Available online at www.sciencedirect.com

ScienceDirect

Procedia Materials Science 12 (2016) 36 – 41

Procedia Materials Science

www.elsevier.com/locate/procedia

6th New Methods of Damage and Failure Analysis of Structural Parts [MDFA]

Proximity factor on transformation from subsurface to surface flaw

Kunio Hasegawa[a]*, Yinsheng Li[b], Ryosuke Serizawa[c],

Masanori Kikuchi[c], Valery Lacroix[d]

[a]*Center of Advanced Innovation Technologies-VSB-Technical University of Ostrava, 17. listopadu 15, 708 00 Ostrava-Poruba, Czech Republic*

[b]*Japan Atomic Energy Agency, Shirakata, Tkai-mura, Ibaraki-ken, 319-1195, Japan*

[c]*Tokyo University of Science, Yamazaki, Noda-shi, Chiba-ken, 278-8510, Japan*

[c]*Tractebel Engineering S.A., Avenue Ariane 7, 1200 Brussels, Belgium*

Abstract

If subsurface flaws are detected that are close to component free surfaces, flaw-to-surface proximity rule is used to determine whether the flaws should be treated as subsurface flaws as is, or transformed to surface flaws. However, specific factors for the proximity rules on transforming subsurface to surface flaws differ among fitness-for-service codes. The objective of the paper is to reveal the proximity factor from the stress intensity factor interaction between the subsurface flaw and the free surface.

Selection and peer-review under responsibility of the VŠB - Technical University of Ostrava,Faculty of Metallurgy and Materials Engineering

Keywords: Proximity factor; Subsurface flaw; Fatigue crack growth; Stress intensity factor interction

1. Introduction

If subsurface flaws are detected that are close to component free surfaces, flaw-to-surface proximity rule is used to determine whether the flaws should be treated as subsurface flaws as-is, or transformed to surface flaws. This is because stress at the ligament between the subsurface flaw and the component free surface is acting high, which can

* Corresponding author. Tel.: 81-29-282-6863; fax: +81-29-282-5406.
E-mail address: kunioh@kzh.biglobe.ne.jp

Selection and peer-review under responsibility of the VŠB - Technical University of Ostrava,Faculty of Metallurgy and Materials Engineering
doi:10.1016/j.mspro.2016.03.007

lead to ligament failure. The concept of the transformation from subsurface to surface flaw is adopted by fitness-for-service (FFS) codes. However, the specific factors for the rules on the transformation differ among the FFSs.

One of the authors had performed fatigue crack growth experiments[2015]. It was found that the proximity factor depends on aspect ratio of the subsurface flaw. It can be inferred that interaction between the subsurface flaw and the component free surface is connected to the transformation. The objective of this paper is to clarify the proximity factor from the view point of stress intensity factor interaction.

Nomenclature

a, a_S	flaw depth, flaw depth after transformation
da/dN	fatigue crack growth rate
$K_{0,1,2}$	stress intensity factor at the location of point 0, 1, or 2
ℓ, ℓ_S	flaw length, flaw length after transformation
N	number of cycles
S	ligament distance between subsurface flaw and component free surface
t	wall thickness
Y	proximity factor (= S/a)
ΔK	stress intensity factor range

2. Proximity rules

A subsurface flaw (Flaw A in Fig. 1) located near a component free surface is transformed to a surface flaw, where a is the half flaw depth, ℓ is the length of the subsurface flaw, a_s is the flaw depth, ℓ_s is the length of the transformed surface flaw and S is the ligament distance from the subsurface flaw to the component free surface. The depth of the transformed surface flaw is expressed by $a_s = 2a + S$. The stress intensity factor at Point 1 is higher than that at Point 2 under membrane stress. Initiation of failure is expected to occur at the ligament of the subsurface flaw.

The subsurface flaw located near component free surface is re-characterized as a surface flaw in all FFS codes. The proximity rules for re-characterization for various codes are tabulated in Table 1. The locations at the transformation of subsurface to surface flaws and the transformed flaw length ℓ_s are different among FFS codes.

British Energy (Current EDF Energy) R6[2000], BS 7910[2005] and European project FITNET procedures[2004] do not provide the distance S for transformation. FKM[2004] in Germany and RSE-M[2010] in France provide proximity rule in that $S/a < 1.0$, a subsurface flaw is transformed to a surface flaw, where the length of the surface flaw ℓ_s are different. Chinese code GB/T -19624[2004] for pressure vessels considers not only the ligament distance but also the back of the subsurface flaw. High Pressure Institute of Japan HPIS Z101[2008] gives the ligament distance S as a function of original aspect ratio a/ℓ and safety factors (SF). ASME[2013], JSME[2004], Swedish SSM[2008] as well as French A16[1995] for nuclear components provide the proximity rules as follows;

$$Y = S/a < 0.4 \qquad (1)$$

When a subsurface flaw is satisfied with Eq. (1), the subsurface flaw is treated as a surface flaw, where Y is the flaw-to-surface proximity factor. WES 2085[1997] of Japan Welding Engineering Society defines transformed surface flaw, if $S/a < 0.25$. Czech code A.M.E.[2005] provided as $S/a < 0.11$ is the shortest distance S among FFS codes. In the American Petroleum Institute API 579[2007], a subsurface flaw is transformed to a surface flaw based on S/t, where t is the wall thickness, irrespective of the flaw depth a.

Although the concepts of the proximity rules are the same in all FFS codes, it can be noted that the locations transformed from

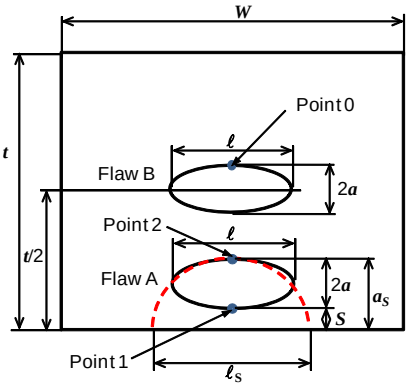

Fig. 1 Subsurface and surface flaws transformed from subsurface flaw.