Maximator Test, LLC - White Paper

Pressure Fatigue Testing

Getting the most out of understanding the dynamic pressure carrying ability of your product

The application of repetitive pressure cycles on a pressure vessel can take their toll in the form of fatigue, even when the maximum stresses in the part are well below the yield strength of the vessel's material. Like all classical fatigue failures, the damage process consists of 2 phases: crack initiation and crack propagation. It is not until the crack progresses sufficiently through the wall that the vessel ruptures in the weakened section.

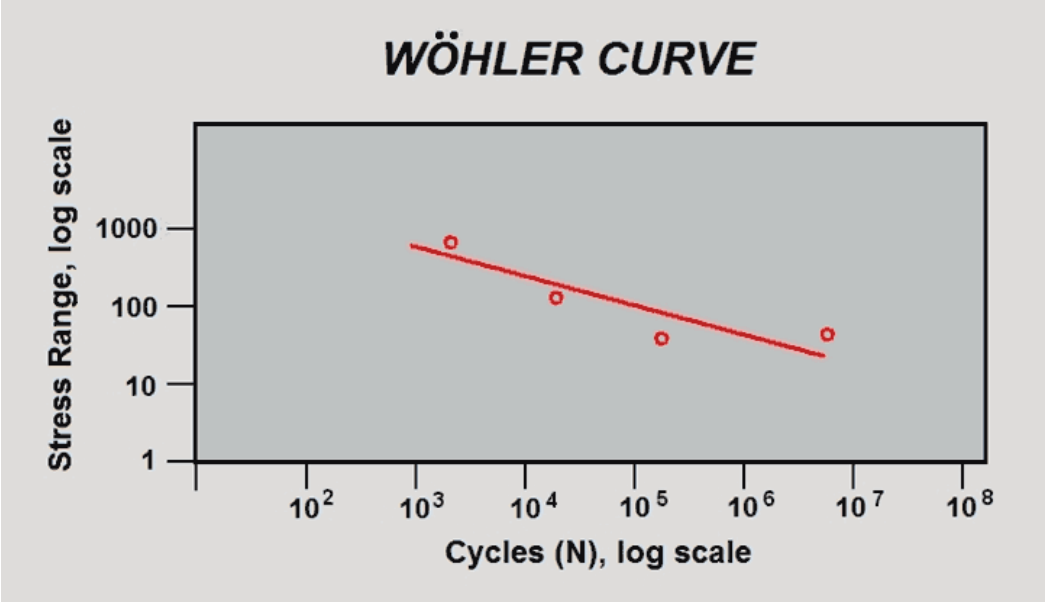
Benefits of Pressure Fatigue Testing

Determining the "weak-link"
One of the prime benefits of pressure fatigue testing is determining the "weak link" in a product's design. In some cases, it may come as a surprise as to the actual location of the weakest part of a pressure vessel. Characteristics such as surface finish may have a much more profound impact on fatigue life than most designers suspect. High surface loading near gaskets and seals can hold significant mean stress levels, adversely effecting fatigue life. When there are multiple stress risers in a product, which one has the most impact on product life, and are there any that can be ignored?

Obtaining actual pressure cycle life data
Another prime objective of pressure fatigue testing is to reveal the actual number pressure cycles a pressure vessel can withstand. In some cases this can be quite tricky, especially when there are multiple pressure cycles at varying levels to be tolerated. Even today's best analytical tools struggle to accurately predict fatigue life, especially in light of complex duty cycles.

In most cases, stress calculations are made (or provided by FEA models) and fatigue is assessed by conventional methods such as equations or software. Actual test data can be used in these cases to verify the accuracy of, or refine the models and methods used in the Engineering product life calculations.

In some cases, it may be advantageous to determine the pressure fatigue resistance of a product at various pressure levels in order to produce a Wöhler curve (S/N curve) of stress versus fatigue cycles, as seen in the next illustration. This gives the Engineer a wealth of fatigue information by being able to then interpolate between test points and evaluate the life of the product at multiple pressure levels.



Evaluating design, material and manufacturing alternatives

Additional uses of pressure fatigue testing involve evaluating alternative designs, such as material selection or design changes regarding cross section or sealing locations. All of the above can play a vital role in driving down costs in today's economically sensitive commercial environment, but could have a significant impact on fatigue life. Another important aspect of pressure fatigue testing is to evaluate the trade-offs of various manufacturing processes such as machining methods and heat treating. Are the processes that you are considering impact pressure fatigue life? Does a process change potentially being considered affect the bore surface finish or features and thus have an effect on fatigue life?

Competitor benchmarking

Some manufacturers are keen to take advantage of competitor benchmarking when it comes to product testing, and pressure fatigue is no exception. A lot of information can be gleaned from testing a competitor's product, and as well it may bolster your competitive advantage in the marketplace if your product is clearly superior.

Implementing Pressure Fatigue Testing

Pass/Fail criteria

Fatigue test pass/fail criteria will typically be dictated by customer usage of your particular product and its application(s). Some objectives may be simply to meet a pressure cycle loading without failure occurring for a given number of cycles. Other objectives may be more complicated, with different usage scenarios, or even multiple loading parameters. In some cases, the manufacturer may dictate the pressure

fatigue life of the product, but in today's demanding market the more technically adept customers will be defining the requirements.

Still other pass/fail criteria may require that the pressure vessel manufacturer display a maximum failure rate at a given reliability level. The last mentioned criteria requires usually that many samples be tested to gain confidence in the results, however there are reliability analysis techniques available to counteract that need.

Evaluating results – the variable nature of fatigue
It is typical that even the best techniques for analyzing the endurance of your products may lead to uncertainty regarding their life expectancy. Some of the most consistent products on the market when pressure fatigue tested could have as much as a 2:1 ratio of tested cycles in a small batch of 4 or 5. Such is the nature of fatigue that the results of testing even under the tightest repeatable controls involve significant scatter. Always make sure that you are testing a statistically significant number of samples to obtain accurate results. There are ways of saving money by testing multiple parts simultaneously.

Tips and tricks
When pressure fatigue testing products, always recreate the exact mating features in pressure seals and joints as accurately as possible, and use specified torque values for all nuts and fittings. Careful attention to detail here will produce accurate test results and realistic failure locations. This can minimize the potential for accidentally removing a real failure mode, or introducing a false one.

Accelerated testing at elevated pressure levels is a very practical way to determine a lot of information regarding the pressure fatigue capability of a design in the least time possible. One caution should be followed here – do not test at abnormally high pressure levels which can induce alternate, unrealistic failure modes. Generally, testing between the maximum operating pressure and short of the proof pressure is a good guideline.

For further information, please consult http://www.maximator-test.com.