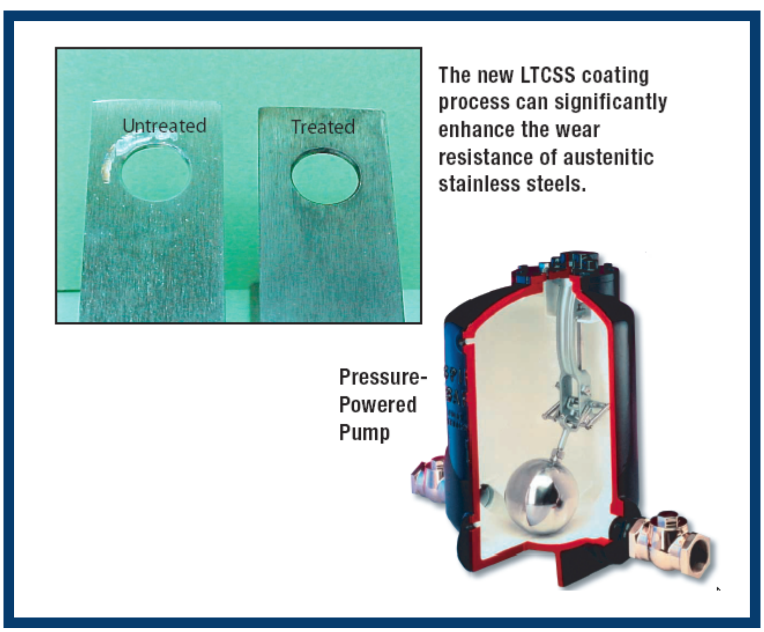
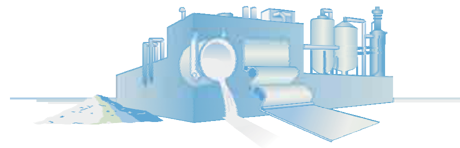
Surface Hardening of Stainless Steels through Low-Temperature Colossal Supersaturation

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 when one needs corrosion resistance in aqueous solutions at ambient temperatures. 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, sigificant 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 would enable carburization of stainless steels at low temperatures and hence improve both the corrosion and wear resistance of components.



Applications of the improved materials are cross-cutting across various industries.



Benefits for Our Industry and Our Nation

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 will yield increased productivity and 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 will also result in economic benefits.

Applications in Our Nation's Industry

The coatings technology developed will be 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 is to develop improved surface characteristics of stainless steels, leading to enhanced corrosion and wear resistance. This will be carried out by developing the LTCSS process.

Barriers

Major barriers to be overcome include:

- 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 method; and
- Limited information on the applicability, feasibility, and performance of the LTCSSmodified stainless steels in various industrial applications.

Pathways

The objectives of this project will be 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 the surfaces of candidate alloys; (4) defining carburization heat treatment process parameters for maximizing surface hardness and depth of hardening; (5) laboratory and inplant 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.

Milestones

- Establish optimum alloy compositions for maximum surface hardening effect
- Prepare second- and third-generation experimental alloys
- Conduct low-temperature carburization of candidate alloys
- Perform hardness depth profiles on LTCSS-treated samples
- Complete microstructural analyses of carburized layers on LTCSS-treated samples
- Complete corrosion testing of LTCSS-treated samples
- Complete wear testing of LTCSStreated samples
- Complete high-cycle fatigue testing of LTCSS-treated samples
- Complete component feasibility testing in laboratory and industrial settings

Commercialization

The project has various partners that will participate in developing and commercializing the technology. Swagelock, as the primary partner, will focus on manufacturing capabilities in order to surface-treat stainless steel components of various shapes and sizes. Energy Industries of Ohio will provide a test bed for evaluating the new materials in industrial settings. Spirax Sarco, as a supplier of pumps and steamrelated equipment, would introduce design changes and new materials in various pump and steam-related test systems and products.

Project Partners

Swagelok Company
Solon, OH
(Sunniva Collins:
Sunniva.Collins@swagelok.com)

Case Western Reserve University
Cleveland, OH

Energy Industries of Ohio
Cleveland, OH

Oak Ridge National Laboratory
Oak Ridge, TN

Spirax Sarco Inc.
Blythewood, SC

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1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

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