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INFLUENCE OF INHIBITOR'S CHEMISTRY AND STRUCTURE ON ALUMINUM CORROSION IN MWF

Metalworking Fluids

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INTRODUCTION

The efficiency of stain/corrosion inhibitors would be dominated by its molecular chemistry, structure and feasibility of charge transfer to metal surface. For metalworking fluids (MWFs) application, the inhibitor chemistry mainly relies on various carboxylate, phosphate and silicate inhibitor systems. The choice of those inhibitors depends on the type of metal alloys, composition of the alloy, metalworking fluid composition, pH and temperature, etc. Along this line, this present paper highlights the effect of different inhibitor chemistries on anti-staining performance especially on various aluminum alloys. For this investigation, diverse phosphates, silicates and complex esters were evaluated as the stain inhibitor systems in semi-synthetic metalworking fluids. For the performance evaluation their inhibition efficiency was assessed by both aluminum alloy metal compatibility test and inductively coupled plasma atomic emission spectroscopy (ICP-AES).

EXPERIMENT & RESULTS

Approximately 80% of inhibitors are composed of organic compounds known as mixed inhibitors. Efficiency of the inhibitor is strongly influenced by the ability to adsorb on metal surface through electrostatic attraction ultimately to form protective film. The adsorption capability is dominated by chemistry/structure of the inhibitor, charge on the metal surface and type of the electrolyte.

Most organic inhibitors possess one or more polar functional groups, also known as anchoring head group mostly consisting of group V or VI elements with non-bonded electron pairs such as nitrogen, phosphorus, oxygen and sulfur. In terms of those elements, last year we reported some useful structure-property-performance relationship of various amine and phosphate inhibitor systems in semi-synthetic metalworking fluids. Hence, in this presentation, we extent our research focus to silicate and complex ester chemistry to cover most of existing organic inhibitor chemistries. Inhibition efficiency of different functional groups is primarily dictated by the ability of electron transfer to or from metal surface and generally follows the order of P> S> N> O. Thus, following this order, phosphates and sulfates (or sulfonates) are regarded as the most effective functional groups. But those phosphorus or sulfur containing compounds have inherent shortcomings of functioning as nutrients for microbials in aqueous system eventually causing microbial proliferation.

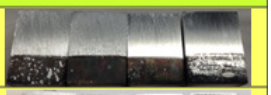
Alternative choice to prevent this microbial growth issue while keeping the high inhibition efficiency could be silicate compounds. Contrary to phosphorus or sulfur, silicon element doesn't possess non-bonded electron pair, but its labile atomic orbitals effectively interact with metal oxide layer to create substantially strong bond formation through chemisorption. However, low hydrocarbyl silicates are known to have tendency to form insoluble three dimensional networks known as gelling especially in high water content system.

Along this line, in the present paper we report the most notable results of our recent research on the effect of the different inhibitor chemistry on anti-staining performance of a specific semi-synthetic MWF on various aluminum alloys; 319, 356, 6061 and 7075.

For this study, different organic inhibitor systems were investigated including tetraethyl orthosilicate (TEOS), polyethylene glycol mono-octadecenyl ether phosphate and complex ester. For aluminum alloy compatibility test, first the semi-synthetic MWF containing each inhibitor system was diluted at 10% in DI water,

respectively. Then four different aluminum alloys were immersed in the diluted solution over 24 hours. The post test solution was retrieved and run on ICP. Inhibition efficiency of those inhibitors was compared, and the major results are summarized in the following table.

Table 1, Anti-staining performance of different inhibitor systems

Inhibitors	Al (ppm)	pH (10% dil)	Al Staining Test
Baseline	123	9.87	
0.8% TEOS	1.0	9.59	
2.0% Phosphate	3.2	9.51	
6.0% Complex Ester	10	9.48	

As indicated in the table, both aluminum staining test and ICP results consistently showed the efficiency trend in the following order:

0.8% Silicate (TEOS) > 2.0% Phosphate > 6.0% Complex ester >> Baseline

It would be noteworthy that ethyl silicate (TEOS) revealed the excellent performance followed by phosphate, complex ester and baseline. Inhibitor type didn't seem to affect pH much although minor discrepancies were found in less than 5% variation range. For this study, TEOS was added at the minimum level (0.8%) which was predetermined by separate experiments as summarized in Table 2.

Table 2, Anti-staining performance of different inhibitor systems

Baseline	TEOS 0.2%	TEOS 0.4%	TEOS 0.8%
			

Interestingly, ICP result indicated that dissolved boron level increased with increase in TEOS. It should be noted that no detectable gelation occurred during the entire course of the experiments. However, there was slight increase in turbidity as TEOS content increased after 24 hours at 120°F (Figure 1).

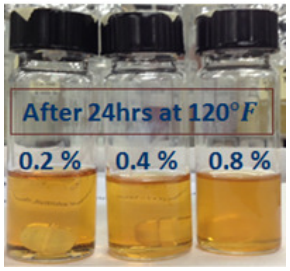


Figure 1. Turbidity increase with TEOS increase

CONCLUSION

In conclusion, the effect of the different inhibitor chemistries on anti-staining performance of a semi-synthetic MWF was investigated especially on aluminum alloys. Organic silicate-based inhibitor system (TEOS)

revealed superior efficiency to phosphate and complex ester as well. Inhibitor type didn't have significant influence on pH for this specific study. Increase of TEOS appeared to cause slight destabilization of the MWF concentrate at 120°F, but there was no indication of gelation or precipitation detected.

REFERENCES

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KEYWORDS

Corrosion/staining inhibitors, Silicates, Phosphates, Complex Esters, Aluminum alloys