TECH BEAT

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Natural corrosion inhibitor from bacteria

An exopolysaccharide coating secreted by bacteria is capable of retarding corrosion on ferrous alloys.

KEY CONCEPTS

- An exopolysaccharide secreted by a specific strain of bacteria exhibits corrosion inhibition in flash rust and electrochemical impedance spectroscopy testing.
- The exopolysaccharide coating forms an active barrier that prevents corrosion, even if the surface is scratched to expose metal to the environment.
- The exopolysaccharide is believed to chelate ferrous and ferric ions, which stops the corrosion process.

Mention bacteria to someone within our industry and the individual will probably cringe with thoughts of premature lubricant fluid failure, generation of nasty odors, clogged filters, a reduction in pH and an increase in corrosion. All of these factors can take place in lubricants such as metalworking fluids.

In a recent TLT article, STLE-member Fred Passman outlined how bacteria and other microbes can adversely affect the operating life of a MWF.[1] Passman lists four factors (energy source, nutrients, acceptable thermal and pH conditions) that need to be understood to control the concentrations of microbes in a MWF system.

Bacteria generate acidic byproducts that lead to pH reduction in their environment, causing corrosion. One of the main problems in controlling bacteria growth is their secretion of byproducts that generate biofilms protecting the bacteria from the biocides designed to kill them.

Corrosion, which can cause machinery to prematurely fail, remains a problem. A number of different technologies have been discussed in this column to detect and retard corrosion. In a previous TLT article, a fluorescent probe has been developed to detect corrosion at an earlier stage than when it can be seen with the naked eye.[2]

Dr. Victoria Finkenstadt, lead scientist in Plant Polymer Research at the United States Department of Agriculture National Center for Agricultural Utilization Research in Peoria, Ill., says, "We have been working on the evaluation of electroactive polymers in nature to determine their effectiveness as either conductors or insulators. One of my co-workers attended a conference and found out that a specific type of biofilm prepared from a polysaccharide was not corroding metal. We found this observation to be very interesting, particularly since the polysaccharide is similar in structure to one we were evaluating."

A polysaccharide exhibiting the properties of a biofilm combined with corrosion inhibition could provide unique characteristics. Such a polysaccharide has now been isolated, and work to determine its effectiveness as a corrosion inhibitor is under way.

EXOPOLYSACCHARIDE COATINGS

Finkenstadt and her co-workers have found that exopolysaccharides secreted by specific bacteria have been found to retard corrosion on ferrous alloys. She says, "Exopolysaccharides are one of a number of components that bacteria release along with proteins and fatty acids as byproducts of respiration. These materials are polymers of sugars such as glucose."

The researchers worked with exopolysaccharides derived from strains B-1355 and B-1498 of the bacteria *Leuconostoc mesenteroides*. The source of the exopolysaccharides is very important as only specific sugar polymers exhibit corrosion inhibition. Finkenstadt adds, "We found that exopolysaccharides that were similar in structure but from other strains of the bacteria did not display similar performance."

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The exopolysaccharides are prepared either by fermenting the bacteria in broth or by isolating the enzyme used to make these polymers. Finkenstadt says, "Working with the enzyme itself is a much cleaner process because cell parts are not involved and you do not have to remove leftovers."

Ethanol is used to isolate specific water soluble exopolysaccharides. The researchers separated two exopolysaccharides at specific concentrations of ethanol in water. Fraction L precipitated at an ethanol concentration of 38%, while Fraction S was obtained when the ethanol level was increased to 46%.

Both polymers exhibit high molecular weights above 10^6 grams per mole. The monosaccharides used to prepare each polymer are different as are the linkages between them.

Initial testing of the exopolysaccharides for flash rust was conducted by forming casting films on SAE 1010 low-carbon-steel metal coupons. Finkenstadt says, "We suspended the exopolysaccharide in water and then poured it out onto a metal coupon, which was allowed to dry at ambient temperature."

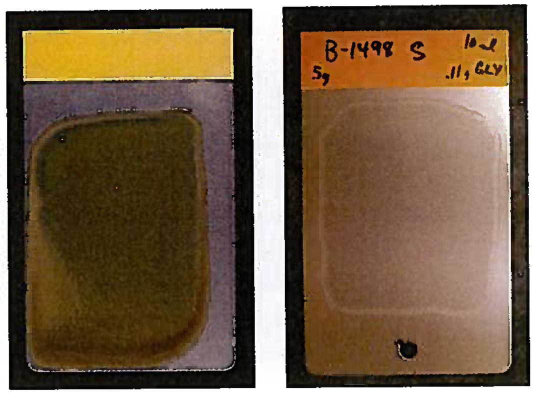

Figure 1 | **Most exopolysaccharides isolated from bacteria displayed reddish brown rust in flash rust testing *(shown on the left)*. The exopolysaccharide obtained from a specific strain showed no corrosion after being left on a carbon steel coupon for 60 days at room temperature *(shown on the right)*.** *(Courtesy of the U.S. Department of Agriculture)*

Most exopolysaccharides tested displayed reddish brown rust under the coating and on the metal surface relatively quickly after the testing was initiated *(see Figure 1)*. But fraction L from the strain 1498 (designated as 1498L) behaved differently, as shown in Figure 1. Finkenstadt says, "We saw no evidence of any corrosion from exopolysaccharide coatings prepared from this strain after 60 days at room temperature."

These experiments were conducted in the researcher's initial publication at coating thicknesses of approximately 50 microns.[3] Since then the exopolysaccharide coating has been found to be equally effective at a thickness of 50 nanometers. Finkenstadt adds, "We have now left metal coupons with the 1498L coating at this smaller thickness for over one year at ambient temperature with no sign of corrosion."

Further work was conducted using electrochemical impediance spectroscopy. Samples of the exopolysaccharides were evaluated in 5% sodium chloride and 0.5% sulfuric acid solutions. The 1498L exopolysaccharide clearly demonstrated superior performance in both of these corrosive environments.

Finkenstadt indicates that the coating prepared by this exopolysaccharide exhibits different characteristics than other corrosion inhibitors. She explains, "Most corrosion inhibitors function by forming a passive barrier that protects the metal surface. The 1498L exopolysaccharide forms an active barrier that prevents corrosion, even if the surface is scratched to expose metal to the environment."

The mechanism for how 1498L exopolysaccharide functions as a corrosion inhibitor is not known. Finkenstadt indicates that the biofilms formed by this polymer act to protect the metal surface from such corrosive species as salt and seawater in a similar manner to how they protect bacteria from their environment.

Finkenstadt speculates that this exopolysaccharide acts to stop the flow of metal ions in the corrosion process. She says, "We believe that the 1498L exopolysaccharide controls the diffusion of metal ions during the oxidation of iron metal to ferric ions. In particular, we know that the initial oxidation to ferrous ions from iron metal does occur because a black surface characteristic of ferrous ions is observed. But the conversion of ferrous to ferric ions is not observed, which means that the exopolysaccharide probably chelates both ferrous and ferric ions significantly inhibiting corrosion."

Future work will involve testing 1498L exopolysaccharide in the humidity cabinet (ASTM D1748) and salt spray (ASTM B117) test procedures, which are widely used to evaluate the efficacy of corrosion inhibitors.

Additional information can be obtained from the initial article submitted for publication[3] or by contacting Finkenstadt at **victoria.finkenstadt@ars.usda.gov.**

REFERENCES

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3. Finkenstadt, V., Cote, G. and Willett, J. (2010), "Corrosion Protection of Low-Carbon Steel using Exopolysaccharide Coatings from *Leuconostoc mesenteroides*," *Biotechnology Letters*, Submitted for publication.