Survival of the Fittest

Assessing the value of effective asset integrity management and fitness-for-service assessments

Project Overview

Fitness-for-Service (FFS) assessment provides the means to improve both reliability and profitability in the process, pipeline, and power industries. In 2000, the American Petroleum Institute (API) published API 579, a recommended practice on FFS assessment of refinery equipment. API 579 is applied widely outside of the refining industry, including pipelines, upstream oil and gas installations, as well as chemical, petrochemical, and power plants. FFS assessments are most frequently employed to address damage found in pressure equipment, piping, and storage tanks. Subsequent revisions of API 579 (in 2007 and 2016) explicitly recognize the widespread applicability of the technology.

While Fitness-for-Service assessments are a critical part of effectively maintaining equipment, it is also important to formulate an asset integrity management strategy to support the full life-cycle of facility equipment/assets. As assets age, specialized strategies around planning, training and implementation of modern integrity methodologies are crucial in addressing and maintaining the condition of assets over time. These strategies should include a number of engineering and equipment life-cycle best practices, including Fitness-for-Service assessments.

This article will provide further insight into the value of implementing Fitness-for-Service assessments within the overall scope of a strategic asset integrity management plan.

What is asset integrity management?

Asset integrity management is an approach to strategically maintain and operate critical assets throughout their lifecycle. Increased risk, often a by-product of age, is a primary driver for the adoption of methods and technologies that offer clarity and confidence in long-term asset condition. The level of risk, acceptable vs. unacceptable, is not universal to all facilities or organizations. Each organization or facility has a level of risk tolerance based upon a collective set of risks to safety, the environment, production, reputation and other drivers. When making decisions to operate, repair or replace a piece of equipment based upon risk, Fitness-for-Service methods provide quantitative means to define risk and to develop a strategy to achieve a tolerable level of risk over the life-cycle of the equipment.

What is Fitness-for-Service (FFS)?

FFS assessment is a multi-disciplinary approach to determine, as the name suggests, whether equipment is fit for continued operation. The equipment or system in question may contain flaws or other damage, or may be subjected to more severe operating conditions than anticipated by the original design. The outcome of a FFS assessment is a decision to run as is, repair, re-rate, alter, or retire the equipment. A remaining life analysis may also be performed as part of the assessment, which can be used to set future inspection intervals and to budget for capital expenditures when existing equipment is to be retired.

A typical FFS assessment may involve several engineering disciplines, and it requires collecting data from a number of sources. Although one person may take a lead role in performing the assessment, they must rely on others to provide crucial data and expertise.

FFS assessments can range in complexity from simple screening evaluations to highly sophisticated computer simulations, including finite element analysis (FEA) and computational fluid dynamics (CFD). The necessary level of complexity varies from one situation to the next. In some cases, an advanced analysis is performed when a simple screening assessment is unable to demonstrate that the equipment in question is fit for continued service. Standardized FFS procedures typically include a range of assessment options that cover the full spectrum of complexity.

The API and the American Society have published the leading FFS standard for pressure equipment (pressure vessels, storage tanks and piping) for Mechanical Engineers (ASME). API published the original version of this method, API 579, in 2000. Both organizations collaborated in the creation of the revised edition, API 579-1/ASME FFS-1, which was published in 2007 and most recently updated in 2016. The original API 579 document pertained primarily to refinery equipment, although the procedure was widely used outside of the petroleum industry. With the addition of the ASME brand name in the 2007 version, there is an explicit recognition that this standard is suitable to a broad range of industries that rely on pressure equipment, including electric power, chemical, pipeline, and pulp and paper. The contents of the standard have been updated to reflect technological advances and the broader industry coverage. The API/ASME FFS standard is discussed in more detail below.

Advantages of Fitness-for-Service assessment

It goes without saying that safety is an important goal of any company. Although there is an inherent risk in processing, transporting, and storing liquids and gases under pressure, it is important to reduce this risk to minimal levels. Design codes and standards are intended to ensure reliable operation of newly constructed vessels, tanks and piping. FFS standards such as API 579-1/ASME FFS-1 can be used to assess whether or not it is safe to operate aging equipment that may have degraded in service.

While improved safety is a clear benefit of FFS assessment, there are substantial economic benefits to this technology that may be less apparent. For example, unplanned shutdowns are extremely costly in terms of lost production. FFS assessments performed on key assets during a scheduled shutdown can greatly reduce the likelihood of unplanned outages.

When flaws or other damage are detected, the decisions on how to deal with such imperfections have enormous economic implications. If flaws are discovered during normal operation, a FFS assessment can determine whether or not it is safe to operate the equipment until the next planned outage. If the outcome of the FFS assessment is favorable in such a case, then the operator effectively avoids a costly unplanned shutdown. Even during an outage, whether planned or not, it is desirable to avoid or postpone repairs, provided the FFS assessment indicates that the equipment can be safely operated until the next planned shutdown. Unscheduled retirement of components can be particularly costly, as long lead times for delivery of replacement components can result in extensive delays in production. FFS assessments provide a rational basis to determine whether or not a damaged component can continue to operate until a replacement can be delivered.

A lesser known but significant economic benefit of FFS technology is that it can lead to improved yields. If the rate of life consumption of equipment can be accurately quantified through FFS assessment, a plant can be run more aggressively between shutdowns. Even if components are replaced more frequently due to accelerated life consumption, the increased output may generate significantly larger net profits for the plant.

The API/ASME FFS Standard

The API 579-1/ASME FFS-1 standard, most recently updated in 2016, covers a wide range of flaw types and degradation mechanisms. A brief overview of this standard is provided below.

Levels of Assessment

The API/ASME FFS standard provides three levels of assessment:

+ Level 1. This is a basic assessment that can be performed by properly trained inspectors or plant engineers. A level 1 assessment may involve simple hand calculations.
+ Level 2. This assessment level is more complex than level 1, and should be performed only by engineers trained in the API/ASME FFS standard. Most level 2 calculations can be performed with a spreadsheet.
+ Level 3. This is the most advanced assessment level, which should be performed only by engineers with a high level of expertise and experience. A level 3 assessment may include computer simulation, such as finite element analysis (FEA) or computational fluid dynamics (CFD).

These three assessment levels represent a trade-off between simplicity and accuracy. The simplified assessment procedures are necessarily more conservative than more sophisticated engineering analyses. In some cases, the component being evaluated may fail a level 1 assessment but pass a level 2 or level 3 assessment because of the conservative simplifying assumptions in the former. In certain situations, the API/ASME standard does not permit a level 1 assessment. For example, level 1 assessments are not applicable to pressure equipment subject to significant supplemental loads, such as dead loads, wind loads, thermal expansion loads, and seismic loads.

With level 1 assessments, the specified procedures must be followed exactly, and there is little or no room for interpretation. Level 2 procedures provide some latitude to exercise sound engineering judgment. For level 3 assessments, the API/ASME standard provides a few overall guidelines, but the details of the assessment are left to the user. The lack of specificity in level 3 is by design. There is no practical way to codify step by step procedures for advanced engineering analyses because every situation is different, and a wide range of approaches may be suitable for a given situation.

As one might expect, the cost of a FFS assessment tends to increase with complexity. Sophisticated computer modeling that is performed as part of a level 3 assessment is obviously more expensive than a simple hand calculation.

Moreover, level 1 assessments may have less onerous inspection requirements than higher level evaluations. When compared with the potential savings, however, the cost of an assessment, even at level 3, is often insignificant. If a complex engineering analysis allows a plant to avoid a catastrophic failure or an unplanned shutdown, then it is certainly a good investment.

Asset integrity management using FFS technology

Quest Integrity routinely performs FFS assessments for industry clients. Generally, FFS assessments are performed when a facility discovers unexpected damage to equipment or damage is more extensive than anticipated. The FFS assessment is performed to allow the facility to quickly decide whether the damage requires equipment repair, replacement, or modifications to operations to manage the equipment. Proactively, FFS can be applied to known or expected damage conditions to allow the facility to make onthe-spot decisions when damage is found during a future inspection.

Several examples of FFS applications are provided below. The examples below represent only a small sample of the wide range of possible applications.

Pressure Vessel with Corrosion Metal Loss and Pitting

Automated Ultrasonic Inspection (AUT) was performed on the pressure vessel by Team Industrial Services (TEAM). A number of regions of general corrosion metal loss and isolated pitting were identified on the shell of the vessel. Isolated pitting was found on the vessel heads. In order to assess the pressure vessel in its current condition, the rules of API 579/ASME FFS-1 [1] Part 4 (General Metal Loss), Part 5 (Local Metal Loss), and Part 6 (Pitting Metal Loss) for the heads were applied.

Following a thorough review of the AUT data, generalized metal loss was found in the AUT scans and an isolated pit was found in an additional scan area. These regions were selected for the FFS assessment as they presented the most severe damage and/or were representative of the damage observed. The minimum wall thickness from the AUT data was 0.337 inches compared to a nominal wall thickness of 0.625 inches.

The assessment calculations were completed using Quest Integrity's commercial software program, Signal™ Fitnessfor-Service. The Part 6 FFS result found the vessel heads to be fit for service in its current condition. However, the FFS assessment of the pressure vessel shell found that the generalized corrosion did not satisfy the Part 4 Level 2 acceptability for continued operation in its current condition. The isolated pit in the shell was evaluated using the Part 5 Level 2 localized metal loss procedures and was found to meet the acceptance criteria. Considering all damaged regions, the pressure vessel was found to be not fit for continued service in its damaged condition under the original design condition (200 psig at 500°F).

Further discussion with the facility found that the pressure vessel was operated near 100 psig with the pressure safety valve set to 140 psig. Since this was found to be less than the calculated reduced maximum allowable working pressure to meet fitness-for-service criteria, no operational modifications or repairs were required and the pressure vessel was returned to operation.

To assess the life of the equipment, the facility provided corrosion rate data for the equipment from their inspection data management system. When this corrosion data was applied to the FFS assessment, a remaining life of the vessel was calculated and allowed the facility to plan for future inspections and repairs or replacement of the vessel.

Convection Section Tube Failure during Operation

A large-scale natural gas manufacturing plant in the United States suffered a tube failure in the convection section of a fired heater. The failure occurred in one of the eight passes of finned tubes near the top of the convection section (see Figure 1).

The operator had an inventory of replacement tubes for the convection section to allow for immediate replacement of several tubes. However, the full extent of the tube cracking was unknown from the inspection due to the configuration of the convection section and the use of finned tubes. Existing cracks which were not through wall or initiated from the ID could not be found with confidence using conventional NDE methods.

Rather than proceeding with a full repair, a hydrotesting procedure was developed using fracture mechanics and a failure assessment diagram (FAD) analysis to proof test the remaining tubes (see Figure 3). FAD is a fracture mechanics model for assessing crack-like flaws. A series of calculations are performed using the component geometry, crack dimensions and material properties. These calculations result in an assessment point on the FAD. Failure is predicted if the point falls on or outside of the curve. The crack is considered to be stable if the point falls inside of the curve. The FAD assessment method is implemented in API 579, Part 9, Level 2.

The failure analysis and engineering assessment results were successfully used to evaluate if the convection tubes were fit to operate until either of two future shutdown opportunities. These methods exemplify how failure analysis and fitness-for-service provided the operator a sound basis to evaluate the business and safety risks of continued operation until long-term repairs and system improvements could be implemented.

Managing Localized Internal Corrosion in a CO_2 Absorber Using FFS

Corrosion in CO_2 absorption systems may be difficult to determine with the system in operation. These pressure vessels are frequently quite large and difficult to inspect due to size and in some cases external insulation. The corrosion is typically very localized and therefore will be difficult to detect with spot ultrasonic inspection.

Localized corrosion in these systems can be affectively evaluated using API 579/ASME FFS-1 Fitness-for-Service criteria. The results of this assessment are used by the operator/owner to determine the level of current risk and to determine a course of action for mitigation. When local thinned areas are found, the procedures in Part 4 (General Metal Loss) may produce overly conservative results. Part 5 (Local Metal Loss) assessment procedures (use a river bottom profile) and can be used to reduce the level of conservatism in the results.

For example, Quest Integrity performed a FFS assessment of a CO_2 Absorber that had been in service since the 1980's. Internal visual inspection had shown localized internal corrosion in the lower section of the tower where CO_2-rich gas enters the tower and contacts the lean amine solution. Later a follow-up external inspection survey by UT was conducted to determine the extent of the corrosion and to allow periodic monitoring of the corrosion from the exterior of the tower. Accurate profiles of multiple Local Thinned Areas (LTAs) were obtained by measuring thickness on a 1" x 1" grid. The results found a decrease in wall thickness of 47–74% from the original nominal wall thickness. The LTA's were each assessed in accordance with API 579/ASME FFS1, Section 5. This Fitness–for-Service Assessment allowed the tower to continue to operate.

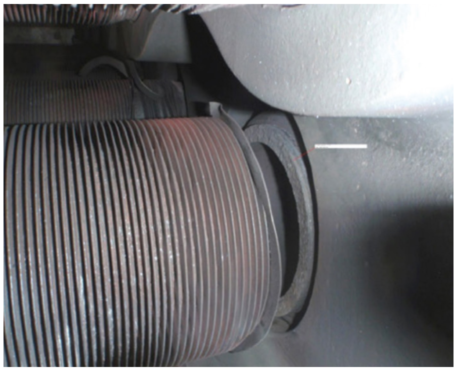

Figure 1. Tube failure at center support

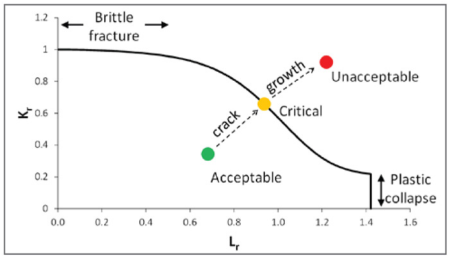

Figure 2. FAD diagram

Figure 3. CO_2 corrosion, LTA

A program for ongoing monitoring of the thinned areas was established, and plans commenced for repairs to the tower prior to or during the next scheduled shutdown, 12 months in the future Application of the API-579-1/ASME FFS-1 methodology allowed this equipment to operate within safe process parameters without loss of production. Continuous operations in the short term when degradation mechanisms have been discovered, assessed, and monitored allow for a better economic determination of the optimum remediation repair method to be planned and implemented.

Figure 4. Monitoring internal corrosion using an external UT grid

Conclusion

Asset integrity management is an approach to strategically maintain and operate critical assets throughout their lifecycle. Fitness-for-Service (FFS) assessment has seen widespread application in a range of industries that rely on pressure equipment. This technology has enormous advantages, both in terms of safety and profitability.

Acknowledgements

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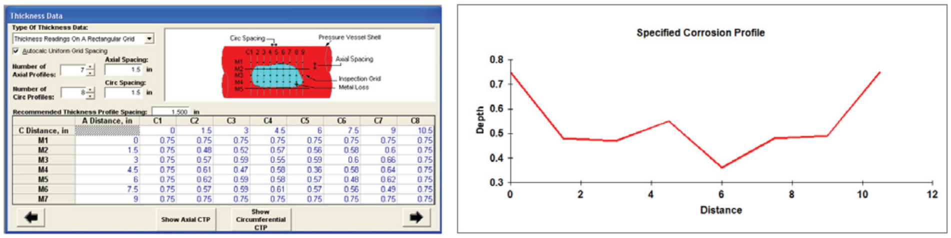

Figure 5. Example of LTA Data in Quest Integrity's Signal™ FFS engineering software.

Quest Integrity, a TEAM company, is a global leader in the development and delivery of asset integrity and reliability management services. The company's integrated solutions consist of technology-enabled, advanced inspection and engineering assessment services and products that help organizations improve operational planning, increase profitability, and reduce operational and safety risks. Quest Integrity is built on a foundation of leading edge science and technology that has innovated and influenced industry best practices since 1971.