

Chapter 2

Literature Review

2.1 Corrosion under insulation of carbon steel

Carbon steel is the most widely used material in engineering. In 2015, the UK produced 11 million tons of steel (see figure 2.1) and it is estimated that 80-90% of that steel goes to the production of carbon steel. The EU produced 166 million tons of steel in the same year, the UK is the fifth biggest producer of steel in the EU (Rhodes, 2016). Carbon or mild steels have less than 2% (in weight) of alloy content, which makes the material susceptible to corrosion. Despite the relatively low corrosion resistance of carbon steel, the production of this material remains high as it is used by many industries such as marine, oil and gas, transportation, mining, construction, manufacturing and others. Because of the high demand of carbon steel, it is easy to understand that the cost of metallic corrosion is measured in millions of pounds per year. All those industries work hard to provide the correct protective system to avoid corrosion or to at least prolong the lifecycle of the material.

Corrosion under insulation (CUI) is an electrochemical process that occurs because of the presence of oxygen and moisture (Silva et al., 2014). CUI generally appears in the form of general or localised corrosion in a range of 24 to 120 °C, but the most severe temperatures are between 45 and 95 °C.

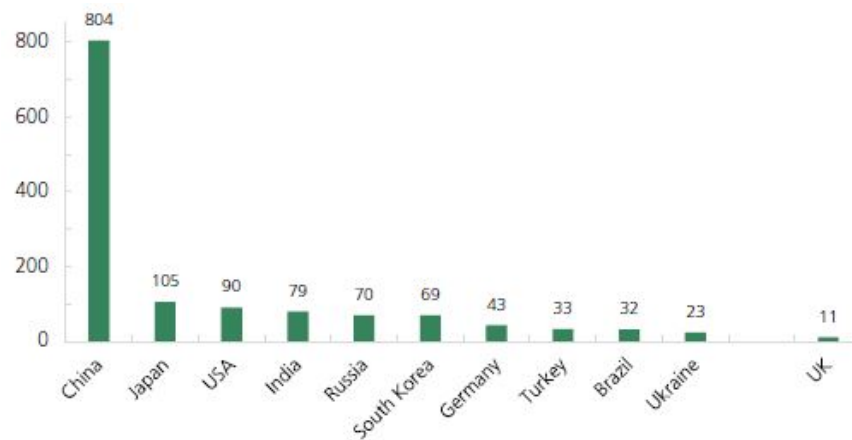


Figure 2.1: Top ten producers of steel and UK (Rhodes, 2016)

CUI is one type of corrosion that has received great attention in the recent years by the operators in gas-, chemical-processing-, and petroleum plants. A substantial number of vessels, pipelines, tanks, heat exchangers are often insulated to conserve energy by keeping hot processes hot and the cold processes cold or to protect the components from the harsh marine environment. There was one time that once the insulation was installed and the component worked properly, the condition of the metal under the insulation was forgotten. It was not until the late 1970's that the problem of corrosion under insulation was observed when the operators changed the 10 to 20-year-old insulation, only to conserve more energy (Committee, 1987).

Insulation is everywhere in any plant. For example, in a small-size petrochemical industry insulated carbon steel pipework, exposed to a marine environment, could reach 1.2 km long, whereas a medium-size oil refinery contains an approximate of 360 km of insulated piping and more than 25 football fields of insulated tanks, equipment and vessels (see an example in figure 2.2). It is estimated that 10% to 30% of the insulation gets damaged within one to three years of the installation. The damage of the insulation cladding could allow water to penetrate into the material insulation, which causes corrosion.



Figure 2.2: a) Insulated pipework and b) Insulated vessels

This is why inspections and repairs, which could be performed during operation, is so important and the costs of it are insignificant compared to the potential savings if no insulation was installed or if no inspection and repairs were carried out (ROXUL).

Carbon steel corrodes when water and a free supply of oxygen are present. Without oxygen, corrosion would be insignificant. Insulation is installed to avoid any space for water to collect and any access of oxygen (air). Some of the active spaces for water and oxygen to enter through the insulation is when steel passes through the insulation material to, for example, an insulation support rings, ladders, platforms, etc; other active places are when the insulation terminates at flanges or other components, when the insulation is damaged, etc. The figure 2.3 shows a typical CUI cycle on a horizontal pipe with the hot product inside of it, where water enters through the insulation cladding and gets trapped on the bottom side. When the cycling temperatures vary to room temperatures, the corrosion rates are high. The corrosion rate of carbon steel is controlled by temperature and presence of oxygen.

To prevent corrosion under insulation there are two options, one is to add a corrosion inhibitor (water soluble) to the insulation, such as Na_2SiO_3 . But laboratory tests show that this has no benefit for the long-term protection as if water runs through the insulation, the water-soluble inhibitor will be extracted. Another option is to rely on a more effective waterproofing, however, these systems do not prevent water vapour and air from contacting the

The CUI Cycle

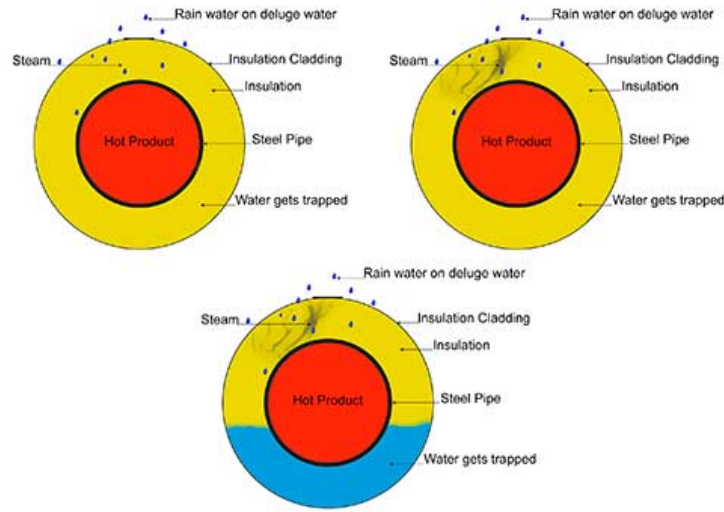


Figure 2.3: The CUI cycle

annular space. Therefore, an inhibitor and a waterproof insulation are not the most effective solutions to prevent corrosion. Instead, the surface of the steel could be covered with a high-quality protective coating and this will be the best long-term solution (Committee, 1987).

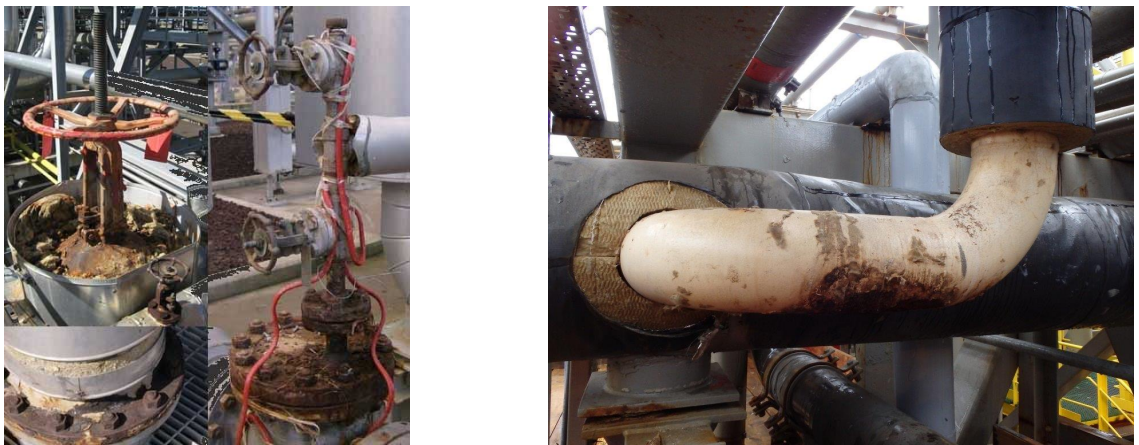


Figure 2.4: Severe corrosion under insulation

Some insulating materials available in the market are fibreglass, mineral wool, ceramic fibre and calcium silicate (Silva et al., 2014).

If corrosion under insulation is not detected at the right time, it could cause catastrophic

effects, costly plant shutdown and in some rare cases, safety incidents. Maintenance, monitoring and inspections every now and then is key to avoid these undesirable effects. There are several non-destructive techniques available nowadays, such as visual and ultrasound inspection, radiographic examinations, ultrasonic guided wave, which have their advantages and disadvantages.

The visual inspection could eliminate any misinterpretation from nondestructive techniques, however, is very unpractical, especially if the insulation material is toxic and expensive as the insulation would need to be removed. Ultrasound wall thickness measurements are also an unpractical technique, insulation would also need to be removed as the probes need to be in contact with the test piece and are difficult to apply at high temperatures (Grenier et al., 2016). In both cases, insulation would need to be reinstalled properly because it could cause areas for water ingress.

Radiograph inspection can easily detect CUI but is limited to inspect small areas at a time so inspecting long insulated pipe lengths would take too long, access to both sides of the component is needed and safety issues are involved as this technique is a form of electromagnetic radiation, which is harmful to the inspectors and those around them (Caines et al., 2013; Cheng and Komura, 2012).

Ultrasonic guided wave inspection only needs a small portion of insulation removal to install the equipment, it can detect external and internal corrosion in long-distances pipelines, however, the detection sensitivity is not high, because of the external noise and attenuation of the guided wave at long distances (Lai et al., 2015). Ultrasonic guided wave inspection can be used in combination with pulsed eddy current, the technique under evaluation in this thesis; both techniques are under development and need assessment and evaluation before it is adopted in mass across the industry.