

WES 2805 : 2011

# WES

## Method of Assessment for Flaws in Fusion Welded Joints with Respect to Brittle Fracture and Fatigue Crack Growth

WES 2805 : 2011

Revised on October 1, 2011

The Japan Welding Engineering Society (JWES)

In the event of any doubt arising,  
the original standard in Japanese is to be final authority.

**WES 2805 : 2011**

---

#### Warning on the Reproduction of the JWES Standards

The permission of the Association or the acknowledgement of the source shall be required to reproduce part or all of this standard. Failure to follow either of the above requirements will result in the infringement of copyright and publishing rights.

---

Enactment Date: November 30, 1976

Revision Date: November 1, 2007 October 1, 2011

Draft Committee: FTE Subcommittee (Chief: HAGIHARA, Yukito) of the Technical Committee (Chairman: MIYATA, Takashi) of JWES Iron and Steel Division

Review Committee: JWES Standardization Committee (Chairman: KOMIYAMA, Teruhiko)

For comments and questions on this standard, please contact JWES Operations Department (9th floor of Sanpo Sakuma Building, 1-11 Kanda Sakuma-cho, Chiyoda-ku, Tokyo, 101-0025 Japan).

# Contents

	Page
Introduction .....	1
1. Scope .....	1
2. Reference Standards .....	1
3. Definitions .....	2
4. Nomenclature .....	2
5. Information Required for Assessment .....	4
6. Assessment Procedures .....	4
7. Characterization of Flaw Dimensions .....	6
7.1 Types of Flaws to Be Assessed and Procedures for Their Characterization .....	6
7.2 Projection of Flaw Indication on Planes normal to Principal Stress .....	7
7.3 Characterization of Flaw Shapes .....	8
7.4 Interactions between Adjacent Cracks .....	10
7.5 Interactions between Cracks and Component Free Surfaces .....	14
8. Crack Growth due to Fatigue .....	15
8.1 Establishment of Stress Conditions .....	15
8.1.1 Stresses to Be Considered in the Evaluation .....	15
8.1.2 Characterization of Stress Distributions .....	15
8.1.3 Stress Intensity Factor Ranges ( $\Delta K$ ) .....	17
8.2 Fatigue Crack Growth Characteristics .....	17
8.3 Evaluation Method for Fatigue Crack Growth Life .....	18
8.3.1 Calculation Formulas for Fatigue Crack Growth Life .....	18
8.3.2 Fatigue Crack Growth Life of Through Thickness Crack .....	18
8.3.3 Fatigue Crack Growth Life of Surface Crack .....	19
8.3.4 Fatigue Crack Growth Life of Embedded Crack .....	19
8.4 Damage Limit due to Fatigue Crack Growth .....	19
9. Crack Dimensions and Strains Used for Assessment .....	20
9.1 Establishment of the Crack Characteristic Dimension $\bar{c}$ .....	20
9.2 Establishment of Local strains .....	23
9.2.1 Strains due to Boundary Forces ( $\varepsilon_1$ ) .....	23
9.2.2 Strains due to Welding Residual Stresses ( $\varepsilon_2$ ) .....	25
9.2.3 Strains due to Stress Concentrations ( $\varepsilon_3$ ) .....	26
9.2.4 Determination of Strains used for Assessment .....	28
10. Determination of Fracture Parameter $\delta$ .....	28
11. Determination of Material Fracture Toughness $\delta_{cr}$ .....	29
11.1 Fracture Toughness Used for Assessment .....	29
11.2 CTOD Test .....	29

11.3 Number of Specimens and Statistical Treatment .....29

11.4 Estimation of Fracture Toughness from Charpy Impact Test Results .....30

12. Judgment .....30

12.1 Judgment for Brittle Fracture .....30

12.2 Judgment for Fatigue Crack Growth .....31

13. Calculation of K Values .....31

**Attached Document (Reference) Reliability Engineering-Based Acceptance Assessment Method  
for flaws Causing Brittle Fracture .....45**

Introduction .....45

1. Scope .....45

2. Acceptance Assessment Method Using Partial Safety Factors .....45

**Explanation .....53**

Introduction .....53

1. Scope .....55

2. Reference Standards .....55

3. Definitions .....55

4. Nomenclature .....55

5. Information Required for Assessment .....55

6. Assessment Procedures .....55

7. Characterization of Flaw Dimensions .....56

7.1 Types of Flaws to Be Assessed and Procedures for Their Characterization .....56

7.2 Projection of Flaw Indication on Planes Normal to Principal Stress .....57

7.3 Characterization of Flaw Shapes .....60

7.4 Interactions between Adjacent Cracks .....60

7.5 Interactions between Cracks and Component Free Surfaces .....64

8. Crack Growth due to Fatigue .....67

8.1 Establishment of Stress Conditions .....68

8.1.1 Stresses to Be Considered .....68

8.1.2 Characterization of Stress Distributions (Surface Cracks and Embedded Cracks) .....69

8.1.3 Stress Intensity Factor Ranges ( $\Delta K$ ) .....69

8.2 Fatigue Crack Growth Characteristics .....70

8.3 Evaluation Method for Fatigue Crack Growth Life .....72

8.3.1 Calculation Formulas for Fatigue Crack Growth Life .....72

8.3.2 Fatigue Crack Growth Life of Through Thickness Crack .....73

8.3.3 Fatigue Crack Growth Life of Surface Crack .....73

8.4 Damage Limit due to Fatigue Crack Growth .....75

<b>9. Crack Dimensions and Strains Used for Assessment</b> .....	78
<b>9.1 Establishment of the Crack Characteristic Dimension <math>\bar{c}</math></b> .....	78
<b>9.2 Establishment of Local Strains</b> .....	81
<b>9.2.1 Strains due to Boundary Forces (<math>\varepsilon_1</math>)</b> .....	81
<b>9.2.2 Strains due to Welding Residual Stresses (<math>\varepsilon_2</math>)</b> .....	85
<b>9.2.3 Strains due to Stress Concentrations (<math>\varepsilon_3</math>)</b> .....	88
<b>9.2.4 Determination of Strains used for Assessment</b> .....	88
<b>10. Determination Fracture Parameter <math>\delta</math></b> .....	93
<b>11. Determination of Material Fracture Toughness <math>\delta_{cr}</math></b> .....	96
<b>11.1 Fracture Toughness Used for Assessment</b> .....	100
<b>11.2 CTOD Test</b> .....	100
<b>11.3 Number of Specimens and Statistical Treatment</b> .....	102
<b>11.4 Estimation of Fracture Toughness from the Charpy Impact Test Results</b> .....	108
<b>11.4.1 Base Metal and Arc Weld Metals</b> .....	108
<b>11.4.2 Multilayer Weld Joints</b> .....	119
<b>12. Judgment</b> .....	122
<b>13. Calculation of K Values</b> .....	123
<b>14. Case Studies</b> .....	125
<b>14.1 Brittle Fracture of Direct Desulfurization Pressure Vessels</b> .....	125
<b>14.2 Fracture of Large Pressed Frames</b> .....	131
<b>15. Reliability Engineering-Based Acceptance Assessment Method for Flaws Causing Brittle Fracture (Explanation in Attached Document)</b> .....	136
<b>15.1 Safety Factors and Reliability Engineering</b> .....	136
<b>15.2 Safety Indices</b> .....	138
<b>15.3 Introduction of Safety Indices into Flaw Assessment</b> .....	141
<b>15.4 Safety Indices and Partial Safety Factors</b> .....	142
<b>15.5 Assessment</b> .....	155
<b>15.6 Coping with Deterministic Approaches</b> .....	155
<b>16. Members of Draft Committee</b> .....	158
<b>17. Background of the Revision of WES2805</b> .....	164



## Japan Welding Engineering Society Standard

# Method of Assessment for Flaws in Fusion Welded Joints with Respect to Brittle Fracture and Fatigue Crack Growth

## Introduction

This standard describes the guidelines for the method of assessing the acceptability of flaws in welded structures detected by various non-destructive tests during manufacturing or use. The method assesses flaws according to the functions required for structural elements from the viewpoints of fitness-for-purpose, taking full account of the service conditions of the structural elements concerned. It is a practical, simplified method, based on the results of previous studies on fracture mechanics. The standard was issued in 1976, partly revised in 1980, and completely reviewed and revised in 1997. The present edition is revised and updated from the 1997 version, based on the results of the latest development in related fields such as elastic-plastic fracture mechanics, toughness assessment methods, reliability engineering, etc.

## 1. Scope

This standard applies to general welded steel structures, specifying the method for assessing the brittle fracture from cracks or similar planar flaws and for assessing the damage or brittle fracture caused by the fatigue crack growth from various types of flaws in fusion welded joints.

When assuming that the final form of damage is brittle fracture, only the flaws existing in the stress concentration areas of structural elements, i.e. those surrounded by elastic stress fields, are assessed. When through-thickness flaws exist in planar joints, this standard only applies to the cases of fatigue crack growth. A pure application of fracture mechanics is sufficient to assess such relatively simple cases.

## 2. Reference Standards

The following standards consist of part of this standard when they are cited in the standard. The latest versions are applicable.

- JIS G 0202** Glossary of terms used in iron and steel (Testing)
- JIS Z 3001** Welding terms
- WES 1108** Standard test method for crack-tip opening displacement fracture toughness measurement
- WES 1109** Guideline for crack-tip opening displacement (CTOD) fracture toughness test method of weld heat-affected zone
- WES 2808** Method of assessing brittle fracture in steel weldments subjected to large cyclic and dynamic strain