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Interim Corrosion Protection with Soy-based Products Incorporating Vapor Phase Corrosion Inhibitors

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ABSTRACT

The use of oil and solvent-based products in the preparation and preservation of metal has been common practice for over one hundred years. While these products may offer good corrosion protection, they often contain hazardous ingredients and are non-degradable. Recently, the use of vegetable oils has been found to offer many similar properties to their petroleum derived counterparts. By incorporating vapor phase corrosion inhibitors (VpCI's) into soy-based products, optimal corrosion protection can be obtained yielding an environmentally friendly, biodegradable product.

INTRODUCTION

Interim corrosion protection is a necessity in the processing of metals. The length and method of this protection varies and is dependent on process, and destination of the component in production. The most common method to provide in process protection is to apply a petroleum-based rust preventative (RP), as it has historically been perceived as an inexpensive and effective method for said protection. This method can provide adequate protection, however there are numerous drawbacks. The most obvious are the inherent problems with removal, disposal, and cleaning requirements.

When metal components are shipped or packaged after being coated with a petroleum-based rust preventative, it creates another set of problems. The components themselves must be cleaned before further processing, such as painting, plating, or assembly. Additionally, the packaging used in transport of the components becomes contaminated with the excess oil, and can cause problems for disposal of the packaging. Increasing environmental regulations, and customer demands are making the use petroleum-based RP's less desirable for manufacturer's of metals and metal components.

The Canadian Autoworkers Union (CAW) has found that constant exposure to petroleum-based metalworking fluids can cause various forms of cancer including skin cancer, lung cancer, cancer of the larynx and colon cancer[1]. Recommended solutions to this problem include: lowering the exposure limit from 5 milligrams per cubic meter, to 2 milligrams per cubic meter, and replacing petroleum-based products with vegetable-based products whenever feasible. Specifically, soy-derived technologies have very low toxicity ratings, and are on the same order as table salt. The LD 50 rating for soy-derived products is 17.4 g/kg, while table salt has a rating of 17.5 g/kg.[3]

At present, alternative methods of protecting metal components include the use of water-based technologies, and vapor phase corrosion inhibited (VpCI) packaging materials for shipping and storage situations. While these technologies provide an environmentally conscious method of corrosion protection[2], they can be cost and time prohibitive for certain operations. In these cases, the manufacturer was left with no choice but to use petroleum-based corrosion protection, or simply do nothing.

Recently, a method of corrosion protection that combines the film forming and barrier properties of petroleum-based products with the environmental conscience of biodegradable technologies has been developed. This has been accomplished by combining VpCI's with soy-derived oils to formulate rust preventatives, cutting fluids, lubricating oils, and cleaning compounds. The focus of this paper will be limited to the development of rust preventatives, and cutting fluids as they relate to in process corrosion protection.

EXPERIMENTAL

In developing soy-derived products, a battery of testing was undertaken to ensure that the desired properties were achieved. These included physical properties, corrosion inhibiting properties, and cosmetic properties. The physical properties were established by using corresponding petroleum-based products as a baseline. Corrosion inhibiting capabilities were established using industry accepted testing, and the products were formulated to be cosmetically similar to their petroleum-based counterparts whenever possible.

For the protection of metal, the most important factor in product development was the capability to prevent the corrosion process from occurring. An assortment of standard tests were used to compare the new VpCI soy-based products with products that are commercially available. The testing included humidity testing, immersion testing, and a cast-iron chip test. Additionally, field trials were made to determine if laboratory results would correspond to real world performance.

Rust Protection by Metal Preservatives in the Humidity Cabinet[4]. Test method for determining rust-preventative properties of metal preservatives under high humidity. Metal specimens are treated with a rust-preventative and exposed to 48.9°C +/- 1.1°C (120°F +/- 2°F) and 95% relative humidity for a given time period in accordance with ASTM D 1748-83. All testing was done as for comparative analysis purposes, and the time period was dependent on failure mechanism.

Half Immersion Corrosion[5]. Carbon steel panels are weighed and immersed in the test solution, using DI water as control solution. The testing period was determined on the alloy used. The panels were removed after the pre-determined testing period, cleaned, and tested for weight loss.

Iron Chip Corrosion of Water Soluble Metalworking Fluids[6]. Method for evaluating the ferrous corrosion control characteristics of water-soluble metalworking fluids. In this test, class 30 gray cast iron chips are submersed in various dilutions of a water soluble (or emulsified) fluid to determine the minimum dilution that can afford corrosion protection. This testing is done in accordance with ASTM D 4627-86. A ladder study was used to determine the lowest concentration that would pass the testing requirements.

Biodegradation[7]. The biodegradability was determined in accordance with the EPA 28-day test method. The requirement states that the ratio of Biological Oxygen Demand (BOD) to Chemical Oxygen Demand (COD) must be greater than or equal to 60%.

RESULTS

Humidity Testing

The results in the humidity test varied from one test to another depending on three factors. The metal substrate, VpCI soy-derived product, and dilution in water that was used all were factors in the length of time before failure in the humidity chamber. In each case, the VpCI soy-derived products outperformed the conventional water-based and petroleum-based products. They also performed equally or better than other water-based and petroleum-based VpCI products. The results of the humidity testing can be found in tables 1-5.

Half Immersion Testing

In the half-immersion testing, the control panels show medium corrosion below the water line after 24 hours for carbon steel, and corrosion above the water line after 72 hours. The aluminum controls have oxidation below the aqueous line after 72 hours. In the same testing, the VpCI soy-derived product showed no corrosion for greater than 30 days, indicating the product has both contact and vapor phase protection capabilities. The results of the half immersion testing can found in table 6.

Cast Iron Chip Testing

The VpCI soy-derived cutting fluid passed the cast iron chip testing at a lower concentration than standard water-soluble cutting fluids, and VpCI water-soluble cutting fluids. The results of this testing can be found in table 7.

Biodegradability

The VpCI soy-derived products all are considered biodegradable. After the 28-day testing period each had a BOD/COD ratio greater than 0.6.

DISCUSSION

As seen by the testing results, VpCI soy-derived rust preventatives and lubricants can provide excellent corrosion protection, and will outperform standard petroleum-based products even in low concentrations. In each case, the VpCI soy-derived products outperformed the standard water-based and petroleum based products.

In immersion testing, there was no corrosion either in the contact phase or in the vapo phase. This indicates that the VpCI soy-derived products will provide protection in situations of direct contact and in situation where there is no direct contact through va phase protection.

For the cast iron chip testing, the VpCI soy-derived cutting fluid passed at a concentration of 1%, while most soluble oil cutting fluids require at least a 2.5% concentration to pass testing requirements. This indicates that the VpCI soy-derived cutting fluid is very resistant to flash corrosion. Additionally, the VpCI soy-derived products were formulated to have similar physical and cosmetic properties to their petroleum-based counterparts, which is important for field acceptance.

The results of field trials have also been very positive, with the biggest success being with VpCI soy-derived cutting fluids. A well-known gear manufacturer in the automotive industry is successfully using the product corporate wide in all gear cuttin applications. They have replaced soluble oil type cutting fluids, and eliminated the corrosion problem that plagued them until implementation.

CONCLUSION

Following the extensive testing, and field trials it is apparent that VpCI soy-derived products will be a viable and important method for interim corrosion prevention now in the future. These products exhibit excellent corrosion inhibiting properties both in laboratory, and real world environment. Since they are biodegradable and produced f a renewable resource, they will continue to gain in market acceptance as environment conscious products will be preferred.

REFERENCES

1. "Occupational Health and Safety Hazardous Substance – Metalworking Fluids"; www.caw.ca/whatwedo/health&safety/factsheet/hsfssubstanceno31.asp
2. Chandler, C., Paper no. 01562, Houston, TX, NACE International, 2001.
3. "Biological Safety Summary"; www.soygold.com/biodegrade_toxicity.htm
4. ASTM D 1748-83 "Standard Test Method for Rust Protection by Metal Preservatives in the Humidity Cabinet"
5. ASTM D 4627-86 "Standard Test Method for Iron Chip Corrosion for Water soluble Metalworking Fluids"
6. ASTM G 31-72 "Standard Practice for Laboratory Immersion Corrosion Testing of Metals"
7. EPA 600/4-79-020, "Methods for Chemical Analysis of Water & Waste", March 1979

Table 1
ASTM D 1748-83 on 1010 Carbon Steel

Percent (%) of Soy-derived Rust Preventative	Time before Corrosion
2.5% in water	220 hr.
5% in water	>500 hr.

Table 2
ASTM D 1748-83 on Heat Treated Carbon Steel Gears

Sample	Coating	Dilution	Hours to Failure
A	VpCI Soy-derived Cutting Fluid	5% in water	>108
B	VpCI Synthetic Water Soluble Fluid	5% in water	108
C	Soluble Oil Cutting Fluid	6% in water	<13.5
D	Control (no coating)	---------	<13.5

Table 3
ASTM D 1748-83 on 1010 Carbon Steel Panels

Sample	Coating	% in water	Hours to Failure
Control	Control (no coating)	-------	8
A	VpCI Soy-derived Cutting Fluid	5	144
B	VpCI Soluble Oil Cutting Fluid	5	144
C	Commercial Cutting Fluid	50	48

Table 4
ASTM D 1748-83 on Carbon Steel Bearings

Sample	Coating	Dilution	Hours to Failure
A	VpCI Soy-derived Rust Preventative	5% in water	>120
B	VpCI Water-Soluble Rust Preventative	10% in water	120
C	VpCI Petroleum Rust Preventative	33% in Napthenic	>120
D	VpCI Petroleum Rust Preventative	10% in Napthenic	>120
E	Commercial Rust Preventative	Undiluted	120

DNF = did not fail during the 336 hours test period

Table 5
ASTM D 1748-83 on Metal Stamped Parts (high carbon steel)

Coating	Surface Prep.	Dilution	Hours to Failure
Control 1	Methanol	----	2
Control 2	None	----	2
VpCI Soy-derived Rust Preventative	Methanol	10% in water	>192
VpCI Water-based Rust Preventative	Methanol	10% in water	24
VpCI Water-based Rust Preventative	None	10% in water	16
VpCI Soluble Oil Rust Preventative	Methanol	10% in water	12

Table 6
Half Immersion Corrosion (ASTM G 31-72)

Alloy	Time Before Corrosion (Days) Control	Time Before Corrosion (Days) VpCI Soy-derived RP
3041 Bare Al	<1	>30
1010 Carbon Steel	<1	>30

Table 7
ASTM D 4627-86 (Cast Iron Chip Test)

Percent (%) of Soy-derived Cutting Fluid (in water)	Sample 2	Sample 4
5	No corrosion	No corrosion
4	No corrosion	No corrosion
2.5	No corrosion	No corrosion
1	No corrosion	No corrosion
0.5	5% corrosion	5% corrosion
0.1	80% corrosion	80% corrosion