Test result
March 2025

NO GALLING OBSERVED WITH EXPANITEPURELOW-T TREATMENT ON EN 1.4404 (AISI 316L)

Cold welding and it's dynamic counterpart – galling, are a pervasive problem related to surfaces with high chemical affiliation mated with high contact pressures and without the presence of lubrication or other separating agents. Some ways of addresing galling realted problems include material selection of distinc materials for counterparts, hard ceramic coatings (e.g. PVD), or use of friction- and adhesion-reducing substances. Those methods however, come at a disadvantage. Changing materials can not always be possible due to the work environment, ceramic coatings are prone to spallation under high contact forces due to low load-bearing capacity, and chemicals are often not allowed in food contact or for high vacuum applications. Expanite has previously documented very high improvements in galling resistance realted to its unique surface hardening solutions, like SuperExpanite®. However, in some cases, processes involving temperatures above stress relief (such as ExpaniteHigh-T) cannot be freely utilized due to the risk of losing high tolerances to distortion or due to cold worked condition that is crucial to mechnical performance of components. ExpanitePureLow-T aims at providing the same galling resistance, without compromising the design.

Standard Test Method for Galling Resistance of Materials (ASTM G98)

Table 1.: Description of ranks of surfaces in ASTM G98 test

Key	Rank
0 = No damage	0
B = Burnished	1
W = Wear	2
S = Scoring	3
I = Incipient galling	4
A = Adhesive Transfer	6
G = Galled	10

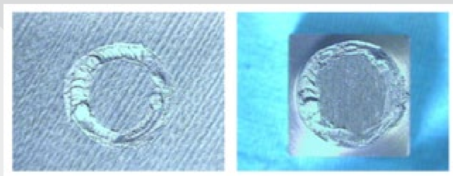

Figure 1.: Severe galling of untreated block and button counterparts made in EN 1.4404 tested under a load of 3ksi.

The test geometry of the ASTM G98 Standard Test Method for Galling Resistance of Materials consists of a hardened block, which acts as a stationary component, and a set of hardened buttons with cylindrical geometry that are rotated 360 degrees about their axis. The buttons are pressed with a constant force against the block. The buttons in this test utilise the ASTM G196 test sample geometry to eliminate issues with zero velocity in the centre of the sample, and to allow for an increase of the stress levels without modifying the equipment. The normal force is gradually increased between tests until galling is observed. When galling is observed, the test load is decreased by smaller increments to determine the galling threshold – a maximum load that does not lead to galling. The range of tested contact pressures in this test goes from 30ksi (about 206.8MPa) to 80ksi (551.6MPa) with a step size of 10ksi. After the test is conducted, the mated surfaces of both the buttons and the block are observed for signs of galling. The inspection results are given as a numerical rating – a "rank". A list of ranks and their descriptions is presented in the Table 1. A surface is considered free of signs of galling until the rank "3" - scoring. An example of severe galling as seen between two untreated counterparts manufactured in EN 1.4404, tested at contact load of 3ksi (20.7MPa) is shown in Figure 1.

ExpanitePureLow-T - purely simple solution

Utilising the same technology as our ExpaniteLow-T step of the SuperExpanite product, ExpanitePureLow-T provides an increase in surface hardness of austenitic EN 1.4404 alloy. The thermo-chemical conversion of the surface creates a layer of expanded austenite with surface hardness above 900HV. The increase in hardness is achieved thanks to diffusion of large amounts of nitrogen and carbon into interstitial sites (specifically, octahedral holes in the FCC lattice). The achieved thickness of the diffusion zone is 20μm ± 5μm. Due to the lack of annealing step, the resulting surface hardness and case depth are strongly related to the initial microstructure and manufacturing history. The microstructure of the treated sample in the surface area, showing the diffusion layer is presented in Figure 2. A hardness profile measured on the test sample used in this test is shown in the graph in Figure 3. To minimise the influence of the subsurface damage layer, a few micrometres thick zone affected by the machining operations, an electropolishing step is conducted as a necessary pre-process.

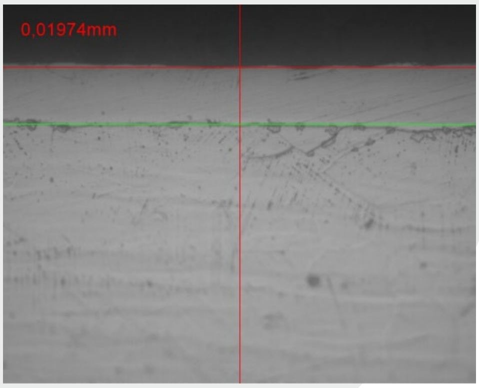

Figure 2.: Micrograph of diffusion layer with measured case depth (20μm) on EN 1.4404 treated with ExpanitePureLow-T. Magnification x40.

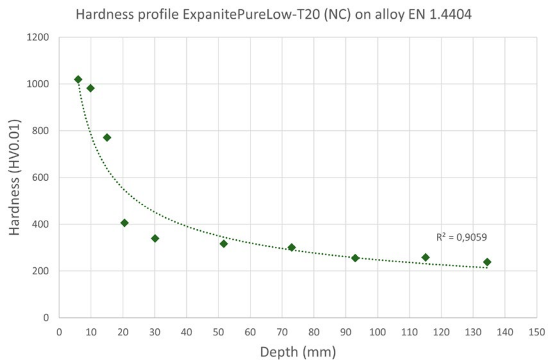

Figure 3.: Hardness profile of ExpanitePureLow-T treated sample manufactured in EN 1.4404. The raw stock material was a wrought and annealed bar.

Analysing the results

The list of ranks for both button and the block for each of the tested contact pressures is summarised in Table 2. There is a slight burnishing visible on the button at 30ksi. For higher contact loads, the buttons experienced wear or scoring issues, seemingly without correlation to the load (with better performance at the highest load of 80ksi than observed for lower loads of 50, 60 and 70ksi). The block has experienced scoring under all but one contact pressures. At 40ksi, only wear of the surface was noticeable. Due to the limitations of the equipment, galling threshold could not be determined, as no galling was observed up to maximum achievable load of 80ksi. For the mating pair consisting of untreated EN 1.4404 counterparts, galling was observed for stresses as low as 200psi (0.2ksi or 1.4MPa). The galling threshold was therefore established at below 0.2ksi.

Table 2.: Ranks of surfaces after ASTM G98 test

Pressure (ksi)	Pressure (MPa)	Rank / Grade	
		Button	Block
30	206.8	1	3
40	275.8	2	2
50	344.7	3	3
60	413.7	3	3
70	482.6	3	3
80	551.6	2	3

Minimum 400 times higher value of galling threshold

All test pieces have been photographed. The surfaces of samples tested at the lowest and highest load are shown in Figures 4 and 5. Almost no signs of test related surface deterioration are visible on the button tested at 30ksi, some burnishing or flattening of roughness seen as increase in surface shine is noticeable. The mated block shows signs of wear and minimal scoring. For the button tested at 80ksi some wear can be seen, however its test counterpart shows quite extensive scoring on the edges of the mark left by the button, mostly due to the yield strength of the underlying material being significantly lower than the test load. Over 500MPa of normal force was not enough to induce serious deterioration of surface during the test. The calculated minimal increase of test pressure required to achieve galling on the ExpanitePureLow-T treated samples is at least 400 times that of the untreated EN 1.4404. Unfortunately, due to the limitations of the test setup, we were unable to determine the exact value.

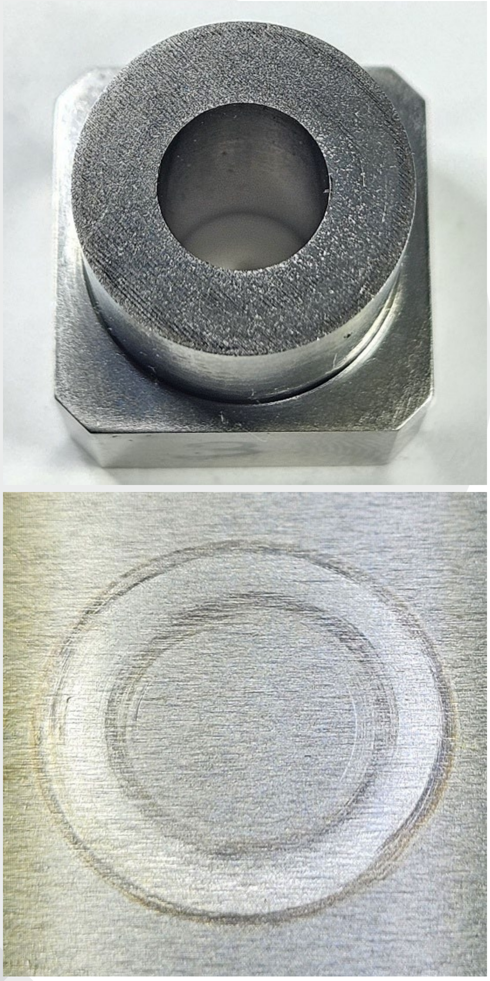

Figure 4.:
Top: surface of a button after test. Bottom: surface of a block after test. Tested at 30ksi.

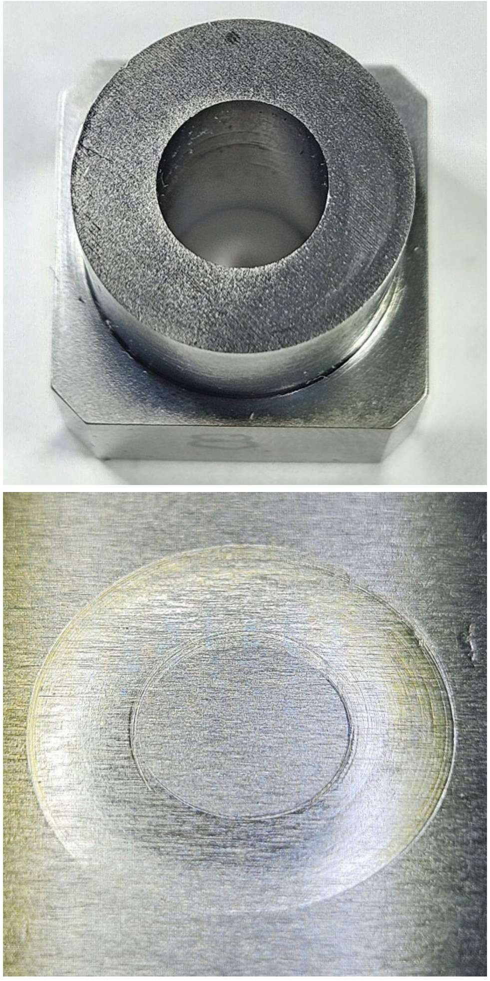

Figure 5.:
Top: surface of a button after test. Bottom: surface of a block after test. Tested at 80ksi.

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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