## Pressure Fatigue/Impulse 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 two 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 / Impulse Testing

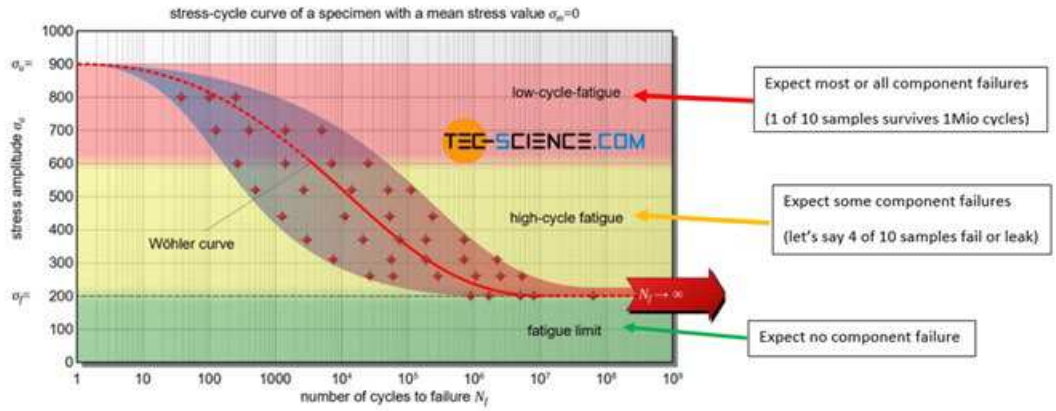
**Determining the "Weak Link":** One of the prime benefits of pressure fatigue testing is determining the "weak link" in a product's design. In some cases, the location of the weak link might be a surprise. Characteristics such as surface finish may have a much more profound impact on fatigue life than most designers suspect. High surface loading near gaskets and seals can hold significant mean stress levels, adversely affecting 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?

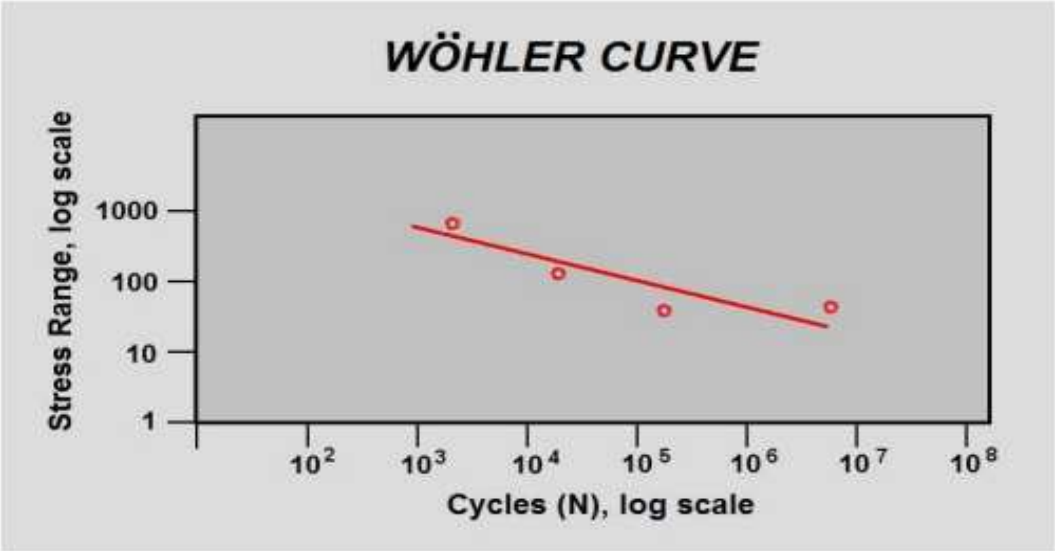
**Obtaining Actual Pressure Cycle Life Data:** Another prime objective of pressure fatigue testing is to reveal the actual number of cycles a pressure vessel can withstand. In some cases, this can be quite tricky, especially when there are multiple pressure cycles at varying levels to be tolerated. Because of complex duty cycles, even today's best analytical tools struggle to accurately predict fatigue life. In most cases, stress calculations are made (or provide by FEA models) and fatigue is assessed by conventional methods such as equations and 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. It might also be beneficial to determine the pressure fatigue resistance of a product at various pressure levels to produce a Wöhler curve (S/N curve) of stress versus fatigue cycles as seen below. 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.

For example, a customer has ten samples they need to test and have expectations of the components surviving 1,000,000 cycles at 5 - 200 bar. If the material certifications are accurate and there are no abnormalities in the manufacturing process, they should all survive the fatigue without failure. The customer decides to take the samples and run them to 1,000,000 cycles, but three of them fail before reaching it. This would go against the expected Wöhler/S-N Curve. The metallurgist might discover impurities in the metal. The material is resourced and then a second test is performed to verify the material change is accurate and they all survive.

This process can also be useful to engineers in other aspects of costs savings. Let's say a customer performs a theoretical S-N Curve and expects all parts to fail by 500,000 cycles at 5 – 500 bar. The parts all survive to well over 2-3 million, indicating they may have over-compensated the material and can get a way with a less expensive choice.

The table below shows this in action. The Y-axis acts as "Pressure", and the X-axis acts as "Cycle Counts". The red dots are actual points where a component was removed/failed, and the red/yellow/green are the theoretical points of the curve.






**Stress versus fatigue cycles**

## Evaluating Design, Material and Manufacturing Alternatives

Additional uses of pressure fatigue testing involve evaluating alternative designs, including material selection or design changes involving cross section or sealing locations. These can play a vital role in driving down costs but could also have a significant impact on fatigue life. Another important aspect of pressure fatigue testing is to evaluate the trade-offs of various manufacturing processes, like machining methods and heat treating. Will the processes you are considering impact pressure fatigue life? Does the process change under consideration affect the bore surface finish or features? Pressure fatigue testing could answer these questions.

## Competitor Benchmarking

Some manufacturers are keen to take advantage of competitor benchmarking when it comes to product testing. Pressure fatigue testing is no exception. A lot of information can be gleaned from testing a competitor's product. A clearly superior product is a competitive advantage.

# Implementing Pressure Fatigue Testing

## Pass/Fail Criteria

Fatigue testing pass/fail criteria will typically be dictated by customer usage of your product and its applications. Your objective might be to meet a pressure cycle loading without failure occurring for a given number of cycles. Other objectives might be more complicated with different usage scenarios or even multiple loading parameters.

Other pass/fail criteria may require a pressure vessel manufacturer display a maximum failure rate at a given reliability level. This criterion usually requires that many samples be tested to gain confidence in the results; however, there are reliability analysis techniques available to counteract this requirement.

## Evaluating Results – The Variable Nature of Fatigue

Even the best techniques for analyzing the endurance of your products may lead to uncertainty regarding 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 four or five. Such is the nature of fatigue that the results of testing even under the tightest repeatable controls involve significant scatter. 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 amount of time.

Caution: Do not test at abnormally high-pressure levels. This can induce alternate, unrealistic failure modes. Testing between the maximum operating pressure and short of the proof pressure is a good guideline.