



Sensitization In Corrosion-Resistant Alloys

Because it can cause a tube to fail, corrosion is alarming. In military and medical applications, sudden failure can result in serious consequences. To mitigate this risk, corrosion-resistant alloys like stainless steels are commonly used as tubing materials. Defective conditions such as sensitization, however, can alter the microstructure of corrosion-resistant alloys—opening them up to attack.

Sensitization, which weakens an alloy's protective chromium oxide layer, makes the alloy more susceptible to corrosion. At HandyTube, we recognize the serious nature of sensitization and work diligently to ensure our tubes reach our customers with a pristine microstructure.

HOW SENSITIZATION OCCURS

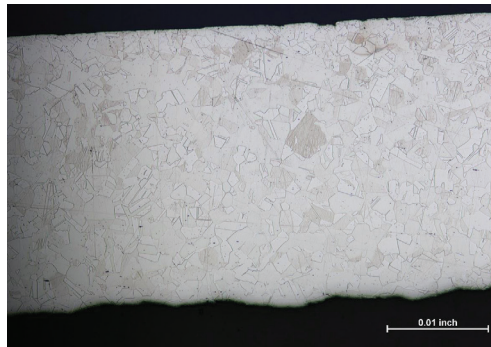
Inconel alloys and stainless steels are known for their corrosion resistance and can seem immune to the effects of salt spray and acidic compounds. However, these hardy alloys can still corrode in the presence of chromium carbide precipitates. A precipitate occurs when material of a different phase falls out of a solution. In this case, chromium carbide precipitates form from the chromium and carbon found within the solid solution of a metal alloy.

At elevated temperatures, sensitization occurs in metals containing chromium. During this process, precipitates form along the metal's grain boundaries, or the interface between two crystals in a polycrystalline solid. The alloyed metals used in HandyTube products are comprised of millions of small crystals, which are considered polycrystalline materials. Chromium carbide precipitation creates localized chromium depletion zones. These regions, which have low concentrations of chromium, are unable to form the impenetrable oxide layer—exposing the alloy to corrosive attack.

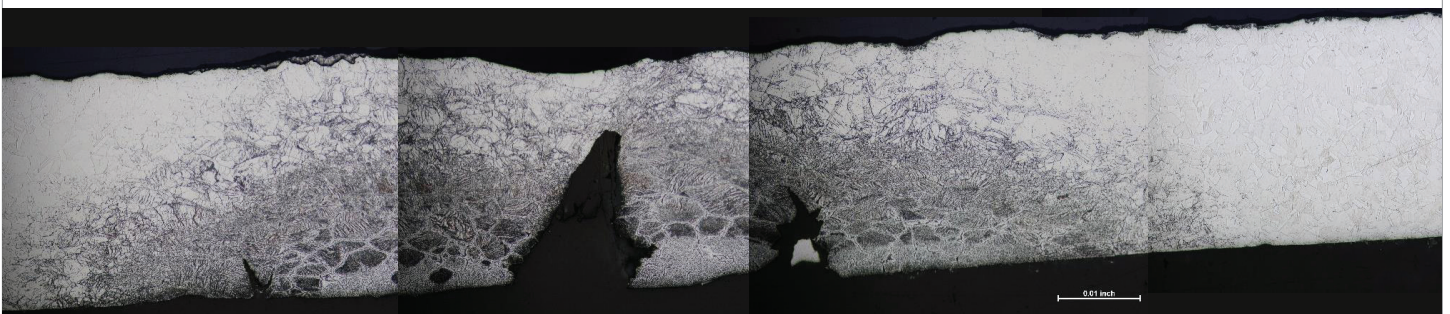
Precipitates form when chromium- and carbon-containing alloys are heated anywhere from 750°–1,500° F. While sensitization does not occur immediately within this temperature range, it slowly develops as more carbides form. Sensitization can take anywhere from 30 minutes to several hours before the material is significantly affected. Due to the relatively sluggish formation of chromium carbide precipitates, sensitization can be prevented by maintaining a fast cooling rate in the metal.

Corrosion is not the only effect of sensitization. The hardness of sensitized steel can significantly drop depending on the degree to which the metal has corroded. Since hardness is proportional to tensile strength, a product will likely fail under stresses it would otherwise be able to withstand.

Sensitization Grain Comparison



Healthy grain structure of 316 stainless steel.



Sensitized grain structure of 316 stainless steel with carbides formed in the grain boundaries.

PREVENTING SENSITIZATION

Metallurgists have developed a few tricks over the years to help mitigate the effects of corrosion. For instance, adding titanium and niobium to stainless steels and Inconel alloys reduces the effects of sensitization. At elevated temperatures, the niobium and titanium also form carbide compounds with the alloyed carbon. In fact, the carbon prefers bonding with niobium and titanium over chromium. As a result of this property, far less chromium is pulled out of the solution to form chromium carbide precipitates—keeping the oxide layer intact. HandyTube offers several alloys that contain titanium and niobium, including 321, 316Ti and Inconel 625.

Another strategy to combat sensitization is to limit the alloy's carbon content. Low-carbon stainless steels generally contain less than 0.03WT% carbon and are preferred for high-temperature corrosion resistance. Regular stainless steels tend to contain up to 0.06WT% carbon. When less carbon is present in an alloy, less carbide precipitates form and more of the alloy's chromium is left behind to maintain the protective oxide layer.

HandyTube offers low-carbon variants of many of our stainless-steel grades, enabling our customers to subject our products to high temperatures without worry. We have also carefully developed heat treatment processes that prevent the formation of chromium carbide precipitates, including annealing above the dangerous sensitization temperature range and rapid cooling. Specialized heat-treatment recipes and well-maintained furnaces also ensure our corrosion-resistant tubing is of the highest standard.

PREVENTATIVE TESTING

Despite taking careful precautions when heat treating metals, sensitization can still occur. Thankfully, inspection methods can identify the signs. When examining the grain mount of a sensitized metal, the affected area will have thick, dark grain boundaries due to the presence of carbides. Grain mounts are etched and polished samples that let you observe the surface-level microstructure of a material using a microscope. Questionable specimens can be tested using a series of acid tests in accordance with ASTM standard A262. Prior to testing, the specimen must first undergo an oxalic acid etch test. If no visible corrosion occurs, a second acid test should be performed using an appropriate compound.

CONCLUSION

Sensitization can cause even the hardest stainless steels and nickel alloys to become vulnerable to intergranular attack. If left unchecked, corrosion can jeopardize the structural integrity of a tube. That's why at HandyTube, we go to great lengths to ensure sensitization does not occur—eliminating the possibility of corrosion. Our company conducts temperature uniformity surveys in accordance with AMS 2750 to make sure all metals reach the same temperature when undergoing heat treatment. By taking this precaution, we can ensure all metals are heated and quenched in a controlled manner. We also perform preventative testing on every order to further guarantee the high quality of our products. Our rigorous production standards guarantee corrosion is one less thing you'll have to worry about when using a HandyTube product.