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DEVELOPMENT OF ANTI FOULING TYPE COATINGS FOR CENTRIFUGAL COMPRESSORS AND INDUSTRIAL STEAM TURBINES

by
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Mr. Dowson graduated from Newcastle Polytechnic, now Northumbria University, with a B.S. in Metallurgy and did his postgraduate work (M.S. Degree) in Welding Engineering. He is a member of ASM, NACE, ASTM, and TWI.

Over the past fifteen years, a great deal of progress has been made with respect to the application of materials and related processes applied to various components for centrifugal compressor and industrial steam turbines. Due to the very competitive market, material selection has moved beyond simply finding the material with the most ideal properties. Material cost and delivery has become one of the most important factors in the overall cost and delivery of the material. Most original equipment manufacturers (OEM's) are continuously reviewing new ways, whether by material changes or processes, to reduce cost or delivery in order to remain competitive. Also, as energy costs increase, the importance of efficiency in each process / machine increases and to be more competitive, OEM's are looking for new ways to enhance the components to perform more efficiently. At the same time, the environments the components are exposed to are increasing in severity leading to the need for more specialized materials. Since these specialized materials can be more costly with long lead times, other materials, such as coatings, have been developed that are resistant to the aggressive environments. In some cases, coatings can enhance the performance of the machine.

Coatings have been applied to the rotating and stationary components of centrifugal compressors and steam turbines to enhance performance in a number of areas:

- Improve resistance to corrosive environments
- Minimize the rate of solid particle erosion

- Minimize the rate of liquid droplet erosion
- Improve the foulant release ability of the component
- Minimize fretting between two components

Elliott Group has developed numerous coatings and application processes for enhancing the performance of turbomachinery components in aggressive environments. One of the company's major developments has been the application of an anti-foulant type coating, amorphous nickel to complete centrifugal compressor and steam turbine rotors. These coatings have superior anti-foulant characteristics for resistance in aggressive environments. Also, Elliott Group has developed multi-component (polytetrafluoroethylene (PTFE[TEFLON]) sprayed coatings designed for foulant and corrosion resistance.

Fouling is a common problem in compressors and to some extent, steam turbines. Fouling refers to the buildup of solids, usually polymeric materials, on the internal aerodynamic surfaces of the machine. While it does not usually lead to catastrophic failure, it does gradually reduce the efficiency of the machine by increasing the mass of the rotor, altering the aerodynamics, and blocking flow paths. If left unchecked, fouling can block the flow path to the extent that production is stopped or it can cause imbalances that can damage the machine. Depending on the service, fouling substances may come from outside of the machine or be generated internally. External foulants may come from airborne salt, submicron dirt, and organic or inorganic pollutants in the process gas. A well-maintained filtration system usually helps to minimize this external fouling. In petrochemical compressors, the situation is much more complicated, as the foulants can be generated internally. For example, in ethylene cracked gas compression, fouling results from the polymerization reactions intrinsic to the compression process. Fouling imposes significant costs on petrochemical production.

In order to resist fouling, the material must have excellent release properties. Materials with a combination of a low coefficient of friction and chemical inertness are usually used in aggressive environments. A common and widely known coating material for centrifugal compressors is PTFE (Teflon). PTFE coatings are multi-component, sprayed coatings designed for fouling and corrosion resistance. Wang, et al, (2003) showed a dramatic decrease in time required to release an applied foulant on samples coated with two PTFE type coatings offered by the author's company versus bare steel samples (compare E and E+ vs. Steel in Figure 1). Figure 2 shows an example of a compressor rotor with PTFE coated impellers.

Unfortunately, PTFE coatings are removed by erosive liquids (i.e., water washing) or solids. Electroless nickel (EN) has also been shown by Dowson (2007) to exhibit excellent release properties (523 in Figure 1), while remaining adherent in erosive conditions. In fact, the release properties are as good as or better than results from PTFE. EN is applied by submerging the component into a Ni and P containing solution where an autocatalytic process plates the part with a well bonded, amorphous Ni-P alloy. The P in the alloy is believed to be responsible for the release properties, while the amorphous nature of nickel aids in corrosion resistance.

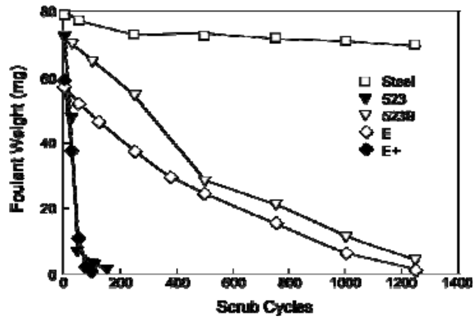

Figure 1. Comparison of Fouling-Release Performance of Bare Steel and Coated Panels.

Figure 2. Centrifugal Compressor Rotor Coated with a PTFE Type Coating.

Fouling and corrosion can also be a problem in steam turbines, not only causing material damage but also reducing turbine efficiency over time. Industrial turbines, whether condensing or non-condensing, can encounter problems with deposits building up on the turbine airfoils. In a turbine, hydroscopic salts, such as sodium hydroxide, can absorb moisture when superheated steam becomes saturated and condenses in the latter stages of the turbine/Wilson line. Wet sodium hydroxide has a tendency to adhere to turbine metal surfaces and can entrap other impurities such as silica, metal oxides and phosphates. Once these deposits have formed, they can be difficult to remove. Buildup of these deposits may be a cause of decrease in efficiency and possibly an increase in vibration. A smooth clean steam path will not collect deposits so easily as a dirty, previously contaminated surface. Consequently, a previously contaminated turbine will accumulate deposits more rapidly than a clean one. Therefore, it is desirable to prevent further deposit buildup and to remove the problems associated with the presence of the deposits by cleaning the turbine. Elliott has provided support to end user turbines for water washing of steam turbines (Watson, et al., 1995). The effectiveness of the water removal procedures mainly depends on the adherence of the deposits to the substrate.

A second route is to coat the surface with a material which has superior antifouling or anti-stick/corrosion characteristics. This in turn is beneficial to the turbine blades by reducing the tendency for contaminants to stick to the blades and increase the effectiveness of the water washing. Titanium nitride coatings with a chromium undercoat (Cr-TiN) have also been used by steam turbine OEMs to coat turbine blades. This coating provides corrosion protection and can be used on all stages of a steam turbine rotor. However, the Cr-TiN only provides limited anti-foulant benefits. Elliott has recently developed a proprietary coating, which is a corrosion resistant anti-foulant coating designed for the later stages of the turbine rotor (where the deposit buildup is most severe). Testing has shown that this coating is provides significant improvement in foulant release ability (Figure 3), excellent corrosion protection (passes over 1,000 hours of ASTM B117 Corrosion Testing under a 5% salt solution), and erosion protection (Figure 4), while having little effect on the fatigue properties (Figure 5).

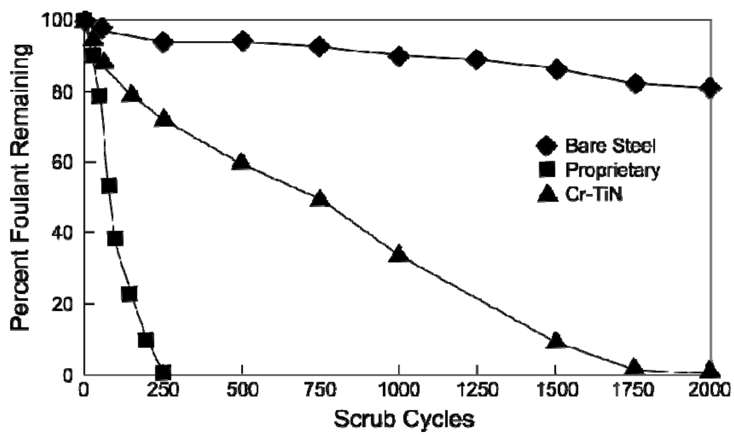

Figure 3. Comparison of Foulant Release Performance of Bare Steel Against Proprietary coating and Cr-TiN Coated Samples.

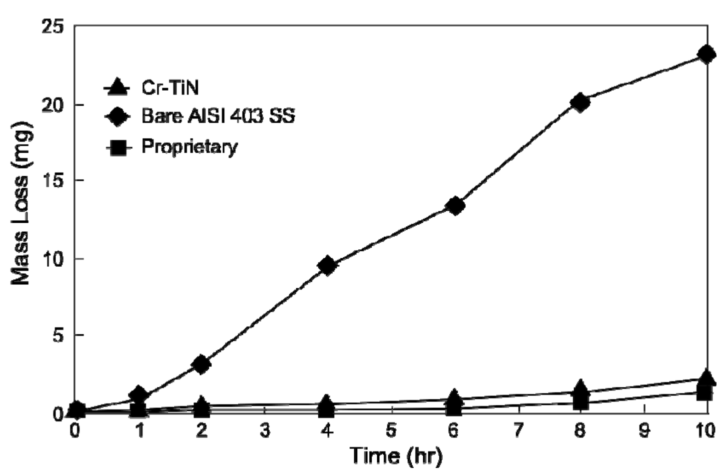

Figure 4. Comparison of Bare AISI 403 Stainless Steel Against Proprietary and Cr-TiN Coated Samples after 10 Hours of Modified ASTM G32 Testing.

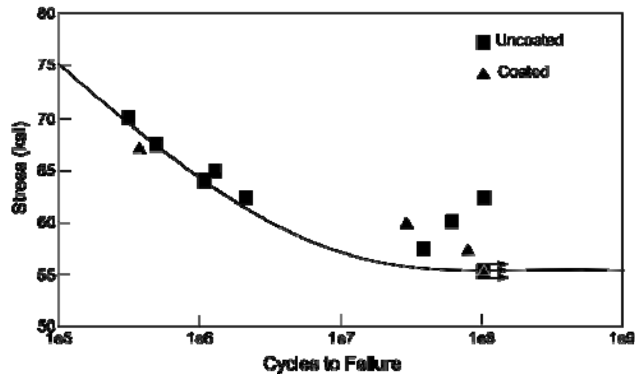

Figure 5. Results of R.R. Moore Fatigue Testing.

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