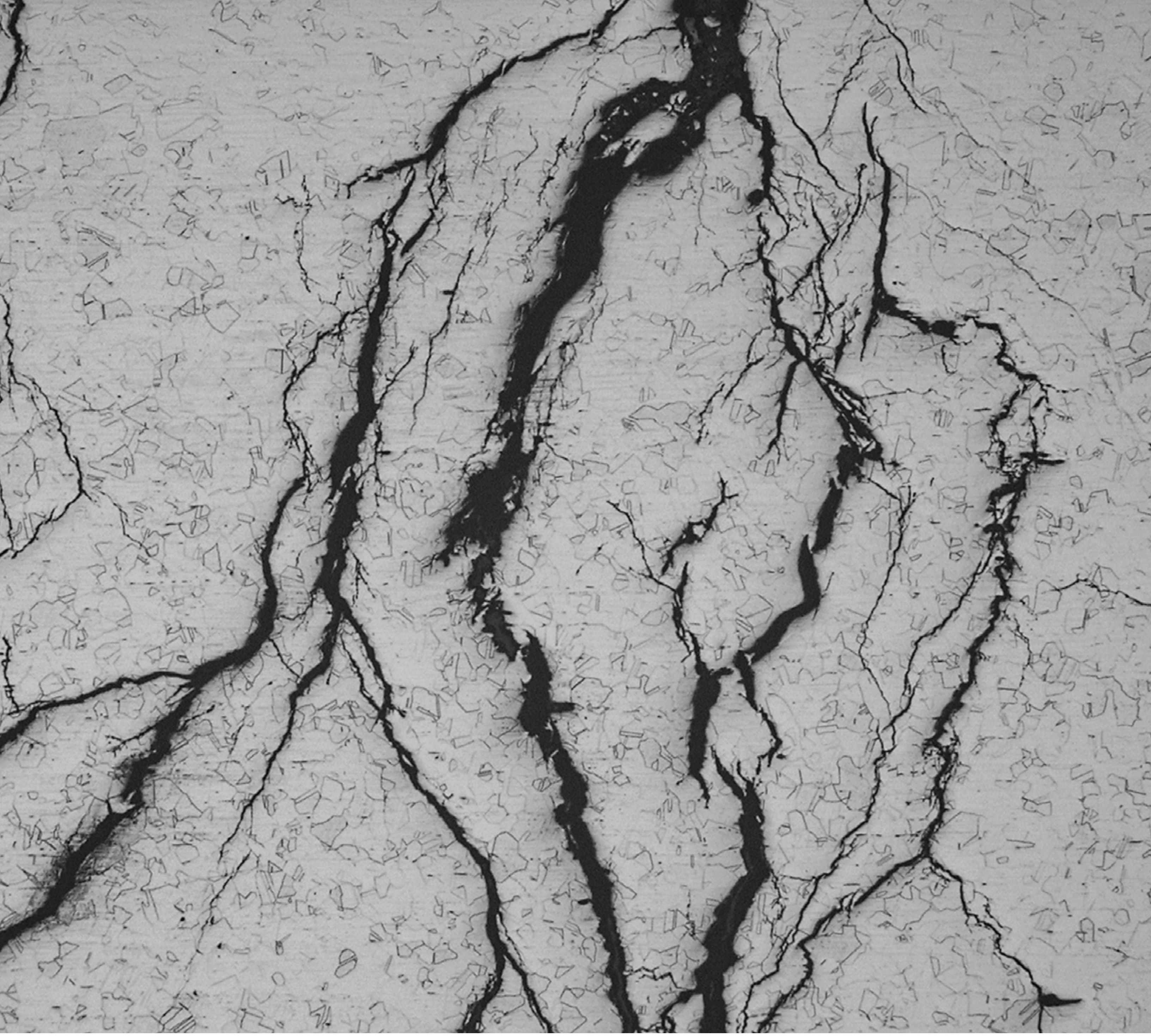

Understanding Stress Cracking Corrosion in Instrumentation Fittings

White Paper

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Understanding Stress Cracking Corrosion in Instrumentation Fittings

The phenomenon of stress cracking corrosion in stainless steels has been known for many decades now. Less well considered, though, is its impact on instrumentation fittings in high-pressure applications in corrosive environments.

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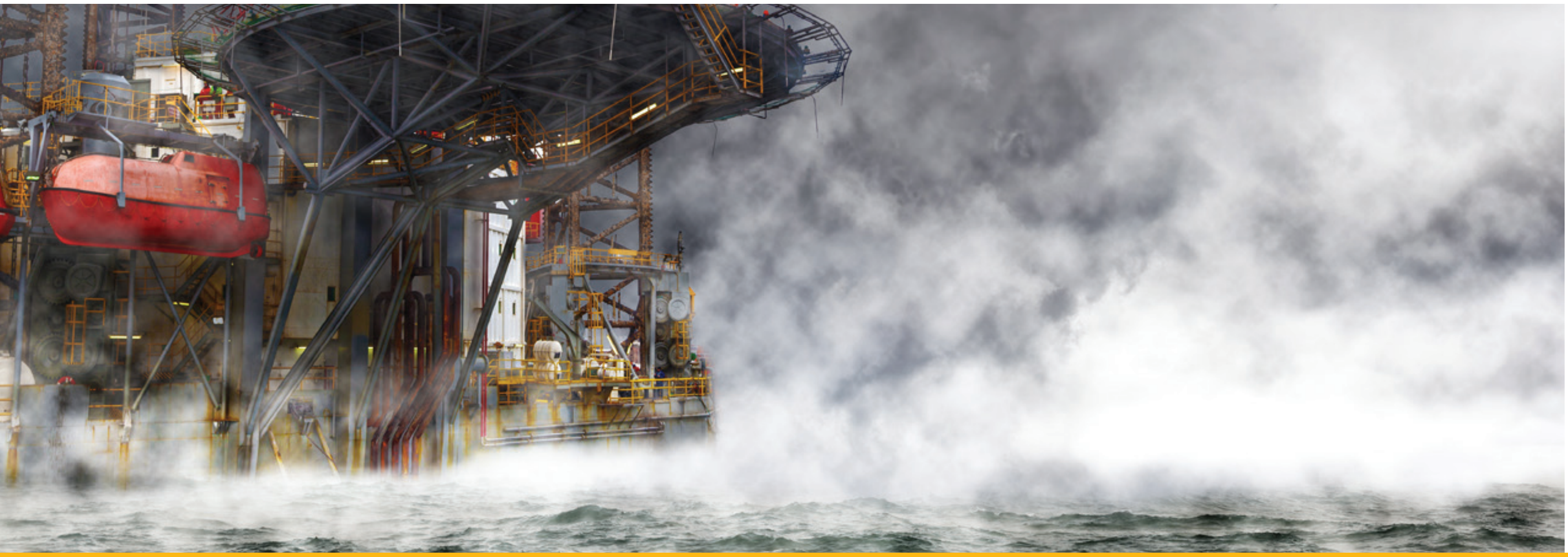
Under certain conditions, stress cracking corrosion can initiate and spread quickly. As a result, fittings that appear in good condition can fail suddenly and catastrophically.

Such failure can present a significant safety risk to personnel working in harsh environments such as those encountered on offshore platforms where high-pressure instrumentation fittings are often used. It can also lead to unexpected downtime and associated maintenance costs.

So, understanding the means of mitigating or preventing stress cracking corrosion in instrumentation applications is an important topic. And it is an area where Parker brings considerable research and expertise for its partners.



What is Stress Cracking Corrosion?

The definition of stress cracking corrosion (SCC) – according to NACE International, the worldwide corrosion authority – is the cracking induced from the combined influence of tensile stress and a corrosive environment. Platform engineers are often familiar with problems associated with stress overloads, and indeed with other corrosive forms such as pitting or crevice degradation. But SCC is unique because it combines the two aspects of stress and corrosion, making it a phenomenon worthy of closer study.

For SCC to occur, there needs to be a corrosive media, the presence of tensile stresses on the material surface as well as a material susceptible to this failure mode. Consequently, the absence of any one of these factors can provide effective mitigation or elimination of this form of corrosion.

As such, it is vital to take a holistic view of each of these factors when considering ways of mitigating this form of corrosion.

The three prerequisites for SCC

As a starting point, it is worth looking at each of the three prerequisites for SCC in greater detail.

1. Surface tensile stresses

These stresses may be in the form of tensile loads directly applied to the material. Additionally, these may include residual stresses in the material that may have developed during strengthening, welding, machining, installation, or service. In the context of SCC, the combination of stresses from each of these sources plays a vital role in determining the possibility of stress cracking corrosion occurring.

2. Corrosive environment

Then there is the specific nature of the corrosive environment that can vary with the type of alloy. This can include the type and amount of the corrodent (for instance, chlorides vs. sulphides) or the amount of moisture in the surroundings. Another factor is temperature (with increased temperature usually meaning more susceptibility to SCC). Additionally, the presence of gases (such as hydrogen sulphide and carbon dioxide) and their concentrations can also impact corrosivity, especially in instrumentation applications.

3. Susceptibility of the material

Finally, the susceptibility of the material in a given environment plays a significant role. Alloy chemistry, material processing, and inclusion content in the material can all have a considerable impact. Ultimately, the combination of these three factors needs to be considered in totality when judging the risk of SCC in a particular application.

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>
> **— Anshul Godha, Parker**

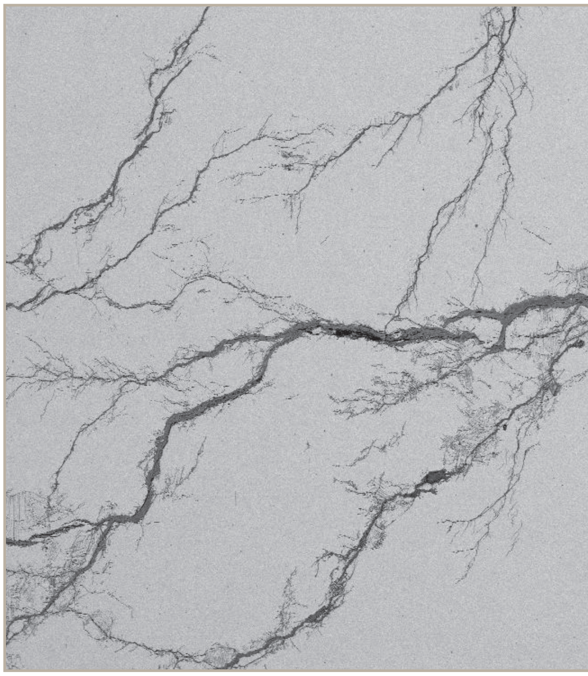

Image 1. Typical “branched” stress corrosion cracking in 316 SS material.

The Individual Types of Stress Cracking Corrosion

There are different types of SCC to be considered – each with distinct characteristics. With high-pressure instrumentation fittings in mind, two primary types can cause particular concern.

Chloride SCC (CISCC)

Firstly, chloride SCC (ClSCC) takes place in chloride-rich environments such as offshore and near shore, where the presence of salt in aqueous atmospheres can initiate this form of corrosion. Among austenitic stainless steels, the 300 series stainless alloys (304/304L, 316/316L) tend to show maximum susceptibility to ClSCC – in part due to their chemical composition. However, as will be discussed later, chemistry is just one of many factors determining the probability of an alloy exhibiting SCC.

ClSCC in instrumentation applications often predominantly occurs in regions where there is local variation in metal composition (presence of inclusions or other phases), reduced/absent protective film, and higher corrodent concentration. Regions with higher stress concentrations such as geometrical edges and corners also favour this crack initiation. When designing instrumentation fittings, therefore, it is essential to minimise regions with high stress concentrations to reduce susceptibility to this type of SCC.

Installation is also something to consider. For instance, the simple aspect of placing equipment vertically or horizontally can, in some assemblies, allow more salt deposits/moisture to sit and accumulate. Over time, this may result in a higher probability of ClSCC occurring.

Sulphide SCC

Another type of SCC to consider is hydrogen embrittlement – with the primary subset being sulphide stress cracking corrosion (SSC) which typically occurs in the presence of hydrogen sulphide. SSC is again prevalent in offshore environments and for offshore instrumentation applications, occurring in a broad temperature range of between -100 and 120°C. The exact mechanism is still unknown, but some theories have been put forward by the scientific community.

Hydrogen embrittlement takes place when the material’s surface gets exposed to hydrogen atoms that may enter the surface voids of the metallic alloy and lead to increased residual stresses within the alloy. It is well known that the presence of hydrogen sulphide in the environment increases susceptibility to hydrogen embrittlement in some stainless steels. This is believed to occur because the hydrogen sulphide acts as a hydrogen recombination poison, thereby increasing the amount of hydrogen available to enter the alloy. In significant amounts, the stresses caused by these hydrogen atoms/molecules can be large enough to make the alloy susceptible to localized cracking.

How to Mitigate or Prevent Stress Cracking Corrosion

So, those are the primary types and causes of SCC. But what actions can be taken to prevent it from occurring?

Firstly, it is possible to reduce stress levels to help mitigate or eliminate SCC. However, such an approach needs to be carefully applied to ensure no detrimental impact on product functionality. For example, stress levels could be reduced by increasing material thickness for better distribution of applied stresses. But that would add weight to the product, reducing efficiency in the field.

It might also be possible to reduce the chance of SCC at the design stage, by minimising the regions with stress concentrations. This can only be done to a limited extent, though, as all products need to perform a desired function. That functionality might require the need for threads, for example, which would in turn result in increased stress concentrations.

Stress relief can also be achieved through mechanical treatment, leading potentially to the roughening up of the surface, which isn't always desired. Thermal treatment, meanwhile, can also be beneficial, but it can reduce product strength.

Another means of eliminating or reducing SCC is to modify the environment, such as by reducing exposure to chlorides, sulphides, carbon dioxide and water. Reducing temperatures or introducing inhibitors that isolate the product from the environment can also deliver extended life without the threat of SCC. Again, each of these approaches can only be used in certain situations.

Finally, consideration of alternative materials presents opportunities to reduce SCC. Techniques such as using more resistant materials including Super Duplex or Super Austenitic stainless steel, deploying annealed materials, or applying protective coatings can all produce good results. These approaches can mean that the cost of fittings goes up, but this can be justified over the whole life of the product.

It is evident, then, that mitigating SCC is a balancing act that requires careful consideration, but it can be highly beneficial under the right circumstances.

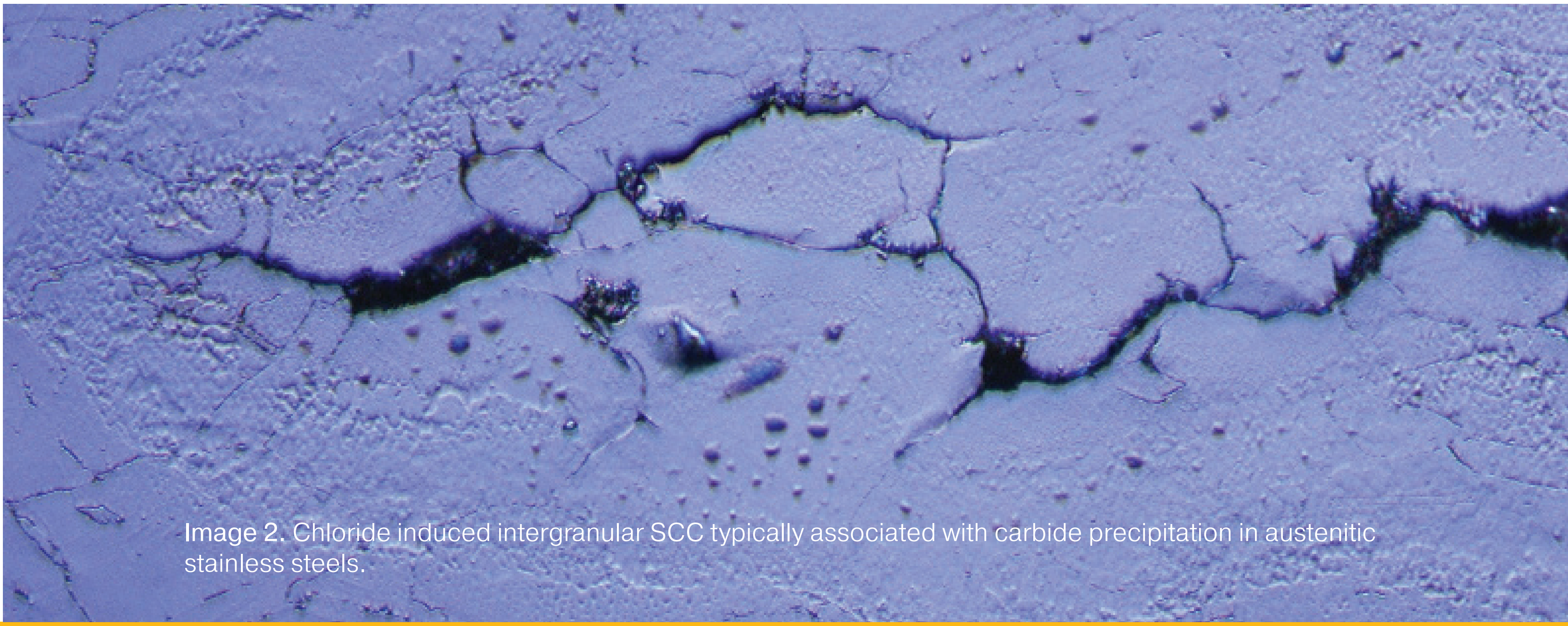

Image 2. Chloride induced intergranular SCC typically associated with carbide precipitation in austenitic stainless steels.

The importance of selecting a fittings supplier with the right credentials

It is clear, then, that SCC is a complex form of corrosion that can occur in multiple environments, and it can manifest itself in different ways.

Parker has spent many years researching SCC at its state-of-the-art metallurgical laboratories, gaining a thorough understanding of the reasons behind its causes, crack propagation, and how to deploy the latest testing to accurately compare the relative performance of different alloys.

Ultimately, this knowledge has resulted in the development of a broad range of instrumentation fittings that offer class-leading resistance to SCC, even in the harshest operational conditions.

Image 4. Parker's permanent, non-welded tube connectors - Phastite® in 2507 Super Duplex material designed to cope with the most demanding environments, from subsea exploration in the north sea to natural gas drilling in Kazakhstan. They can be used in applications up to 22,500 psi (1,550 bar) and temperatures ranging from -45°C to 93°C (-50°F to 200°F).

Parker offers an extensive range of corrosion resistant alloys for the most demanding applications.

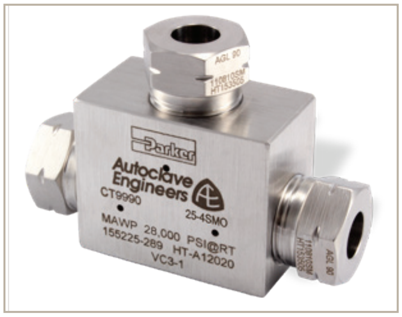

Image 3. Parker Autoclave Engineers fitting in 6MO material for applications up to 28,000 PSI.

Image 5. Parker Autoclave Engineers fitting in 316 material for sour gas applications up to 30,000 PSI.

We can offer all the range of materials compliant to the metallurgical requirements of NACE MR0175.

Our experienced credentials in materials selection are the results of years of expertise in successful applications worldwide.
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