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A Review Level Assessment for Creep in API 579-1/ASME FFS-1 Fitness for Service

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Abstract

Fitness-For-Service (FFS) assessments are quantitative engineering evaluations that are performed to demonstrate the structural integrity of an in-service component containing a flaw or damage. The API 579-1/ASME FFS-1 Standard was developed to provide guidance for conducting FFS assessments of flaws commonly encountered in the refining and petrochemical industry that occur in pressure vessels, piping, and tankage. In this defect assessment is critical to fitness-for-service determination and failure pressure prediction. This work develops a comprehensive review of the principles of Levels 1, 2 and 3 defect assessment methods developed in the past four decades.

Keywords—Fitness for Service Assessment, Structural Integrity, Level Assessment

I. INTRODUCTION

Pressure Vessels, are widely used in nuclear power industry, petrochemical industry and fossil fired power plants, and generally operate under elevated temperature and high pressure environment. As it operate at different conditions and are exposed to various environmental attacks and loading, these attacks weaken the load-carrying capacity and affects the remaining life of Vessel, (10) so their mechanical behavior should be studied broadly. Creep is one of the mechanical properties of materials, which results in permanent deformation of material even under applied constant stress less than yield strength. Creep deformation is time, stress, and temperature-dependent, and an increase of any of these parameters causes significant effects on creep strain. Therefore, for the safe operation structural integrity assessment of Pressure Vessel under elevated temperature and high pressure conditions is essential. (12) The existing standards and specifications for safety assessment of in-service pressure vessels with volumetric defects give severe limitations and requirements to the allowable dimensions of volumetric defects. Many articles have also reported the studies on effects of the dimensions of volumetric defects on the load-carrying capacity under steady and cyclic loads. These standards and relevant research works, to some extents, provide the scientific and reasonable criteria and theoretical basis for the structural integrity assessment of Pressure Vessel. However, these results are only based on the elastic-plastic analysis under normal temperature condition and do not consider the creep effect under elevated temperature condition. (7)

The ASME and API design codes and standards for pressurized equipment provide rules for the design, fabrication, inspection, and testing of new pressure vessels, piping systems, and storage tanks. These codes

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typically do not provide assessment procedures to evaluate degradation due to in-service, environmentally-induced damage, or flaws from original fabrication that may be found during subsequent inspections. (6) Fitness-For-Service (FFS) assessments are quantitative engineering evaluations that are performed to demonstrate the structural integrity of an in-service component containing a flaw or damage. The API 579-1/ASME FFS-1 Standard was developed to provide guidance for conducting FFS assessments of flaws commonly encountered in the refining and petrochemical industry that occur in pressure vessels, piping, and tankage. The results from a FFS assessment may be used to make, run, rerate, repair, or replace decisions to ensure that pressurized equipment containing flaws that have been identified (David Osage et el., 2015)

FFS assessment is routinely conducted on three different levels. Level 1 is more conservative related to level 3, which in turn leads to more conservative assessment as compared to level 3 resulting in realistic outputs. In other words, each level of assessment provides a balance between the skill of the practitioner, the degree of conservatism, and the intricacy of the analysis.(6)In general, FFS assessment decides to either keep damaged equipment in-service, re-rating for a specified remaining life, or to be completely retired leading to replacement. When a damaged component is kept in-service, FFS determines its remaining life under original design or rerated operational conditions. FFS assessment methods evaluate different damage during an inspection can continue to operate safely. (Sh.Zangeneh et el., 2021)

II. LITERATURE REVIEW

Sh. Zangeneh et el. has explained the level assessment for damaged pipe and procedure and result for level 3 assessment. They also explained the FEA procedure for damaged pipe. (1) David Osage et el. have discussed procedure and steps required in FFS assessment as well as required acceptance criterion for level assessment of component. (2) Guojin Qin et al. have discussed critical review of the principles, methods, and typical applications of Levels 1, 2 and 3 defect assessment on pipelines for FFS determination, failure pressure prediction and integrity management, along with commentary remarks made on each method. In their work they explained the introduction of finite element analysis & definition of the defect geometry, especially the complex shaped defects, also mentioned the need of level 3 assessment in industry. (3) Bakhtiari et al. employed the FFS assessment to examine the condition of a reactor subjected to a fire damage in an oil refinery unit. In their work, FFS assessment was combined with microstructural studies and hardness measurement to obtain the information required to assess the condition of the damaged reactor. According to the calculation, the mechanical strength of the damaged reactor was found to deviate from the original design and a new Maximum Allowable Working Pressure (MAWP) was calculated and implemented. (4)

A. FFS Assessment Procedure

The FFS Eight-Step Assessment Procedure used in API 579-1/ASME FFS-for all damage mechanisms is provided in Part 2 and is summarized in below table.

Steps	Procedure
1	Flaw and Damage Mechanism Identification

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2	Applicability and Limitations of the FFS Assessment Procedures
3	Data Requirements
4	Assessment Techniques and Acceptance Criteria
5	Remaining Life Evaluation
6	Remediation
7	In-Service Monitoring
8	Documentation

(8)

B. Level Assessments

As our focus on level assessment in fitness for service procedure we have to focus on first two steps as it is required to which level of assessment is required.

Identifying Damage Mechanisms

The first STEP in a FFS assessment performed in accordance with API 579-1/ASME FFS-1 is to identify the flaw type and cause of damage. The original design and fabrication practices, the material of construction, and the service history and Environmental conditions can be used to ascertain the likely cause of the damage. Once the flaw type and cause of damage are identified, the appropriate Part of this Standard can be selected for the assessment.

Assessment Levels

The applicability and limitations of the assessment procedure are described in each Part, and a decision on whether to proceed with an assessment can be made. The data required for a FFS assessment depend on the flaw type or damage mechanism being evaluated. Data requirements may include the original equipment design data, information pertaining to maintenance and operational history, expected future service, and data specific to the FFS assessment such as flaw size, state of stress in the component at the location of the flaw, and material properties. Data requirements common to all FFS assessment procedures are covered in this Part. Data requirements specific to a damage mechanism or flaw type are covered in the Part containing the corresponding assessment procedures Assessment techniques and acceptance criteria are provided in each Part. If multiple damage mechanisms are present, more than one Part may have to be used for the evaluation

Three levels of assessment are provided in API 579-1/ASME FFS-1 for each flaw and damage type. In general, each assessment level provides a balance between conservatism, the amount of information required for the evaluation, the skill of the practitioner performing the assessment, and the complexity of analysis being performed. Level 1 is the most conservative and the easiest to use. Practitioners usually proceed sequentially from a Level 1 to a Level 3 assessment (unless otherwise directed by the assessment techniques), particularly if the current assessment level does not provide an acceptable result or a clear course of action cannot be determined. It should be noted that the definitions of assessment levels in API 579-1/ASME FFS-1 are significantly different than those used in other standards.(8) A general overview of each assessment level and its intended use is described below:

Level 1 Assessment:

The Level 1 assessment procedures apply only if all of the following conditions are satisfied:

a. The original equipment design data should be assembled to perform a *FFS* assessment. The extent of the data required depends on the damage mechanism and assessment level. A data sheet is included to record

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the required information that is common to all *FFS* assessments. In addition, a separate data sheet is included with each Part of this Standard to record information specific to the flaw type, damage mechanism, and assessment procedure.

b. The component has not been subject to fire damage or another overheating event that has resulted in a significant change in shape such as sagging or bulging, or excessive metal loss from scaling.
c. The material meets or exceeds the respective minimum hardness and carbon content
d. The component does not contain:
   i) An LTA or groove-like flaw,
   ii) Pitting damage,
   iii) Blister, HIC, or SOHIC damage,
   iv) Weld misalignment, out-of-roundness, or bulge that exceed the original design code tolerances,
   v) A dent or dent-gouge combination,
   vi) A crack-like flaw, orMicrostructural abnormality such as graphitization, sigma phase formation, carburization or hydrogen attack

Remark: Level-1 defect assessment models are generally semi-empirical in nature. They are easy to operate and obtain results with a certain accuracy. However, complex stressing conditions and irregular defect geometries limit the modelling accuracy. (3)

.Level 2 Assessment:

The Level 2 assessment procedures apply only if all of the following conditions are satisfied:

a) The original design criteria were in is defined as any part that is designed and fabricated to a recognized code or standard, and equipment is defined to be an assemblage of components

b) A history of the operating conditions and documentation of future operating conditions for the component are available.

c) The component has been subject to less than or equal to 50 cycles of operation including startup and shutdown conditions, or less than that specified in the original design.

d) The component does not contain:

   i. An LTA or groove-like flaw,
   ii. Pitting damage,
   iii. Blister, HIC, or SOHIC damage,
   iv. Weld misalignment, out-of-roundness, or bulge that exceed the original design code tolerances,
   v. A dent or dent-gouge combination,
   vi. A crack-like flaw, orMicrostructural abnormality such as graphitization, sigma phase formation, carburization or hydrogen attack

Remark: Although the Level-2 assessment method reduces conservatism compared with the Level-1 assessment, problems still exist to affect the modelling accuracy.

Level 3 Assessment:

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A Level 3 Assessment should be performed when the Level 1 and 2 methods cannot be applied due to applicability and limitations of the procedure or when the results obtained indicate that the component is not suitable for continued service.

a) Conditions that typically require a Level 3 Assessment include the following.

1. *Advanced stress analysis techniques are required to define the state of stress because of complicated geometry and/or loading conditions.*
2. *The component is subject to cyclic operation.*
3. *The component contains a flaw listed in above level a detailed assessment procedure is provided for a crack-like flaw; however, this procedure cannot be used to evaluate crack-like flaws that are caused by stress corrosion, oxide wedging, or similar environmental phenomena.*

b) The Level 3 Assessment procedures, with the exception of the procedure for the evaluation of dissimilar metal welds, can be used to evaluate components that contain the flaw types in

i) An LTA or groove-like flaw,
ii) Pitting damage,
iii) Blister, HIC, or SOHIC damage,
iv) Weld misalignment, out-of-roundness, or bulge that exceed the original design code tolerances,
v) A dent or dent-gouge combination,
vi) A crack-like flaw, orMicrostructural abnormality such as graphitization, sigma phase formation, carburization or hydrogen attack

Remark: The Level-3 method has made significant progress in defect assessment on pipelines by solving highly nonlinear problems through FE modelling. Due to requirements of background knowledge and engineering mathematics fundamental, as well as a lengthy modelling and computational process, the method has not been popular in industry application.

III. CONCLUSION

The applicability and criticality analysis of the Level 1 and Level 2 fitness for service assessment according to API 579. The critical fitness for service assessment conducted on the pressure vessel equipment helped to eliminate unnecessary turnaround maintenance and inspections that would have incurred cost and impacted on business. If sometimes as both criterion for level assessment 1 and 2 then level 3 assessment is carried out.

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