Liquid Erosion / Wear

Technical White Paper

SureScreen Scientifics

Description

Mechanical destruction of a surface from the high energy flow of liquid on a surface. Damage can occur as a consequence of 1) the collapse of bubbles in the liquid, generating localised stress waves, termed ‘cavitation’, or 2) by stress induced in the surface from the direct impact of the liquid droplet, termed ‘liquid impingement’. This differs from erosion caused by the abrasive action of particles in the liquid as this is the direct action of the particles rather than by the liquid per se.

There are many different terms describing the differing mechanisms of metal surface degradation from the effects of fluid flow, and the recognition of the not insignificant influence of corrosion mechanisms acting alongside these has led to terms such as erosion-corrosion, and cavitation-corrosion etc. The term, ‘Flow-Induced Corrosion’[1] is a more generic term that may be used to cover all those mechanisms that relate to degradation of a metal driven by liquid flow and corrosion.

Mechanism

The mechanisms discussed here are limited to cavitation and liquid impingement.

Cavitation
Cavitation is the damage that occurs to a surface due to the collapse of bubbles that have formed in the liquid. The bubbles are formed at regions of low pressure caused by the rapid acceleration of the liquid such as that generated by flow of liquid across propellers, pump components, and geometric features at a surface. The bubbles, or cavities in the liquid, form when the pressure of the liquid has been reduced to its vapour phase. As the liquid flows, it takes the bubbles with it away from the region causing the drops in pressure i.e. back to the higher, or operating pressure, causing the bubbles to then collapse, and the vapour to return to the liquid phase. The collapse of the bubbles produces a transient pressure pulse or stress wave i.e. ‘water hammers’ of high intensity energy as shock. If these bubbles collapse close to or on the surface of a metal, the stress wave can cause damage to the surface of the metal. The shock wave first produces a compressive stress on the solid surface, and then when it is reflected, produces a tensile stress that is normal to the surface.

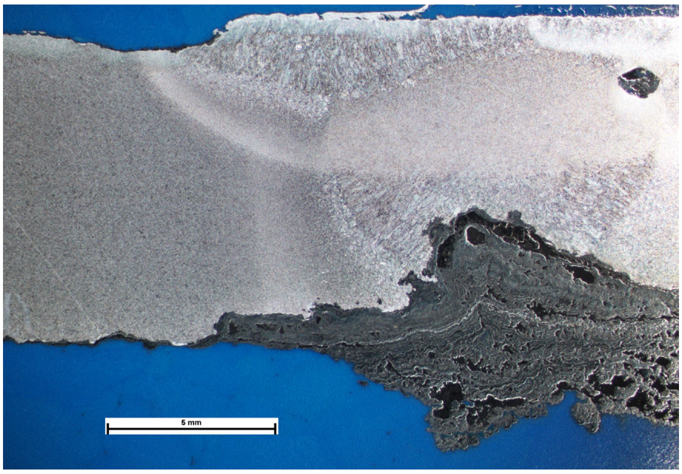
This cyclic shock wave induces a corresponding cyclic stress in the surface of the metal and these lead to fatigue damage, and eventually the initiation and propagation of micro-fatigue cracks. As with other fatigue failures, initiation is generally associated with surface stress raisers such as changes in geometry, scores, and other surface defects. In addition, these surface defects may also initiate or worsen cavitation themselves which compounds the destruction at those locations.

Liquid Impingement
Liquid impingement is the high velocity impact of a drop of liquid on the surface of the metal. The impact causes high loading and pressure (stress) at the surface. At a microscopic level, each impact is capable of causing damage in the form of small deformations of the surface. Any asperities caused either by this deformation, or those inherent on the surface, may be prone to high loading and eventually cracking and detachment from the surface. With continued impingement, cracking continues culminating in the detachment of more material and the damage then continues.

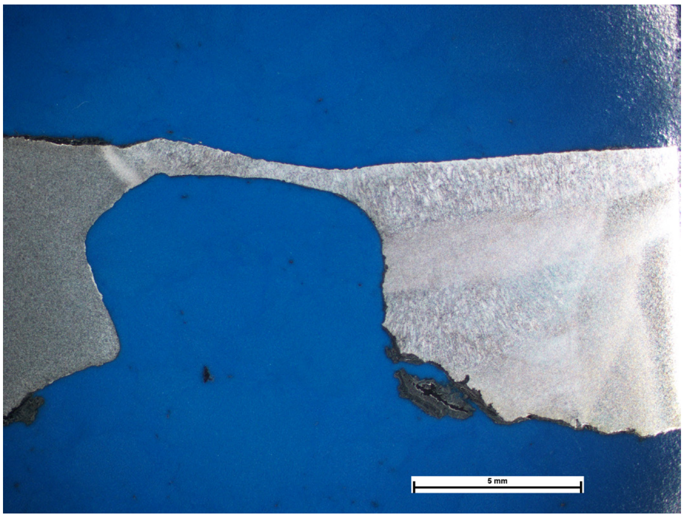
Appearance and Examples

The appearance of cavitation and liquid impingement damage may be similar with craters and pits of varying sizes. As an example, a section of pipe used to transport water had perforated leading to severe leaks adjacent to a circumferential butt weld. The pipe was sectioned to reveal severe corrosion attack at the weld root in a significant portion of its length as shown on the next page.

1. J. Weber (1992) Flow Induced Corrosion: 25 Years of Industrial Research, British Corrosion Journal, 27:3, 193-199, DOI: 10.1179/000705992798268620



However, in other areas of the weld, severe cavities had developed on the downstream side of the weld. These cavities were well rounded, with a smooth surface devoid of any significant corrosion; only very light surface corrosion was present. These were typical of cavitation damage.



Minor changes in the composition of the weld, compared to the pipe material were considered to have rendered the weld more susceptible to corrosion. The build-up of corrosion scale changed the flow dynamics of the liquid which eventually lead to the development of the cavitation damage observed.

Avoiding

A fundamental means of avoiding cavitation is to avoid or minimise velocities in the liquid that could lead to sudden pressure drops. Smooth surfaces, slow changes in directions such as at bends and fittings (e.g. valves, inlet/outlet ports), and use of liquids with a low vapour pressure are also measures that can be adopted. Generally, materials with a low hardness exhibit a lower resistance to cavitation damage but materials with high hardness and corrosion resistance, such as Stellites (Co-Cr alloys) can still be degraded.

Surface coatings may be used to act as a 'dampening' layer. Polymers and elastomers can be used as although they exhibit a low resistance to cavitation or impingement damage themselves and will eventually fail, but they will absorb and reflect some of the energy for a finite period, eventually requiring renewal. Their degradation will in part be due to their poor thermal conductivity, leading to degradation by heating.

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