the latter that this document is concerned. It is emphasized, however, that a proliferation of flaws, even if shown to be acceptable by an ECA, is regarded as indicating that quality is in need of improvement. The use of an ECA is not intended to be viewed as an alternative to good workmanship. The response to flaws not conforming to workmanship criteria needs to be the correction of the fault in the process causing the non-conformance. The methods covered by this British Standard are complementary to, and not a replacement for, good quality workmanship.

A procedure for an ECA is described throughout whereby the significance of flaws under a particular set of circumstances can be determined. All parties need to agree to its use.

It is impossible to provide a single list of flaws that are known not to cause premature failure as a large number of variables are involved as enumerated in this British Standard. Where relevant experience and data already exist it is possible to dispense with the full ECA procedure and to use authenticated previous assessments as a basis for the establishment of acceptability limits. An ECA may also be used as a basis for deferring necessary repairs to a time mutually agreeable to the contracting parties. Unsatisfactory repair of innocuous flaws can result in the substitution of more harmful and/or less readily detectable flaws.

Flaw assessment on a fitness-for-service basis requires thorough examination by NDT using techniques capable of locating and sizing flaws in critical areas. This British Standard may be used to identify such areas and to assist in optimizing the NDT procedures by identifying those aspects of flaw characterization, size and position that need to be determined. Such NDT is normally carried out after any post weld heat treatment (PWHT) and/or proof test. However, since a major objective of this British Standard is to reduce costs by eliminating unnecessary repair, careful consideration needs to be given to the level of inspection required to implement this British Standard, and to the limitations of NDT methods.

Figure 1 **Example of integrity management procedure for flaws**



NOTE If a component is rejected on the basis of a fitness-for-service analysis, downrating or retirement of the component may be considered as well as repair. Alternatively, the more advanced methods of this British Standard may be used, e.g. analyses based on leak-before-break (see Annex F) or recharacterization of flaws (see Annex E).

Where NDT has revealed the presence of flaws, the following options apply.

- If the flaws do not exceed the quality control levels in the appropriate application standard, no further action is required.
- If acceptance limits have already been established on the basis of an ECA for the appropriate combination of materials, fabrication procedure, welding consumables, stress and environmental factors, flaws need to be assessed on that basis.
- If no relevant documented experience exists, then an ECA based on the guidance given in this document needs to be carried out.

An ECA helps to identify the limiting conditions for failure or the limiting design conditions. It is emphasized that some aspects of an ECA are based on new concepts that could be subject to review.

The application of ECA principles means that "safe" results are obtained. The option of using appropriate safety factors has been incorporated or is inherent throughout the standard. If the accuracy of the input information employed (e.g. stress levels, material properties at the appropriate temperature, flaw size determination) is in question, appropriate additional safety factors need to be agreed. Equally a flaw is not necessarily unacceptable when it is found initially to exceed the acceptance levels that are derived from this standard. A further assessment may be made following the principles given in this standard incorporating more precise input data or analysis methods or by testing structurally relevant components.

This British Standard also gives guidance on the use of safety factors, reliability factors and probabilistic methods. These factors and methods do not constitute a full risk analysis of the component undergoing assessment as they do not quantify the consequences of a failure. Where failure of the structure under assessment could pose an unjustifiable or intolerable risk to the surrounding environment or population, a full risk analysis might be needed, with due recognition of both individual and societal risk [4].

The assessment methods given in this British Standard provide a quantitative measure of the acceptability of a flaw in a structure. They are not to be used in isolation but are to be used as part of an overall process for the management of flaws. The management of flaws is part of a wider integrity management plan for the structure or system. The management processes for flaws addresses factors such as:

- the cause of the flaw and remedial action to prevent further occurrences or growth;
- whether a previous inspection failed to detect this flaw. If so, the reasons for not detecting the flaw need to be determined. The inspection technique or assumptions about sub-critical crack growth rates might need to be reviewed;
- the previous history of the structure and whether it is consistent with the nature, location and size of the flaw;
- whether an inspection suggests that the flaw has grown and the observed growth is consistent with assumptions about loading and sub-critical crack growth rates after allowing for uncertainty in the inspection results;
- the implications for other structures of the same or similar design and whether modifications to the structure or a change in the service conditions might be required;
- whether there is a pattern of this flaw being detected in other structures of the same design.

An example algorithm for managing the assessment of flaws is shown in Figure 1. Alternative approaches may be developed.

1 Scope

This British Standard gives guidance and recommendations for assessing the acceptability of flaws in all types of structures and components. Although emphasis is placed on welded fabrications in ferritic and austenitic steels and aluminium alloys, the procedures may be used for analysing flaws in structures made from other metallic materials and in non-welded components or structures. The methods described are applicable at the design, fabrication and operational phases of a structure's life.

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.

ASTM E1820, *Standard test method for measurement of fracture toughness*

ASTM E1921, *Standard test method for determination of reference temperature*

BS 7448 (all parts), *Fracture mechanics toughness tests*

BS EN 583 (all parts), *Nondestructive testing – Ultrasonic examination*

BS EN 12454, *Founding – Visual examination of surface discontinuities – Steel sand castings*

BS EN 12517 (all parts), *Non-destructive testing of welds*

BS EN ISO 6892-1, *Metallic materials – Tensile testing – Part 1: Method of test at ambient temperature*

BS EN ISO 6892-2, *Metallic materials – Tensile testing – Part 2: Method of test at elevated temperature*

BS EN ISO 7539 (all parts), *Corrosion of metals and alloys – Stress corrosion testing – Preparation and use of precracked specimens for tests under constant load or constant displacement*

BS EN ISO 11666, *Non-destructive testing of welds – Ultrasonic testing – Acceptance levels*

BS EN ISO 12737, *Metallic materials – Determination of plane-strain fracture toughness*

BS EN ISO 15548 (all parts), *Non-destructive testing – Equipment for eddy current examination*

BS EN ISO 15549, *Non-destructive testing – Eddy current testing*

BS EN 17640, *Non-destructive testing of welds – Ultrasonic testing – Techniques, testing levels, and assessment*

BS EN ISO 15653, *Metallic materials – Method of test for the determination of quasistatic fracture toughness of weld*

BS EN ISO 17636-1, *Non-destructive testing of welds – Radiographic testing – Part 1: X- and gamma-ray techniques with film*

BS EN ISO 17636-2, *Non-destructive testing of welds – Radiographic testing – Part 2: X- and gamma-ray techniques with digital detectors*

BS EN ISO 17637, *Non-destructive testing of welds – Visual testing of fusion-welded joints*

BS EN ISO 17638, *Non-destructive testing of welds – Magnetic particle testing*

