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A look at Stainless Steel in the Water Industry

Introduction

Stainless steel is commonly used across Europe in the water industry due to its significant corrosion resistance over other metals. In the UK, this beneficial characteristic seems to be overlooked in the majority of situations due to its apparent expense. The literature reviewed in this editorial will reveal the key benefits that make stainless steel the most cost effective material and why it is more suitable than galvanised steel in the water industry.

A comparison of some key characteristics of stainless steel and galvanised steel within the water industry:

Characteristics	Stainless Steel	Galvanised Steel
Corrosion Resistance	Complete resistance throughout metal	Surface resistance only
Leaching/contamination of water	Very low	High
Initial cost	High	Low
Life Cycle Costs	Low	High
Coating required	No	Yes
Maintenance	Low	High

Corrosive Resistance

Figure 1. An illustration of the effect of oxygen on carbon steel and stainless steel

Galvanised steel is one of the most commonly used fabricated metals in the water industry. Its popularity is due to its low initial cost and relatively effective corrosion resistance. Galvanisation is the process in which carbon/mild steel is passivated in a zinc coating. The zinc coating provides a certain amount of corrosion resistance, dependent on the thickness applied.

Stainless steel is a metal alloy with a growing popularity within the water industry. There are various groups of stainless steels and the most commonly used in the water industry is austenitic, due to its superior corrosion resistance. Austenitic stainless steels contain at least 10.5% chromium, less than 1.2% carbon and varying quantities of nickel, molybdenum, nitrogen. This means these steels are stainless 'throughout' unlike metals protected by a coating e.g. galvanised, painted.

Within austenitic stainless steels there are a range of grades, most notable being 304 and 316. The key difference is that 316 has a higher nickel content and the addition of molybdenum. This increases its corrosive resistance making it an appealing stainless steel for harsh environments within the water industry such as costal or moderate chloride conditions.

Furthermore, if a higher corrosive resistance is needed for environments such as marine or high chloride, then a stainless steel group known as duplex can be used. This is the combination group of 50% austenitic and 50% ferritic (another group of stainless steels). The interaction between the two groups forms a balanced microstructure which significantly increases its corrosion resistance (Muthupandi, Bala Srinivasan, Seshadri and Sundaresan, 2003) (Kocijan, Merl and Jenko, 2011). The variety of stainless steel grades reveals the broad range of environments stainless steel can withstand within the water industry.

It is important to correctly treat stainless steel during the fabrication process prior to use. Pickling with nitric-hydrofluoric acid is performed to remove free iron that may remain embedded in the stainless steel surface (Powell and Jordan, 2005). Pickling prevents surface rust marks forming and allows correct passivation to take place (see below), allowing for the highest corrosion resistant state.

Comparison of corrosion resistance

The chromium content of stainless steel is integral to its corrosive resistance, as when the chromium (contained in the stainless steel) is in contact with oxygen, a 1nm chromium oxide layer forms on the surface of the stainless steel. This process is known as passivation and the chromium oxide formed is the passive layer, which is the key resistance barrier to corrosion (Figure 1b). If this passive layer is removed when scratched, damaged or dented then the stainless steel is capable of ‘renewing’ and the chromium oxide layer will reform. This is due to chromium being a constituent element of stainless steel, uniformly distributed throughout. Whenever damage is sustained, it is able to retain its corrosive resistance, a key beneficial characteristic.

In comparison to carbon/mild steel, where contact with oxygen forms an iron oxide better known as rust (Figure 1a). This is the major risk faced with using galvanised steel. As soon as the protective zinc coating is removed or damaged this exposes the mild steel beneath to oxygen and the integrity of the steel is risked. This is a problem as zinc is a soft metal meaning scuffs and chips can be common.

Life Cycle Costing

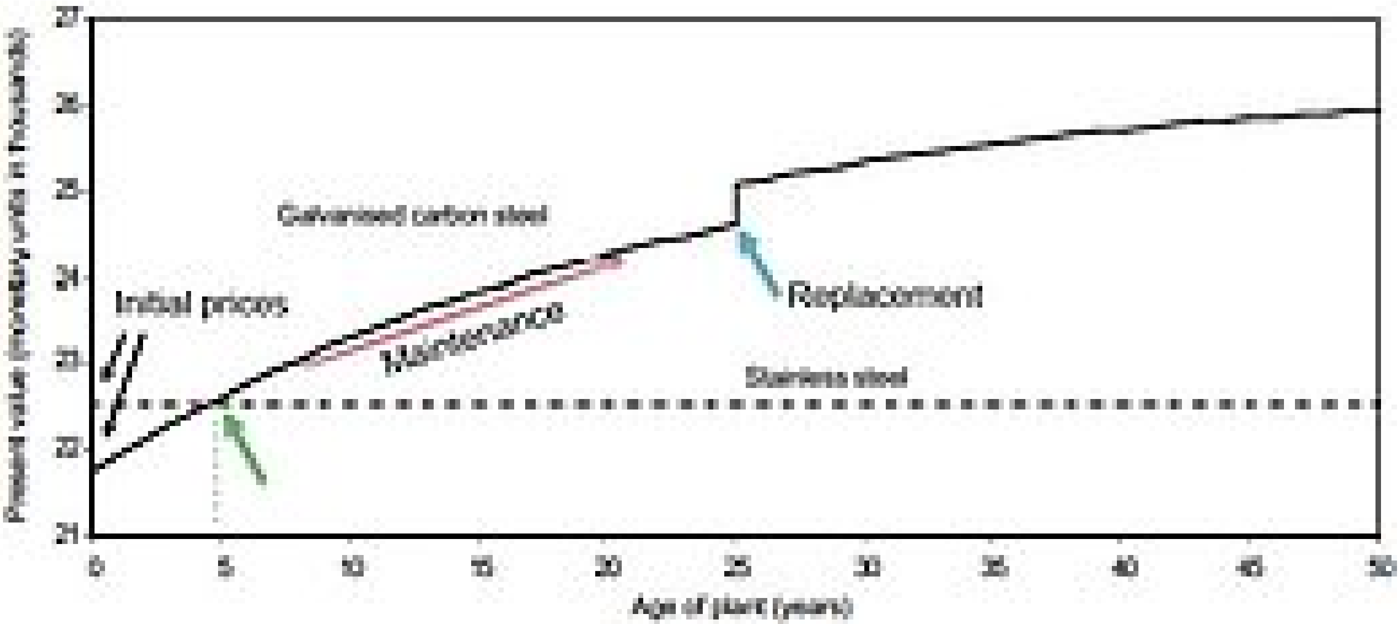

Figure 2. A comparison of the Life Cycle Costing (LCC) of a galvanised carbon steel and stainless steel access cover (800mm diameter) (incl. ladder and ventilation) over 50 years. Published on Water UK, 1999

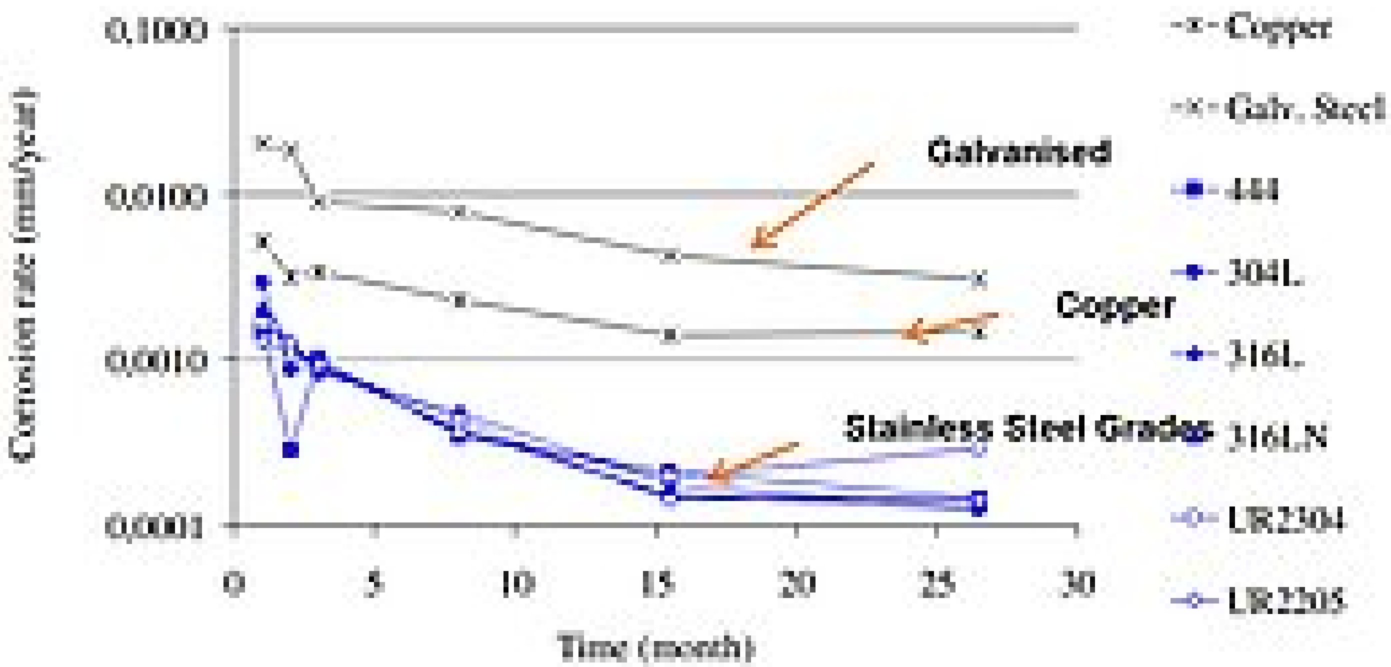

Figure 3. A line graph taken from Allion et al., (2011), revealing the corrosion rates (mm/year) for stainless steel copper and galvanised steel

To combat corrosion of galvanised steel regular maintenance is required, regalvanising and painting are performed to extend the products life. When looking at the price of an asset it is important to take into account all the costs associated, throughout its life – initial, operating, maintenance, replacement and disposal. This is the assets Life-Cycle Cost (LCC). The maintenance and servicing associated with galvanised steel incur costs over time, which increases its LCC.

The addition of alloying elements such as chromium and nickel often leads stainless steel to having a higher initial cost. However, LCC calculations have been performed to determine which metal is the most cost effective over time.

A review published on Water UK provides some examples of different applications of stainless steel and galvanised steel within the water industry and a comparison of their life cycle costings (please refer to the reference list). One of these examples is shown in figure 2, revealing that after less than 5 years (green arrow) a galvanised steel access cover is more expensive than its stainless steel equivalent cover. The reason for this is regular maintenance and servicing (regalvanisation, painting) of galvanised steel, to preserve its corrosive resistance, incurs costs that add to its overall LCC. In addition, this study takes into account that a galvanised steel cover is replaced after 25 years, whereas a stainless steel equivalent will last longer than 50 years, another factor that is considered by LCC calculations. The lower life cycle costing of stainless steel is a significant benefit and one that is most often overlooked within the water industry.

Corrosion in Drinking Water Systems

Within the UK a wide range of metals are used in association with potable water systems such as pipes, access covers, water-tight doors, storage tanks and so on. Galvanised steel is popular within potable water systems due to its low initial cost and corrosion resistance. However, it is commonly seen that the zinc coating on galvanised steel products is below the European standard due to corrosion by, chlorine and sulphate concentrations, pH and temperature elevations (Delaunois, Tosar and Vitry, 2014). Stainless steel will still be susceptible to these factors. Yet, due to stainless steel not having a protective coating and its corrosive resistance being

Figure 4. A galvanised cover vs HUBER stainless steel covers

Figure 5. Extreme example of corrosion of a galvanised steel pipe after 6/7 years in a water supply system (TX, USA), compared to a stainless steel pipe (Raines, 2018)

throughout the metal, this problem is only associated with galvanised steel.

When looking at figure 3, which was taken from a study by Allion *et al.,* (2011), it clearly reveals that galvanised steels corrosion rate is far higher than stainless steel within potable water systems. Other studies have shown this clear difference in corrosion rate which can lead to leaching and leaks (Lee, Rasheed and Kong, 2018). Leaching of metals into potable water could be problematic depending on the constituent elements of the zinc coating (some older galvanised pipes may contain lead and cadmium). The higher corrosion rate also means more maintenance and eventual replacements are necessary for galvanised assets and not for stainless steel (Figure 4 and 5).

Both preserving water quality and maintenance of assets have associated costs and in turn, add to galvanised steels Life-Cycle Cost.

A comparison in wastewater

Wastewater treatment plants typically suffer from frequent and accelerated corrosion due to the extremely harsh environment subjected on the metals used. Depending on the location of the wastewater plant, various types of corrosion are common.

Areas of high flow rate experience flow-induced corrosion and erosion-corrosion. A typical example is screening, in this scenario, the equipment used needs to be able to withstand highly concentrated chemicals and abrasive particulates such as grit. As noted earlier, zinc is a soft metal that is easily damaged. In these harsh environments, the zinc coating on galvanised steel will be removed quickly exposing the unprotected mild steel beneath (Figure 1a). In comparison, stainless steel is much harder which reduces erosion-corrosion. Chromium has a hardness of 8.5 Mohs compared to Zinc at 2.5 Mohs (Tabor, 2007). This significantly increases the hardness of stainless steel making it much more resistant to abrasion compared to galvanised steel.

When looking at the comparison of sludge screens in figure 6, the pictures reveal no corrosion on the stainless steel screens after 12-13 years whereas the coated carbon steel equivalent screens reveals extensive corrosion after 12 years and required total replacement. The maintenance and replacements required due to corrosion incur costs and will add to its Life Cycle-Costing (LCC). It is more beneficial to invest in stainless steel, as over the LCC significant savings will be made.

In areas of low flow rate pitting corrosion is more common. Pitting corrosion is where a localised area of material is exposed to concentrated solutions or microbes for an extended period causing cavities and eventually holes. Pitting corrosion is problematic for both galvanised steel and stainless steel. The fast nature of pitting and reduction of oxygen means the passive layer for stainless steel cannot reform (Corrosion Handbook, 2015). In environments where pitting corrosion could be an issue it is important to consider the use of stainless steels with a higher molybdenum content such as duplex (British Stainless Steel Association, 2002). The variety of stainless

Figure 6. A comparison of various components of two similar sludge screens. The pictures above reveal components of a coated carbon steel screen with extensive corrosion after 12 years. The pictures below reveal components of a stainless steel screen after 12-13 years with no corrosion.

steels makes them a great material to deal with the range of extreme environments found within the wastewater industry.

Summary

It is clear to see that stainless steel has several significant benefits over galvanised mild steel. It is corrosion resistance and low life cost makes it an excellent choice for all applications within the water industry.

It is important to determine which grade of stainless steel to use for your application. For example in regular atmospheric environments, 304L is suitable due to low corrosive particles/deposits. In harsh environments (wastewater treatment) and marine or chloride bearing atmospheres, 316L or even super duplex is recommended for complete corrosion resistance (British Stainless Steel Association, 2002). Once the correct grade of stainless steel is selected, the applications are endless. As seen in figures 4 and 5, a slight initial investment in stainless steel allows for a low maintenance longer life.

At HUBER Technology, we pride ourselves in using the highest quality stainless steels for a variety of municipal and industrial applications. Benefits such as ease of fabrication due to its ductile property mean complex shaped products can be formed. Our large manufacturing facility, extensive range of manufacturing machinery (nesting and laser cutting) and variety of stainless steels means we can find the solution to any application. As part of our manufacturing process at HUBER, all of our machine components and products are acid pickled in an acid bath prior to passivation to maximise corrosive resistance. Stainless steel products will last a lifetime and prevent the need for regular maintenance, thus providing the most cost effective solution.

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