Material selection for wastewater pumps: Raise performance and extend system lifetime

Wastewater can sometimes be both corrosive and abrasive. Selecting the most suitable material for wastewater pumps is therefore crucial to obtaining a reliable, long-lasting and cost-effective operation. This paper provides recommendations for suitable wastewater pump materials and protection for use with different media. It also describes various phenomena associated with corrosion and abrasion.

Background

The increasing complexities in the composition of wastewater are growing. This has made it important to select a pump in the correct material with suitable protection.

The reason for the increased complexity differs depending on geographical area; a few causes are discussed below:

Due to increased labor costs, customers want maintenance-free pump stations. It is therefore more cost-effective to allow the pumps to transport sand over great distances within the system than it is to use vacuum trucks to remove the sand and grit frequently throughout the wastewater network and transport it for disposal.

In some geographical areas, the amount of runoff from streets in cities and towns has increased due to the higher proportion of paved areas. This increase in paved areas contributes to more sand in the system, which in turn leads to a higher degree of abrasive wear on the hydraulic parts of the pumps.

As a result, higher demands are placed on the selection of material as well as the protection of the pump to ensure optimal long-term performance that provides a longer life time as well as a sustained high efficiency. This ultimately leads to greater energy savings and a lower total cost of ownership.

It is equally important to understand when it is possible and suitable to use a pump in standard grey iron materials without extra protective measures. In most wastewater applications this is the recommended solution while other material choices or extra protection will only increase the cost.

Hydraulic parts of a wastewater pump, available in a wide range of material options.

How wastewater influences pump lifetime
There are several different types of wastewater. Depending on the sewage type, the use of different materials is required in order to extend the life of the pump. Chloride content, pH value, temperature, oxygen content and abrasives are factors that affect the selection of material and protection.

Untreated wastewater does not normally contain dissolved oxygen because the microorganisms use the oxygen to consume the organic material present in the wastewater. If oxygen is present, even in low quantities, unacceptably high levels of corrosion may occur if grey iron and carbon steel are used.

The chloride content in wastewater may vary from anywhere between 10 and 500 mg/l; in some cases, however, it can be higher due to seawater infiltration.
As a comparison the chloride level in the Atlantic Ocean is 19500 mg/l.

The pH value in wastewater typically lies around 7.

In untreated wastewater, abrasive particles are often present; this increases the risk of wear on the hydraulic parts. Material corrosion and wear can cause unplanned breakdowns and operational stops and reduced the useful lifetime of the pump.

Example of a typical wastewater station with propeller pumps.

Impeller after an accelerated wear test in a laboratory.

Wear
Wear is, by definition, the loss of material from a surface. Generally speaking, more than a single wear mechanism might occur at the same time; however, one of the wear mechanisms usually has a dominant effect. Wear due to abrasive particles is common in wastewater. If the velocity in the pump volute is high, water-erosion is accelerated. Pump parts, such as impellers, propellers, suction covers and volutes, that are in direct contact with the pumped media are primarily subject to erosive wear. Wear is not linear proportional to the velocity of the pumped media. For metallic material the wear is normally proportional to more than the square of the velocity. Tests indicate that an exponent of 2.4 is appropriate (Wear $=c*V^{2.4}$) In other words if the velocity increases by 50% the wear increases 2.6 times.

There is a strong linear relationship between wear resistance and the hardness of the same type of metallic materials (Figure 1). These wear resistance tests have been conducted at the Xylem material laboratory using a specially designed test apparatus, which simulates the actual conditions inside the pump.

Hard-Iron™ has an extremely high wear resistance due to its embedded hard chromium carbides.

Relative wear resistance test in slurry with 20% natural granite sand (Grain size: 0.70 mm)

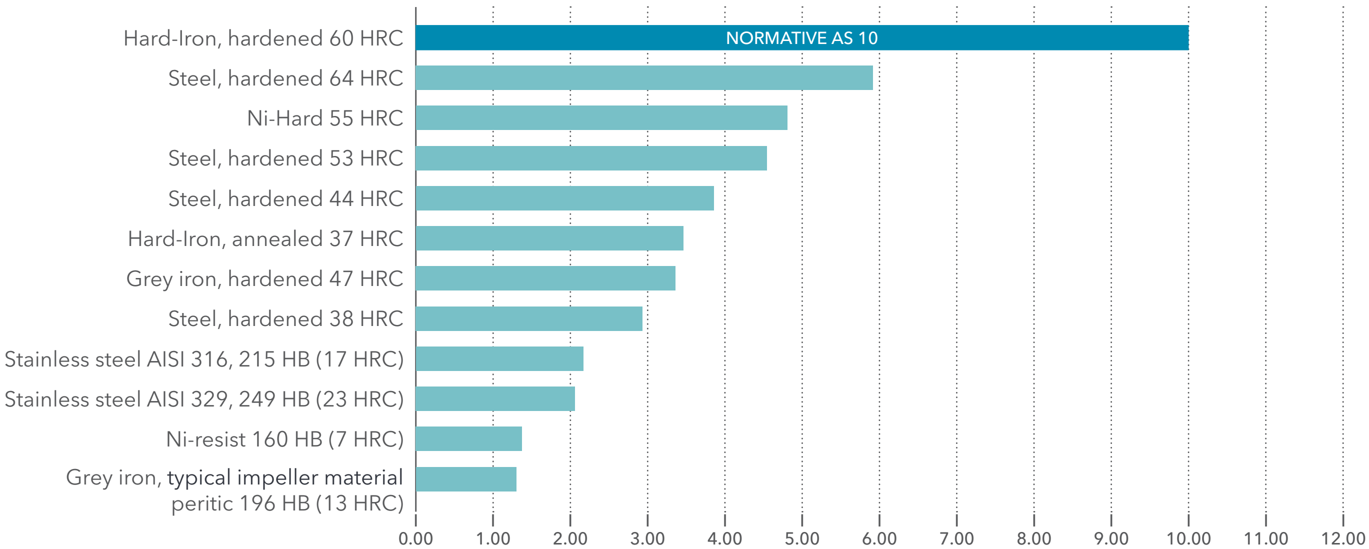

Figure 1: An overview of relative wear resistance of various materials. The graph shows the strong linear relationship between wear resistance and the hardness within the same type of metallic material. This can clearly be seen for steel in different hardness.

The linear relationship between hardness and wear resistance can most clearly be seen with hardened steel. Although these types of steels are made using the same technique and share a common structure, the hardness differs. Grey iron with embedded soft graphite in the structure has a lower wear resistance in the hardened state and in the as-cast state compared to carbon steel with similar hardness. Stainless steel, on the other hand, performs somewhat better than grey iron due to the higher corrosion-resistance properties of stainless steel.

Types of corrosion

There are numerous types of corrosion phenomena. General corrosion and erosion-corrosion, are the most common for grey iron and carbon steel that come into direct contact with wastewater. Galvanic corrosion is another type commonly associated with aluminum pumps; however, the risk of galvanic corrosion is also significant, for instance, when using stainless steel impellers in wastewater.

General corrosion

General corrosion attacks all types of surfaces but usually occurs at low rates. General corrosion is usually not a problem for components that are cast with thick walls therefore the function of the pump is not affected.

The corrosion rate for oxygen-induced corrosion may be accelerated for many reasons, including high temperature, media with high or low pH values, high oxygen content, or high chloride content.

The most common of these accelerating effects is chloride content. As a rule of thumb, if the chloride level is below 200 mg/l, no additional protective measures are necessary for grey iron and carbon steel.

The effects of general corrosion on a wastewater pump that is still functioning after 50 years of use.

Erosion-corrosion
When water flows at high velocities and oxygen erodes the corrosion products from the surface, erosion-corrosion is common. Generally localized to areas with turbulent flow, the attacks are even more severe when gas bubbles and solid particles are present.

Erosion-corrosion damage can be mistaken for cavitation damage. Cavitation can occur if the pump is not working in the correct area of the QH curve or doesn't have enough NPSH. For a correctly applied pump the risk of cavitation is low. In such cases erosion- corrosion is most likely the cause of damage to the material.

Galvanic corrosion
When two different metals are electrically connected and placed into contact with wastewater that contains chlorides, they form a galvanic cell where the more noble material is cathodic and the less noble anodic. The anodic material is then subject to corrosion.

The rate of corrosion depends upon the:
- Surface area ratio of the cathode to the anode. A bigger anode area compared to the cathode area reduces galvanic effects.
- Magnitude of potential difference (Figure 2). A larger potential difference increases the corrosion rate.
- Conductivity of the liquid. Higher chloride content leads to a higher corrosion rate.

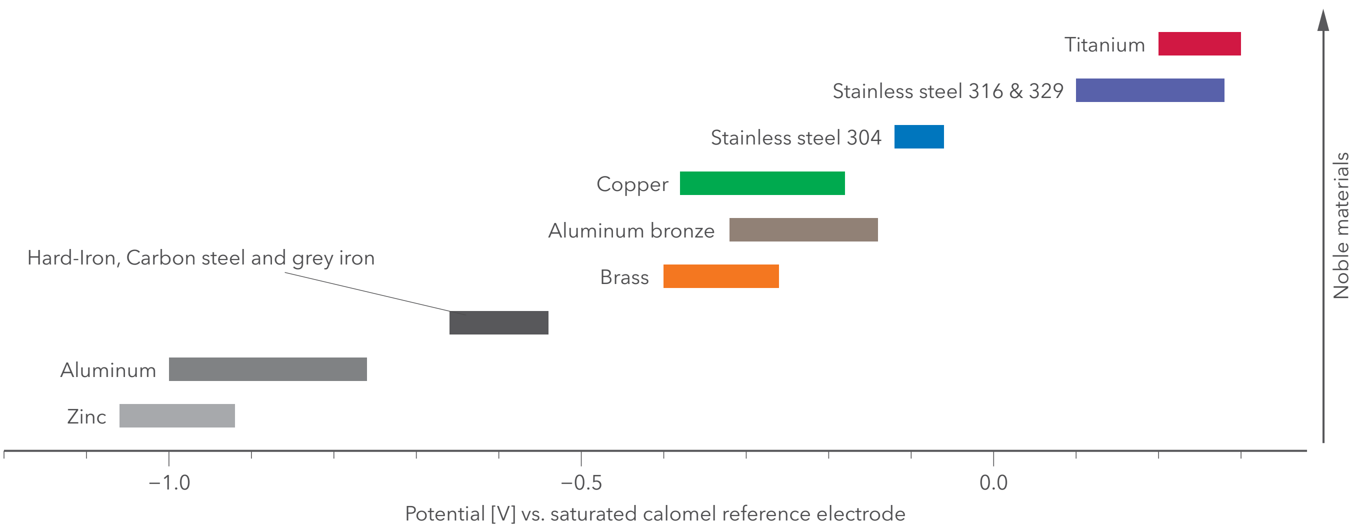

Figure 2: The electropotential of metals can be measured in different water solutions and listed in galvanic series.

Erosion-corrosion of an impeller.

Effects of galvanic corrosion on a lifting bolt with stainless steel chain.

Types of materials

The choice of pump material primarily depends upon the application, and the selection is very important to achieving long pump lifetime. The material in the impeller is the most important factor because the impeller is heavily affected by wear and erosion-corrosion due to its high velocity relative to the liquid.

Frequently used pump materials

Material	Nickel	Chrome	Hardness (hardened state)	Hardness (not hardened state)	Relative wear resistance	Electro-chemical potential	pH limitations	Chloride limitations (Without Zinc anode protection)
Grey iron	0	0%	47 HRC	13 HRC	1.3 (3.3*) *hardened	–0.55 to –0.65	5.5–14	<200 ppm
Stainless steel 316/329	4–11%	17–25%	–	10–20 HRC	2	0.1–0.3	0–14	<500 ppm
Hard-Iron	0	25%	60 HRC	37 HRC	10	–0.55 to –0.65	5–14	200–300 ppm

Figure 3: The most frequently used pump materials along with their respective wear-resistance and corrosion-resistance properties.

Grey iron

Known for its excellent casting properties, grey iron can also be hardened and demonstrates good machining properties. Grey iron is the most common impeller material suitable for most municipal wastewater applications where no special requirements for corrosion protection or wear resistance exist.

Grey iron can be used with wastewater in the pH range of 5.5 to 14 on the condition that the chloride content does not exceed 200 mg/l. If the chloride content exceeds the maximum allowable values, then both the use of zinc anodes and a special epoxy coating is recommended.

Stainless steel

Stainless steel (material type 316/329) demonstrates high resistance towards corrosion, yet has a low wear resistance. Wastewater can at times contain abrasive particles, which limits the suitability of stainless steel in wastewater applications.

If a stainless steel impeller is requested by the customer as preferred material, it is possible to use instead of grey iron, this will however have negative effects. If zinc anodes are required because of corrosive media the anodes will be consumed faster and needs replacement more often than compared to using a grey iron impeller.

Changing a grey iron impeller to a stainless steel impeller also poses the risk of galvanic corrosion. This increases the corrosion potential on the other wetted pump components and surroundings made of less noble materials. Stainless steel is therefore not generally the recommended material in wastewater applications.

Hard-Iron™

Hard-Iron has medium corrosion-resistant and very good wear-resistant properties. Wear tests show that the lifetime of an impeller made of Hard-Iron can be more than three times longer than an impeller made of hardened grey iron.

Hard-Iron is a high-strength cast iron alloy composed of 25% chromium and 3% carbon. During the solidification process, the chromium and carbon transform into very hard carbides. This makes Hard-Iron highly resistant to abrasive wear and erosion-corrosion.

Hard-Iron is more suitable for use in typical wastewater applications than stainless steel. Stainless steel will cause galvanic corrosion of the surrounding materials and reduce the total lifetime of the system.

Accelerated wear tests with sand have been conducted at the Xylem laboratory. Before the tests, the clearance between the impeller and the pump volute measured 0.3 mm. The test results show that impeller wear of stainless steel and grey iron occurs at approximately the same rate. After 50 – 63 hours of accelerated testing the impeller clearance was measured at 2 mm (Figure 4). An impeller made of Hard-Iron lasts approximately three times longer after 190 hours of accelerated testing wear widened the impeller clearance to 2 mm.

Accelerated wear test

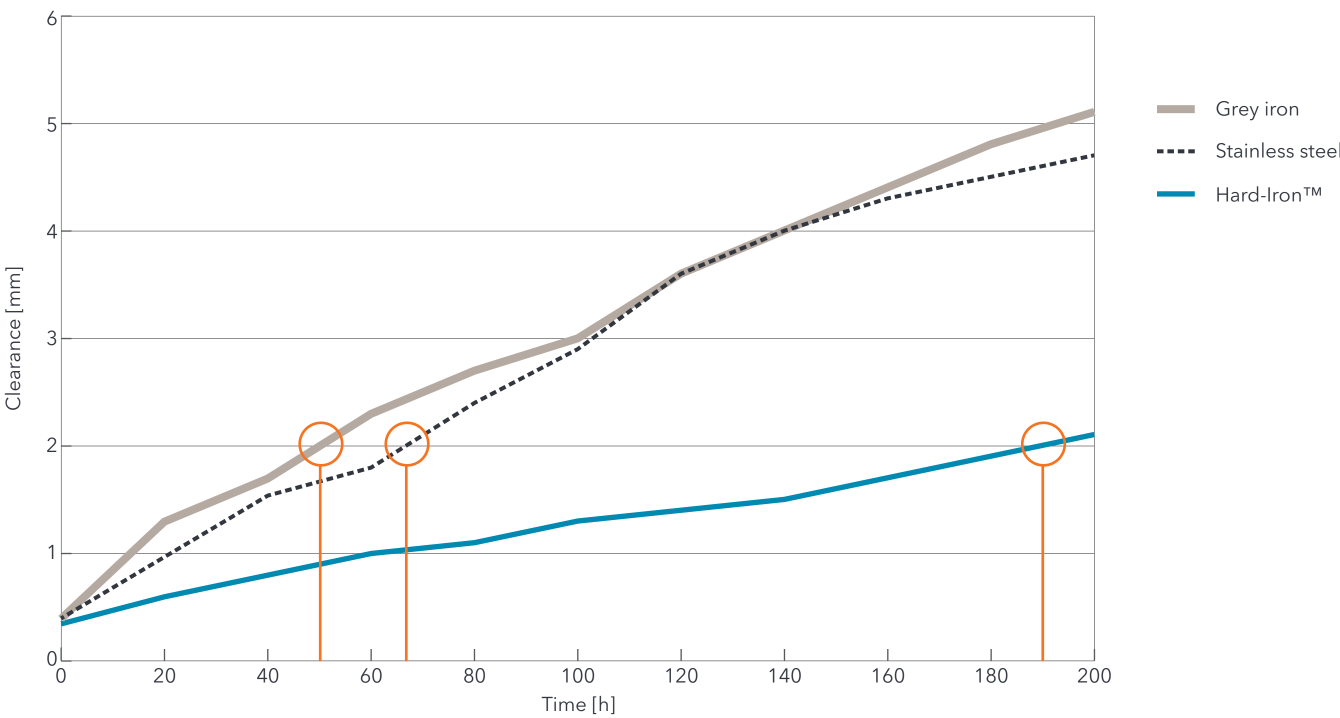

Figure 4: The tests above shows the comparison of material wear. The use of Hard-Iron minimizes wear on pump impellers and prolongs impeller lifetime.

Conclusion

The increasingly complex mixtures of wastewater affect the pump and result in both corrosion and wear in tougher applications. This places higher demands on selecting the right material for the impeller as well as providing proper pump protection such as zinc anodes and protective coatings. As previously mentioned, the choice of material for the pump depends upon the amount of chloride ions and abrasive particles in the pumped media.

The most common wastewater application has conditions of low wear with low amounts of corrosives. Here grey iron as impeller material is the best solution and no extra protection is needed. For high wear conditions a Hard-iron impeller is necessary since it increases the wear resistance three times and will give a long lasting operation. If a high amount of chlorides exists protection by zinc anodes and special epoxy painting is needed regardless of impeller material. If a stainless steel impeller is specified; it can be used instead of grey iron but the risk for galvanic corrosion increases. Stainless steel is therefore not our general recommendation for impeller material in wastewater applications.

Figure 5: This graph shows recommended impeller materials for grey iron pumps. Other materials may be available but are not recommended for wastewater applications.

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1) The tissue in plants that brings water upward from the roots;
2) a leading global water technology company.

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