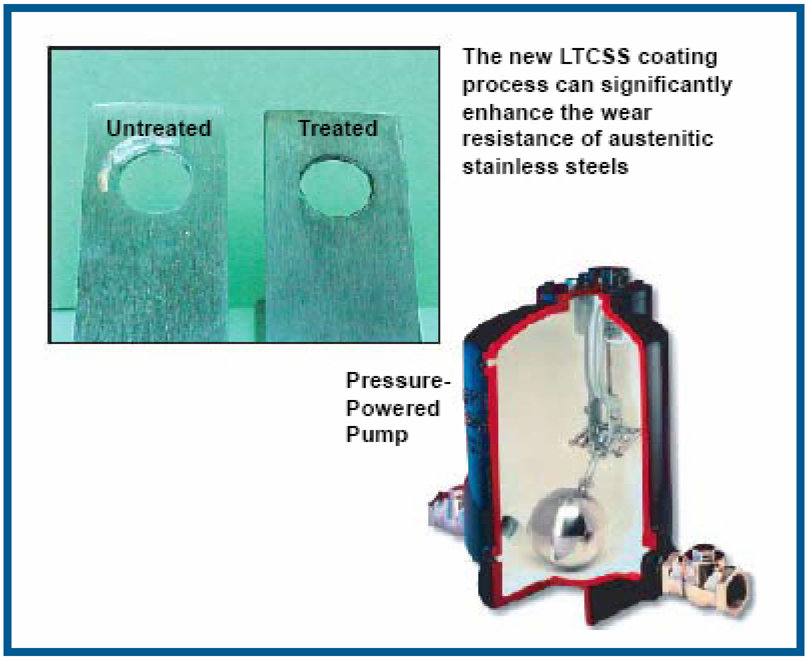
Surface Hardening of Stainless Steels through Low-Temperature Colossal Supersaturation

New Coating Technology Can Lead to Reduced Wear Rates, Improved Resistance to Pitting and Crevice Corrosion, and Retention of Fatigue Resistance for Pumping Systems

Austenitic stainless steels of types 316, 304, 347, and 321 are the primary materials of choice for a very broad range of applications in which corrosion resistance in aqueous solutions at ambient temperatures is required. While austenitic steels are excellent for their corrosion resistance, they possess low hardness values and cannot be heat-treated to increase their hardness. When they are used in pumps designed for liquids and slurries, significant wear of pump impellers and the pump casings occurs. Thus, there is a need for stainless steels that have high corrosion resistance combined with enhanced hardness and wear resistance. The development of the low-temperature colossal supersaturation (LTCSS) process will enable carburization of stainless steels at low temperatures thereby improving both the corrosion and wear resistance of components.



Applications of the improved materials cross-cut various industries

Benefits for Our Nation and Our Industry

The new technology imparts corrosion and wear resistance, high surface hardness, and high fatigue resistance to stainless steel components. Decreased wear in pumps and pump parts yield increased productivity and will yield estimated energy benefits of over 22 trillion Btu/year by 2020. Replacement of expensive stainless steel components with less expensive grades with sufficient wear resistance results in additional economic benefits.

Applications in Our Nation's Industry

The coatings technology developed is used in pump and pump impeller components and steam traps. Pumping systems are utilized in many industries, including aluminum, chemicals, forest products, mining, petroleum, and steel.

Project Description

The goal of the project was to develop improved surface characteristics of stainless steels, leading to enhanced corrosion and wear resistance. This was carried out by developing the LTCSS process.

Barriers

Barriers addressed:

- Lack of data or a knowledge base on the impact of the LTCSS process on the hardness of a wide range of stainless steels currently used throughout the industry;
- Lack of optimized processing knowledge for producing surfaces utilizing the LTCSS treated samples method; and
- Limited information on the applicability, samples feasibility, and performance of the LTCSS modified stainless steels in various

Pathways

The objectives of this project were achieved through the following: (1) understanding the effects of alloying on the maximum solubility of carbon in stainless steels; (2) identifying and obtaining alloy compositions with maximum capacity for colossal supersaturation of carbon; (3) establishing methods for activating surfaces of candidate alloys; (4) defining carburization heat treatment process parameters for maximizing surface hardness and depth of hardening;(5) laboratory and in-plant corrosion resistance testing to study pitting, crevice, and stress corrosion resistance; (6) tribological evaluation of the hardened austenitic steel surfaces to determine wear resistance to unidirectional and reciprocating sliding; and (7) fatigue testing to understand the effect of residual stresses on the performance of modified steels in industrial applications.

Results

- Established optimum alloy compositions for maximum surface hardening effect
- Prepared second- and third generation experimental alloys
- Conducted low-temperature carburization of candidate alloys
- Performed hardness depth profiles on LTCSS treated samples
- Analyzed microstructure of carburized layers on LTCSS-treated samples
- Completed corrosion testing of LTCSS-treated samples
- Completed wear testing of LTCSS treated samples
- Completed high-cycle fatigue testing of LTCSS-treated samples
- Completed component feasibility testing in laboratory and industrial settings

Commercialization

The project has had various partners in developing and commercializing the technology. Swagelok focused on manufacturing capabilities to surface-treat stainless steel components of various shapes and sizes. Energy Industries of Ohio provided a test bed for evaluating the new materials in industrial settings. Spirax Sarco introduced design changes and new materials in various pump and steam-related test systems and products.

The LTCSS process received an ASM Engineering Materials Achievement Award in October 2006. Additionally, the technology was given a grant by the Ohio Third Frontier Project for further commercialization. With this grant, Swagelok formed Swagelok Technology Services Company (STSC) to further commercialization of LTCSS steel, and to provide treatment services to customers including the U.S. Naval Research Laboratory.

Project Partners

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Case Western Reserve University
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Energy Industries of Ohio
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Oak Ridge National Laboratory
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A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

U.S. Department of Energy
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Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Ending FY07
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