WELD DEFECTS AND FAILURES: QUANTIFYING FITNESS FOR SERVICE

How finite element mathematical simulations can mitigate risk, cut costs and improve overall safety

For chemical and petrochemical companies facing the threat of fugitive emissions, the ability to quantify a component's fitness for service could be the difference between safety and disaster. This article shares insight about managing risk specific to weld failures.

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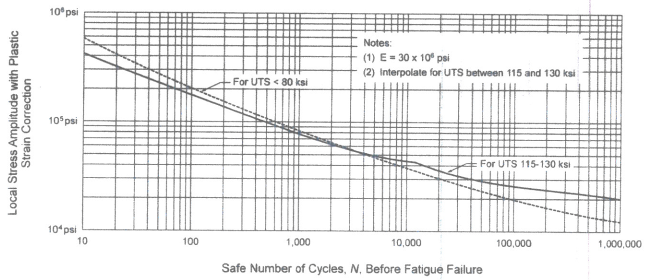
The predictive power of finite element mathematical simulations can often prevent the loss of millions of dollars in downtime, industrial catastrophes, injuries and loss of life.

Cyclical stress factors

In materials science, fatigue refers to failure that results from cyclical stress. Most often, such failures manifest themselves in some form of mechanical or thermal fatigue, often as a result of vibration, loading and unloading, or repetitive fluctuations in temperature. These failures are often blamed on the designer or fabricator, when the real cause is transient operating conditions. For instance, operators often increase applied loads and temperatures in an effort to increase productivity; as a result, they inadvertently push the limits of fatigue damage and increase the risk of failures.

As a point of reference, it is estimated that fatigue contributes to approximately 90% of all mechanical service failures[1]. An increasing demand for high performance industrial systems has exacerbated the likelihood of structural fatigue.



Design fatigue curves for carbon, low alloy, series 4XX, high alloy steels and high tensile steels for temperatures not exceeding 700° F (371° C).

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Fatigue as the cause of weld failures

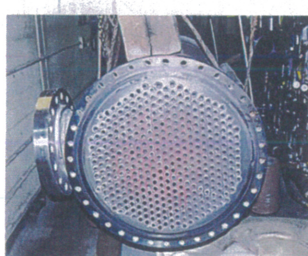
Weld failures present one of the most serious financial, safety and reputational threats across many sectors including: chemical, petrochemical, aerospace, automotive, construction and energy. Any component that exceeds its fatigue or endurance level can trigger a weld failure. They can occur suddenly, causing catastrophic failures that could have been avoided by prior analysis and repair.

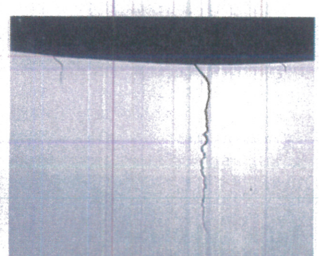
The nuclear industry was the impetus to develop Fitness-for-Service (FFS) practices. In particular, the ability to quantify the tolerance of weld defects played a key role in validating the safety of nuclear vessels.

Even today, however, few industries outside of the chemical and nuclear are well-versed on the availability and exactness of FFS procedures. As a result, many companies fail to verify fatigue tolerance and safety margins before making the costly decision to replace components that are evidencing surface damage.

By employing FFS measures, many companies could have the capacity to design and safely implement repairs to restore fatigue and fracture-safety margins, even given an operational environment of cyclical stresses. Making an informed decision to repair or replace the compromised component requires a multi-faceted investigation that yields quantifiable results.

Companies often opt for metallurgical analyses to evaluate and act in response to weld cracks. Metallurgical analyses are limited, however, and unlikely to address fatigue





This heat exchanger exhibits multiple cracks at the flange bolt holes because design did not accommodate severe thermal transients.

or fracture analyses. Without quantifying a component's integrity, decision makers are left to select a path of action based on an incomplete picture. Only in the presence of reliable data can the decision to extend life be made with confidence.

The predictive power of mathematical simulations and fatigue evaluations

Modern materials science and mathematical simulations provide the most robust method of evaluating FFS. Finite element analysis is a process that integrates engineering principles and mathematical physics. As the name implies, finite element analysis divides the entirety of a complex structure into multiple and precise elements. This exercise identifies what occurs under various conditions of cyclical stress and allows for accurate predictions about future cracking.

Mathematical finite element simulations are able to quantify stresses even with increased operating loads and the reduction in brittle and ductile fracture margins that arise from higher applied static and dynamic loads. Simulations are also useful in quantifying the reduction in fatigue life due to an increased number of operating cycles, as well as the relationship between failure causation and aggressive operating conditions. Also of importance, mathematical finite element simulations can confirm whether stress limits meet industry Codes and Standards.

When is FFS the right choice?

Two circumstances often prevent companies from engaging an expert to conduct an FFS evaluation. First, many companies are unaware of the value of finite element analysis and mathematical simulations in identifying and resolving fatigue-related failures. Secondly, because fatigue failures can occur as a result of unexpected cyclical stresses rather than an anticipated source of stress, the existence of fatigue damage is often overlooked.

Specific to weld failures, FFS evaluations can demonstrate the structural integrity of tanks, vessels and other process equipment. The acquired data empirically supports the decision to run, repair or replace the component in question. At times, companies assume that weld repairs are not an option, so they replace damaged components. In many cases, however, repairs are feasible. The critical decision to repair or replace an in-service component can be guided by finite element mathematical analysis.

In general, FFS investigations are well-suited when companies need to quantify and predict continued service: the residual life of an in-service component; safe operation beyond the original design life; tolerance to defects; and the impact of an outage or shutdown.

Capturing the value of FFS

Most companies are stretched to the limit to increase production, decrease costs and ensure safety. Unfortunately, fatigue failures are all too common, and work in direct opposition to a company's objectives.

Decision makers can more confidently mitigate the risk and expense of failures when they can reliably assess their options. FFS evaluations can quantify and demonstrate the ability to extend service life and avoid the costly process of replacement. FFS evaluations often reduce maintenance and operating costs as well, which is one more benefit companies can glean in today's competitive marketplace.

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Reference

1. *http://www.asminternational.org/documents/10192/1849770/05224G_Chapter14.pdf*

The prevalence of joint weld failures

Perhaps the most prevalent and underestimated weld failure is the common soldered joint. Few

in one of the school's restrooms, she went to the boiler room to investigate. She was in the wrong

ABOUT THE AUTHOR

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