

Improving material performance with surface hardening

Stainless steel screw connections can be susceptible to galling due to factors such as insufficient surface hardness, excessive roughness, or lack of lubricants. Surface hardening offers a solution to this problem.

By Mia Grundtvig, Expanite

Fasteners are essential in many applications to allow for particularly frequent assembly and disassembly or high tightening torques, so it is important to carefully tailor the properties of such elements. When fasteners are jammed due to galling, removal can be an enormous challenge, especially to avoid damaging the bolt or destroying the nut.

Surface hardening, a process in which only the surface layer (few to tens of microns) of a workpiece is hardened, has been proven to significantly improve the seizure behaviour of stainless steel screws (Figure 1). The diffusion-based process increases the hardness of the surface through solid solution hardening and subsequently reduces its susceptibility to plastic deformation. Depending on the material, the corrosion resistance is maintained or even improved, and the stiffness of the base material is not impaired.

The surface hardening process

Surface hardening is not an applied coating, but a diffusion-based thermo-chemical surface hardening process. Although classic processes for the surface hardening of corrosion-resistant stainless steels have long been available, their application has two main disadvantages: firstly, all classic processes, such as salt baths, are known to reduce corrosion resistance. On the other hand, the hardness values of stainless steels usually hardened with nitrogen or carbon drop very quickly, i.e. the hardening depth is only a few micrometers and the underlying base material is very soft, which



Figure 1. Generic image of a cold-welded screw connection

can potentially lead to the egg-shell effect. Expanite has developed its proprietary technology (SuperExpanite®) to solve these shortcomings. In this process, not only the outermost layer but also the underlying material is hardened to a greater depth, which also often contributes to an improvement in corrosion resistance. In many cases, a two-stage process is used. Nitrogen is introduced deep into the surface area in the first step called ExpaniteHigh-T (high-temperature process), whereby the material is hardened to approximately 300 HV for austenitic materials and 850 HV for alloys with martensitic structure to a depth of up to 1 mm. In the second step, ExpaniteLow-T (low-temperature process, see Figure 2), the workpiece is heated to temperatures below 500°C and the surface layer is hardened to 1100-1300HV at a

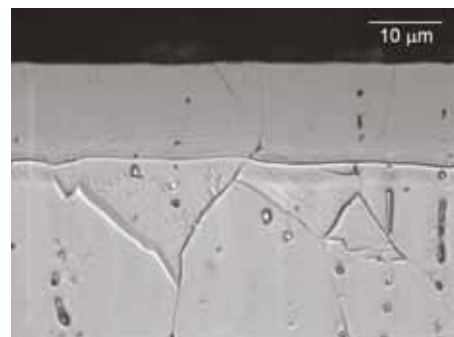


Figure 2. Micrograph of expanded austenite layer created with ExpaniteLow-T process (as a part of SuperExpanite product) on AISI 316L alloy.

hardening depth of 5-30µm (depending on the solution). The hardening is achieved by incorporating large amounts of interstitial carbon and nitrogen.

By combining the two process steps, the so-called eggshell effect is avoided, offering a decisive advantage for applications requiring improved load-bearing capacity (Figure 3).

Wear resistance

To test wear resistance, 316L samples hardened using its SuperExpanite® process to ASTM standard G 133 were tested. In this

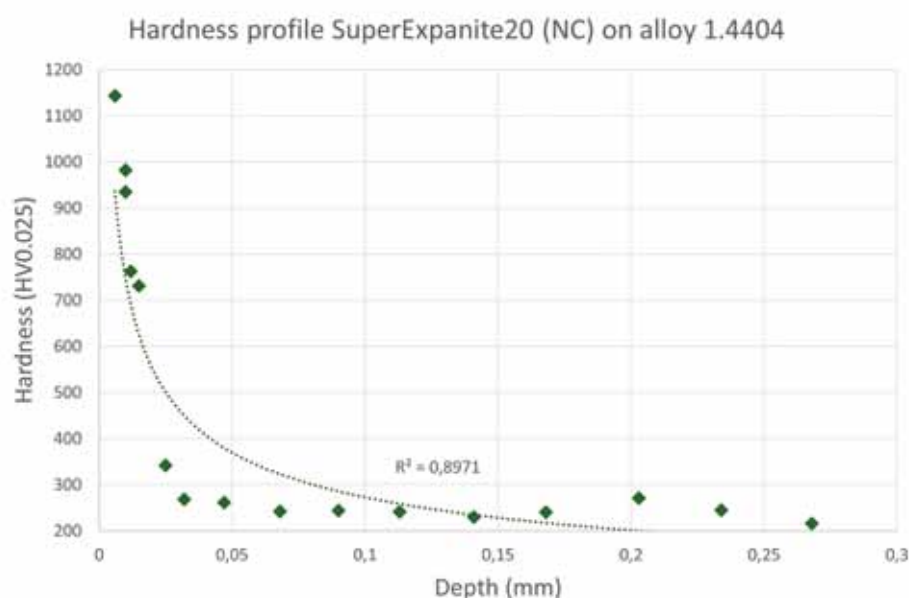


Figure 3. Hardness profile of AISI 316L. Below the extremely wear-resistant surface layer (produced in the ExpaniteLow-T process, approx. 1.200 HV) lies a medium-hard transition layer (250-300 HV), which is created in the ExpaniteHigh-T process. Power curve fitted for visual aid.

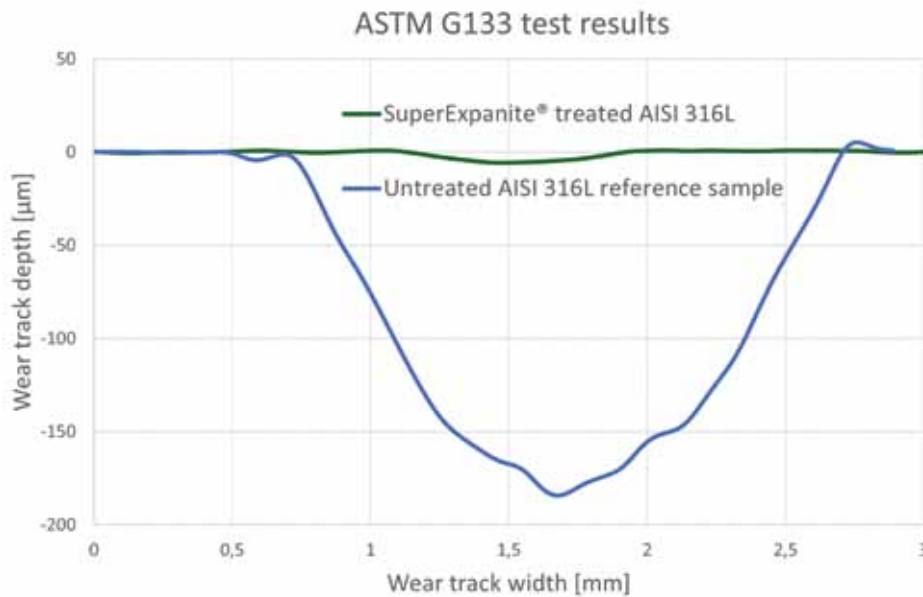


Figure 4. Wear measurement according to ASTM G133

procedure (Figure 4), the test specimen is subjected to the reciprocating motion of 100Cr6 counterpart, under a contact pressure of 25N. The wear volume is determined after a sliding distance of 100 meters. The results are shown in Figure 2. The 316L sample with this process is 125 times more abrasion-resistant than the untreated sample.

Following the ASTM G133, an ASTM G98 galling test (cold wear) was carried out with test specimens made of AISI 316L, the results of which are shown in Figures 5 and 6. In comparison to the unhardened test specimens, which already exhibit galling at a contact pressure of 35 bar, the test specimens hardened with SuperExpanite® do not show any galling even at a contact pressure of 2758 bar. This is even though the first plastic deformations occur at this pressure due to the yield strength being exceeded. The risk of galling is therefore eliminated in the case of both friction partners being hardened.

Corrosion resistance

Although the basic intention of conventional surface hardening processes is to produce harder surfaces, this is usually at the expense of corrosion resistance. However, tests have shown that 316L samples hardened with SuperExpanite® can spend up to 1,000 hours in a salt spray chamber without showing signs of corrosion (Figure 7). In some cases, the pitting corrosion resistance can be significantly increased by the surface hardening process, even beyond the level of the unhardened base material (Figure 8). 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.

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

With the assumption of applicability of Eq. 1 for large amounts of dissolved nitrogen¹ 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 a PREN number of around 30,



Figure 7. Results of the salt spray test on SuperExpanite hardened 316L alloy part (far right) as compared to competitors' solutions



Figure 5. Untreated AISI 316L test specimens after ASTM G98



Figure 6. SuperExpanite treated AISI 316L test specimens after ASTM G98

providing additional improvement even if the case hardening has been damaged or worn down.

A potentiodynamic polarization curve for SuperExpanite® treated and reference AISI 316 material is shown in Figure 8. This test is a common tool used to evaluate the pitting corrosion potential and characteristics of a metal. There are several highlights that can be derived from the graph, showing the undeniable positive influence of the treatment on the