The danger of biological corrosion in fire systems & pipelines - Part 1

In daily practice, there are several corrosion mechanisms that are known and rightly feared; some examples are pit corrosion and crevice corrosion, and galvanic corrosion and stress corrosion. If the term biological corrosion is mentioned, people often shrug it off and think 'so be it'. Still, there is a form of biological degradation which can have serious consequences: microbiological induced corrosion (MIC), which is also known as Microbiological Influenced Corrosion. In this two-part article we examine the causes of MIC and the role of sulphur-reducing bacteria and cathodic depolarisation. Next month, Part 2 will look at the dangers of MIC in fire prevention systems, the BART test, the influence of piping materials and ways to prevent MIC.

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Microbiological induced corrosion (MIC) is often caused by sulphur-reducing bacteria (SRB's) which can live under both aerobic and anaerobic conditions. The former is mostly active in an oxygen-containing environment, while anaerobic bacteria only flourish in an oxygen-deficient, or even in a low-oxygen environment. Anaerobic bacteria can create a corrosive biofilm on the metal surface which can lead to severe corrosion damage. Moreover, these bacteria can be concurrently present in a biofilm as aerobic and anaerobic. The aerobic bacteria are present on the water side because they always need oxygen; the anaerobic bacteria will prosper on the metal side. In practice, this relative new form of biological corrosion is very devastating and manifests on many metals and metal alloys. Carbon steel and stainless steel are very sensitive to this form of corrosion. The damage that arises from MIC is approx. 1% of the gross national product and therefore there is more interest in fighting this form of corrosion.

Microbiological induced corrosion is a serious threat to industrial fire protection systems and proper measures must be taken to detect and prevent it.

What causes MIC?

While MIC is usually caused by sulphur-reducing bacteria, iron and manganese oxidising micro-organisms can also be a cause. It only occurs in aqueous environments, and rough surfaces are very sensitive to MIC because in these places the conditions are very favourable for the deposition of corrosive biofilms. MIC occurs mainly in water cooling systems, sprinkler systems, storage tanks, heat exchangers, fire mains, sand bed filters, etc. As the temperature rises, the bacteria multiply faster, with negative consequences, and they may mutate to become resistant to higher temperatures. A couple of years ago, it was stated that this bacterium could not survive in an environment of approximately 62°C; today that threshold appears to be around 25°C higher. Three mechanisms are known to initiate MIC: degradation by secretions, cathodic depolarisation, and sometimes the formation of electrochemical cells. Some bacteria produce aggressive substances when they decompose such as sulphite, sulphuric acid, hydrochloric acid, or organic acids. Sulphuric acid and hydrochloric acid are strong reducing acids to which steel and stainless steel are not resistant, whereby serious corrosion will occur. Wall thicknesses of a couple of millimetres can be completely perforated after a couple of months.

As metal corrodes in the anaerobic layer of the biofilm, the mentioned tubercles reagents will form. This manifests itself as rust clusters in the shape of small cauliflowers. Under these clusters, sulphuric acid occurs which attacks the material at the weakest spot while the rest is etched. That is why that next to a hole one often can see a clear affected spot.

Sulphur-reducing bacteria

SRBs have been an increasing problem in recent years because materials are infected quickly and may succumb to MIC in a short amount of time. In addition, the biofilms have a disadvantageous effect on heat transfer, and water filled systems may clog due to congestion, which creates an unacceptable problem for the sprinkler systems. Figure 1 shows an affected water pump made from stainless steel 304, suffering the effects of MIC after one year. The pump was infected during pressure testing at the manufacture because the test reservoir was contaminated with SRBs. The bacteria in the thin water film that remained in the pump developed into an aggressive biofilm. When the pump was used this biofilm was able to develop further, leading to MIC. The resulting tubercles in the form of cauliflowers can, in time fill, up the whole pump area. Furthermore the foot of the pump started leaking after about a year. That was noticeable because of the brown wet stripes visible on the outside. There is a good chance that MIC will arise in still water, particularly when the temperature starts to rise. It is known that fire system mains constructed of stainless steel AISI316, which are filled with still water, will leak within one year.

Cathodic depolarisation

In addition to the aforementioned corrosion mechanism cathodic depolarisation is also known to cause of MIC, and also occasionally the formation of electrochemical cells. With cathodic depolarisation, the bacteria use the hydrogen that arises at the cathode to grow, whereby the galvanic cell is further activated. Because there is more hydrogen required, the anodic partial reaction is further enhanced, accelerating the dissolution of the metal. Electrochemical cells forming occurs when bacteria form a biofilm on the surface. Below and next to this layer there can be large differences not only in the degree of aeration, but also in salt and acid concentrations. This causes local electrochemical cells that initiate corrosion.

Figure 1: The foot of a pump constructed in stainless steel AISI 304 affected by MIC (photo: Innomet private company)

Figure 2. Steel 4" pipe affected by MIC (photo: MIC Europe private company)

Conclusion

In conclusion, one could state that one should be more focused on this serious 'new' form of corrosion, and to fight it with all possible measures. But prevention is even better, and this can be done when taking the right measures. For example, there are biocides such as sodium hypochlorite can effectively kill such bacteria, but these cannot be applied everywhere as the final product may be adversely affected, and sometimes a biocide is too corrosive for the metal used. It is well known that sodium hypochlorite is very corrosive to stainless steel, because it has an unstable chloric-compound. We also achieved encouraging results with UV light and ozone. Therefore, the right approach needs to be determined by using a process engineer.

Because MIC is a new form of corrosion, the question quickly arises: why didn't this bother us before? Twenty years ago one almost never heard about these phenomena, yet today it almost seems as if it is the most common form of corrosion. Opinions are divided on this question. The most likely scenario is that globalisation and rising temperatures have allowed sulphur-reducing bacteria to spread around the world. Whatever the reason we must deal with it and also prevent it from worsening.

Part 2 of this article will be published in the March issue of Stainless Steel World

Sources: Microbiological Influenced Corrosion (MIC) in Sprinkler systems; by Jos Braes Kluwer Yearbook.
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