



IMPROVED PITTING CORROSION RESISTANCE BY USING EXPANITE HARDENING ON AUSTENITIC STAINLESS STEEL

Localized corrosion is one of the most common causes of corrosion-related material failures of passivating metals such as austenitic stainless steels. Pitting corrosion is one of the commonly referenced forms of localized corrosion, mostly due to the reliable testing methods that allow for direct comparison between different materials. Outstanding improvement in pitting potential has been shown for the Expanite treated surfaces, as shown by potentiodynamic polarisation measurements.

Austenitic grades

Austenitic stainless steels are a group of alloys that, due to their chemical composition, keep their austenitic structure even at low temperatures. The austenite stabilisers mostly provide this behaviour – a group of alloying elements that promote face-centred cubic (FCC) crystal lattice and lower the eutectoid temperature. The most prevalent austenite stabiliser in austenitic stainless steels is nickel, however, levels of manganese and especially nitrogen are commonly used to control the thermodynamic behaviour of austenitic stainless steels. Although a primary alloying element in stainless steels is chromium (usually above 16wt% for austenitic grades), addition of around 8wt% nickel and resulting microstructure modification provides superior protection in elevated temperatures, and the low carbon content allows for even further increase of chromium levels.

Pitting corrosion

Pitting corrosion is a type of localised galvanic corrosion – a form of corrosion caused by electrical coupling of species with different potentials. The difference in nobility between the protective, nanometre thick oxide layer and the underlying material in the presence of an electrolyte leads to an autocatalytic process where cathodic and anodic reactions are separated, and electrical contact through the bulk of the material as well as an ion exchange in the electrolyte is established. A local dissolution or imperfection in the passive layer gives rise to an anodic site, usually orders of magnitude smaller than the surrounding cathodic passive layer-protected metal surface leading to accelerated metal dissolution that can shorten your parts' lifetime and lead to material failures resulting in costly downtimes.

Surface hardening with SuperExpanite

The SuperExpanite (NC) process family consists of two main steps. First is ExpaniteHigh-T that anneals the core material and provides increased hardness up to 1mm depth. The hardness is increase by around 100HV relative to the core, thanks to 1 wt.% of dissolved nitrogen. The second step, ExpaniteLow-T creates a conversion layer of expanded austenite (solid solution of interstitially dissolved large amounts of nitrogen atoms that occupy octahedral holes of the FCC lattice) which provides a surface hardness of 1200HV.

Pitting resistance

In some cases, the pitting corrosion resistance can be significantly increased by the Expanite surface hardening process, even beyond the level of the unhardened base material. (Fig. 1). This effect is caused mainly by the large amount of nitrogen dissolved in the surface layer. A common formula for calculating the pitting resistance equivalent number (PREN) for alloys not containing tungsten, is given below (Eq. 1). It is easy to notice a relatively large 16x modifier in front of the nitrogen content expressed in weight percent (wt. %). This means that even small amounts of nitrogen have a significant positive influence on pitting resistance.

$$\text{Eq. 1: PREN} = \% \text{Cr} + (3.3 \times \% \text{Mo}) + (16 \times \% \text{N})$$



With the assumption of applicability of eq. 1 for large amounts of dissolved nitrogen [1], usually between 5 and 13 wt.% [2], the PREN number can be calculated. For the AISI 316L alloy the calculated PREN numbers then range from around 100 even up to 230. A minimum of 4-fold increase over untreated material which has a PREN number of around 24. The underlying ExpaniteHigh-T zone can be characterized with PREN number of around 30, providing additional improvement even if the case hardening has been damaged or worn down.

Potentiodynamic polarization measurements

A potentiodynamic polarization curve for SuperExpanite treated and reference AISI 316 material is shown in Figure 1. This test is a common tool used to evaluate the pitting corrosion potential and characteristics of a metal. Several highlights can be derived from the graph, showing the undeniable positive influence of SuperExpanite treatment on the pitting corrosion resistance of austenitic alloys. Firstly, the open circuit potential of SuperExpanite treated sample is around 100mV higher than for the reference, suggesting better corrosion resistance in the absence of galvanic coupling. The polarization curve of the reference material also shows a much narrower passive region, that is characterized with many intermittent peaks (rugged line). Those lines indicate a sudden increase in current density (increased corrosion rate) – initial pit formation and subsequent repassivation. The plot obtained for SuperExpanite sample is free of those irregularities, and the material stays in the passive zone for potentials almost twice as large, with much more gradual decline towards the breakdown potential.

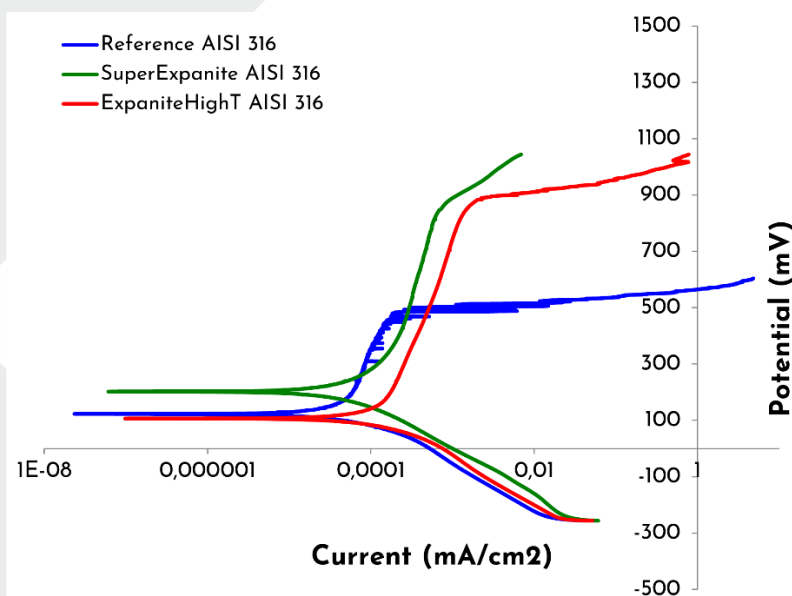


Figure 1: Potentiodynamic polarisation curves for untreated reference AISI 316 (EN 1.4401) material (blue line), ExpaniteHigh-T treated (red) and SuperExpanite treated (green) test coupons.

About Expanite

Expanite was founded in 2010 by leading experts in material and surface hardening from the Technical University of Denmark. The company has its head office in Hillerød near Copenhagen and service centres and licensees in the USA, Germany, Korea, and China. Expanite's DNA is based on sustainable solutions to extend the life of components made of stainless steel, titanium, and other high-value alloys - and the business model allows for license agreements whereby customers may implement the technology in their own production lines. The customers for Expanite's services are found within several industrial sectors, including process equipment for the food and pharma industry, pumps, valves, medical devices, the automotive industry, watch production and many others - everything from large global groups to specialists with a niche focus.

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