3 Terms and definitions

The information in this Section is intended to provide guidance on some of the terms and definitions used in this FITNET FFS Procedure for assessment of flaws in welded or non-welded metallic components.

3.1 Fitness-For-Service (FFS)

The term Fitness-for Service (FFS) is the suitability of the welded or non-welded component for use under the expected service conditions. It is method to establish acceptance levels for flaws revealed by the use of non-destructive testing methods on existing constructions. In cases where it is necessary to examine critically the integrity of a new component at the design stage by the use of postulated flaw, this is also considered a part of a FFS assessment. The derivation of acceptance levels for flaws is based on the concept of "fitness-for-service". By this concept, a particular fabrication route is considered to be adequate for its purpose, provided the conditions to cause component failure are not reached, even after allowing for some measure of abuse in service.

Conventional quality control processes are of significant value in the monitoring of quality during manufacturing of welded or non-welded components. Flaws which are less severe than acceptance levels set by such quality control process can be considered as "acceptable" without further consideration. However, if flaws more severe than the specific quality control level are found, rejection of the component is not necessarily automatic, but decisions on whether rejection and /or repairs are justified may be based on FFS assessment. It is however, important to mention that even if flaws are found to be acceptable by FFS analysis, the quality of the component should be regarded as indicative for improvement.

The FITNET FFS flaw assessment procedure will help to identify the limiting conditions for possible failure and operates for following objectives:

- to find the defect tolerance of a structure
- to find if a known defect is acceptable
- to determine or extend the life of a structure
- to determine the cause of failure

Other objectives may also be covered, but in all cases these must be compatible with the data available and the reserve factors required. It is therefore important to have a clear understanding of what can be achieved.

3.2 Modes of Cracking and Failure

Identifying the cause of cracking of a metallic component in terms of the mechanistic process may be challenging unless service conditions allow ready discrimination; for example, an absence of significant cyclic loading or environmental effect. Characterising the crack and failure mode may be possible from visible observation.

The service conditions that need to be defined include the stress state and the environmental conditions.

The effects of the flaws listed in Part 3.1 for the modes of failure listed below can be assessed by using this document. Attention should be given during the detailed assessment of the various modes of failure, and possible interaction between them should be considered. The modes of failure are as follows;

Section 6: Fracture and plastic collapse due to overload of remaining cross section, **Section 7:** Fatigue, **Section 8:** Creep and Creep Fatigue, **Section 9:** Corrosion, Corrosion Fatigue, Stress Corrosion, Local Thin Area (erosion).

The document does not cover structural instability by buckling. However, it covers leakage (leak-before-break) and crack arrest events of components in service.

3.3 Non-Destructive Examination (NDE)

Non-destructive testing (NDT) or examination (NDE) is an essential aspect of the FITNET FFS assessment where quantitative information about the size and shape of the flaw are required as an input for the analysis. The details of the NDE methods are given in Annex D. The NDE method(s) used for flaw evaluation should be chosen so as to provide the type of information required with an acceptable degree of accuracy. Such NDE methods should be employed after any post-weld heat treatment (PWHT) and/or proof test. However, since a major objective of the FITNET FFS Procedure is to reduce costs by eliminating unnecessary repair, careful consideration should be given to the level of inspection required to implement this procedure.

The flaw information should include some or all of the following:

a) flaw length, b) flaw height, c) flaw position, d) flaw orientation with respect to the principal stress direction, e) whether flaw cross section is planar or non-planar.

One or combination of the following NDE methods may be suitable for the detection of **surface breaking flaws**:

a) visual, b) liquid penetrant, c) magnetic particle (for ferromagnetic materials), d) eddy current, e) electrical potential drop (AC or DC), f) radiography, g) ultrasonic.

All the above listed methods are suitable for measuring the surface length of such flaws, but only ultrasonic and potential drop methods are capable of providing a measurement of their height.

One or combination of the following methods may be suitable for the detection of **embedded flaws**:

a) radiography, b) ultrasonic, c) eddy current (for non-ferromagnetic materials), d) electrical potential drop (d.c only).

Both radiography and ultrasonic are capable of providing a measurement of flaw length, but ultrasonic only can provide a measurement of flaw height. Eddy current and potential drop methods tend to provide a measurement of the cross-sectional area of the flaw.

The limitations of NDE techniques have to be taken into account. It should further be noted that standard inspection techniques, which are suited to the examination of long weld lengths, may not necessarily be appropriate for highly accurate measurements of particular flaws for the purpose of FFS assessment. In such cases, supplementary techniques should be employed.

Embedded or surface flaws may in some cases be recharacterised as surface or through-thickness flaws, respectively.

3.4 Weld Strength Mismatch

By their very nature, welded joints exhibit highly inhomogeneous properties in both microstructure and mechanical property characteristics. Both characteristics significantly vary from base metal (BM). The microstructure varies both in the weld metal (WM) and in the heat affected zone (HAZ). This is also true for recent solid state friction stir welds (FSW) and laser beam welds (LBW) in structural metallic materials. The weld centre (nugget) and thermo-mechanical heat affected zone (TMHAZ) regions of FSW joints exhibit different property characteristics from those of base material.

The FITNET FFS Procedure provides a comprehensive weld joint assessment route in fracture module with consideration of weld strength mismatch. If the mis-match ratio (M) between the weld and base metal strengths is larger then 10%, the procedure recommends using the „Mismatch Option“ to take account of the beneficial (in the case of overmatching; weld metal has higher yield strength than base material) or detrimental (in the case of undermatching; weld metal has lower yield strength than base material) effects of the weld metal strength on the behaviour of the flawed weld joint.

3.5 R-Curve

Generally, engineering metallic materials with high fracture toughness do not fail with catastrophically at a particular value of CTOD or J. These materials in welded or non-welded condition exhibit a rising R curve, where CTOD and J increase with crack growth and this generally associated with growth and coalescence of microvoids. While initiation toughness (δ_i or J_{Ic}) provides information about the fracture behaviour of a ductile material, the entire R-curve gives a more complete description. The slope of the R-curve at a given amount of crack growth has indicative value, as a material with a steep R-curve is less unlikely to experience unstable crack growth.

The shape of the R-curve is furthermore depends on the fracture mechanism as well as the stress state at the crack tip. Cleavage fracture exhibits a flat or falling R-curve, while microvoid coalescence provides a rising R-curve. The slope of an R-curve tends to decrease with increasing stress triaxiality.

3.6 Stresses

3.6.1 Primary stress, which includes all stresses arising from internal pressure and external loads. The primary stress category also includes long range thermal and residual stresses, unless there is conclusive evidence to the contrary. Depending on the circumstances, the primary stresses may be divided into membrane and bending components or expressed as a polynominal function.

3.6.2 Secondary stresses are self-equilibrating stresses necessary to satisfy compatibility in the structure. Thermal and residual stresses are usually considered as secondary stresses. A significant feature of these stresses is that they do not cause plastic collapse since they arise from strain/displacement limited phenomena. They may contribute to severity of local conditions at a crack tip, however, and have to be included in calculations of K_I, δ_I and ΔK_I.

3.6.3 Peak stress is the increment of stress that is added to the primary plus secondary stresses due to concentrations at local discontinuities. Peak stresses fall into three basic categories:

1) Additional stresses due to gross structural discontinuities, 2) Additional stresses due to misalignment or deviation from intended shape, 3) Stress concentrations at local structural discontinuities, such as holes, notches, sharp corners or weld toes. The detailed descriptions of these definitions are given in Section 5.

3.7 Warm prestressing

A warm prestress (WPS) is an initial pre-load applied to ferritic steel structure containing a pre-existing flaw which is carried out at a temperature above the ductile-brittle transition temperature, and at a higher temperature or in a less-embrittled state than that corresponding to the subsequent service assessment. A WPS approach differs from a proof-test approach in conferring added resistance to fracture under the assessment conditions; that is , it is considered to elevate the stress intensity factor at failure, above the corresponding fracture toughness, K_{mat} in the absence of WPS. The WPS effect is most beneficial at low values of K_{mat}.

3.8 Leak-Before-Break (LbB)

If a flaw grows in such a way as to cause, in the first instance, a stable detectable leak in a pressurized component rather than a sudden disruptive break.

3.9 Local Approach

The application of micro-mechanical models relating the stress, strain and 'damage' local to a crack to the critical conditions required for fracture.

3.10 Time Dependent Failure Assessment Diagram (TDFAD)

TDFAD is a modified FAD which incorporates the effects of creep.