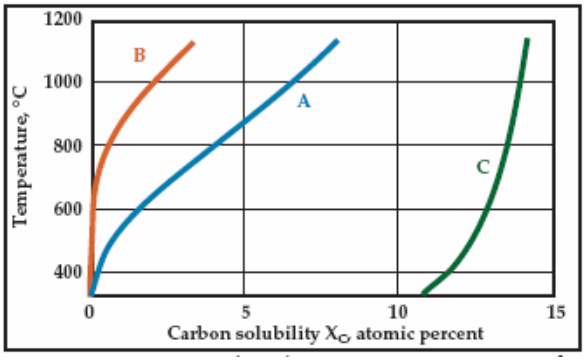
Award Winning Treatment Process Hardens Stainless Steels and Improves Corrosion Resistance

Materials scientists have long sought to find methods to optimize both the hardness and corrosion resistance of austenitic stainless steels. A key problem at high temperature is the carbon that is added to increase hardness instead combines with alloy elements to form carbides which can reduce corrosion resistance. A new surface treatment process developed by Swagelok Co. allows carburization of steels, without causing the formation of carbides, and offers the promise of providing lower cost, higher performing alloys that can be produced using less energy.

For this work, Swagelok's project "The development and commercialization of low-temperature colossal supersaturation (LTCSS), a novel surface hardening method for the carburization of austenitic stainless steels" received the American Society for Materials (ASM) 2006 Engineering Materials Achievement Award in October, 2006.

LTCSS hardens steel through diffusion. The formation of carbides is kinetically suppressed, enabling extremely high, or colossal, carbon supersaturation. As a result, surface carbon concentrations in excess of 12 at. % are routinely achieved. The treatment provides a uniform and conformal hardened gradient surface with no risk of delamination or peeling. Treated steel retains the austenitic phase, and because parts are treated at low temperature, there is no distortion or change of dimension.

Swagelok, Case Western Reserve University (CWRU), and Oak Ridge National Laboratory are conducting a $2.5 million three-year research project, funded in part by the Department of Energy through the Energy Efficiency and Renewable Energy Industrial Technologies Program (ITP). The project objective is to extend the LTCSS treatment to other alloys, and to quantify improvements in fatigue, corrosion, and wear resistance. Thermodynamic modeling has been used to design experimental alloys with enhanced affinity for carbon solubility at treatment temperatures. At Oak Ridge, four of the experimental alloys have been melted, rolled, and manufactured into test specimens. Initial LTCSS treatment indicates successfully enhanced results.



Carbon solubility in pure iron without ferrite (A) is reduced by chromium, which forms carbides in type 316 stainless steel (B), but can be greatly enhanced if carbide formation is inhibited by LTCSS (C).

The Treatment Process:
Under ordinary conditions, carbon diffusion into steel is blocked by the naturally forming Cr_2O_3 surface layer on the stainless steel. In the LTCSS process, the Cr_2O_3 surface layer is removed to “activate” the surface for carburization by placing the steel in an atmosphere of carbon-assisted gaseous HCl.

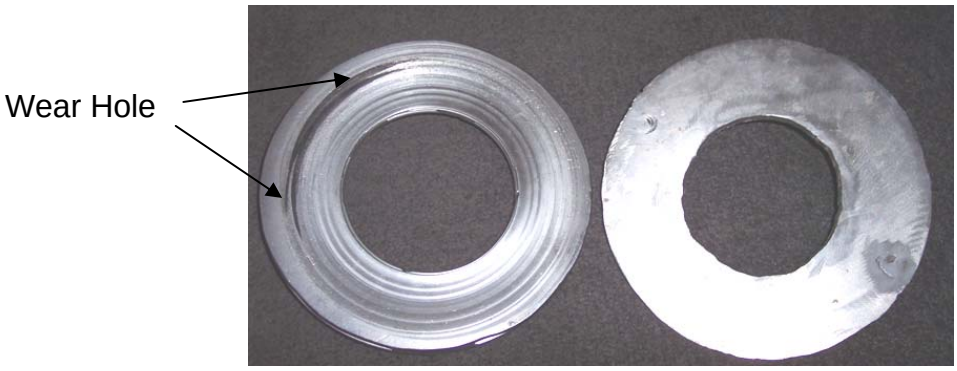
After initial activation, the metal alloy is heated in a mixture of CO, H_2, and N_2 at a temperature of 470°C for three hours. A carbon solid-solution case begins to form at temperatures high enough to promote carbon atom diffusion from the surface, but low enough to prevent carbide formation. The surface is then activated once again, this time with carbon assistance, and then carburized again at 470°C for 20 to 30 hours. The final result is an alloy containing in excess of 12 at. % carbon in the region close to the surface.

Treatment Results:
LTCSS treatment increases the surface hardness by a factor of four to five. Polarized crevice corrosion tests showed five orders of magnitude improvement in crevice-corrosion resistance for treated vs. non-treated type 316L stainless steel. Cavitation tests show that treatment on type 316 specimens reduces weight loss by a factor of about 5.5 times. Standard ASTM tests show wear rates 100 times lower and a 30% reduction in wear volume for treated vs. non-treated 316 specimens. The treatment has also been shown to increase fatigue resistance by an order of magnitude. Industrial component trials are showing over 2× life extension in severe wear operations.

Applications:
At present, Swagelok uses the technology for treatment of tube fitting rear ferrules, mostly manufactured in type 316 stainless steel. The ITP project is pursuing commercial applications for pumps, bearings, fasteners, water treatment, analytical and process instrumentation, and in the pulp and paper industry.

Increased erosion resistance enabled by LTCSS is particularly important for slurry and corrosive pumping applications. The process has shown the ability to treat chromium-containing precipitation-hardening stainless steels, duplex alloys, nickel-based alloys, and cobalt-based alloys, in addition to austenitic stainless steels. Swagelok intends to make the technology available commercially to third parties, and plans to set up a new business unit to support these efforts.

An initial installation of treated pump clutch plates at the Sonoco Pulp and Paper Mill has demonstrated a 3X improvement in product life. A trial of treated pump impellers at Sonoco has begun. A second industrial trial with Spirax of treated steam trap oriface components has also demonstrated improved component life.



Untreated and treated 304SS Pump Clutch Plates after 3 Months in Pulp and Paper Service. Notice large erosion hole in upper left of untreated plate.

Energy Savings:
Sonoco has shown that the new treated wear resistant clutch plates reduce pump motor loads, and estimates and annual energy savings of 56 million Btu/year for a single 10HP pump. They expect the energy benefits from reduced impeller wear on 50-200 HP pumps to range from 223 to 1,120 million Btu/year.

For a fact sheet about on the ITP project:
http://www.eere.energy.gov/industry/imf/pdfs/16948_surface_hardening.pdf

For more information on the Swagelok process and ASM Award:
http://www.asminternational.org/Template.cfm?Section=SearchArchives&template=JournalAbstractDetail.cfm&AbstractID=11537

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