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Influence of Elastomeric Seal Contact Surface Chemistry on Interface Integrity in Biofouling-Prone Systems

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ABSTRACT

The scientific hypothesis of this work is that modulation of the properties of hard materials to exhibit abrasion-resistant and low-energy surfaces will extend the functional lifetimes of elastomeric seals pressed against them in abrasive underwater systems. There are many biomedical, food handling, industrial, and environmental circumstances in which elastomeric materials pressed against more rigid seal plates are expected to continuously prevent aqueous fluid leakage, even in the presence of potentially mineralized and abrasive biological fouling.

To date, this investigation has monitored the influence of an intrinsically abrasion resistant, low critical surface tension epoxy-silicone co-polymer coating on dry and underwater friction/wear behavior of a cyclically driven, surface-characterized synthetic-rubber sealant in contact with both coated and uncoated control seal plates. Preliminary results indicate excellent coating adhesion as well as some difference in wear depth and area dimensions between coated and uncoated seal plates. Some bidirectional material transfer was observed. These conclusions will be further validated by mass loss analysis, scanning electron microscopy, and digital stereoscopic image analysis, as well as two or more of the following techniques; profilometry colorimetry, contact angle/critical surface tension (CA/CST) determination, multiple attenuated internal reflection (MAIR-IR) spectroscopy, x-ray fluorescence (XRF), the latter three all being used also in initial material characterization.

Further investigation of sealant/plate combinations will include testing on a bidirectional, linear apparatus under varying load conditions. See photograph beside rotary device. The contacting seal & coating surfaces will be examined for variable wear rates and changes in surface properties with increasing cycle time, per techniques listed above, and a correlation proposed for the relationship of seal integrity to seal plate surface properties. Results to date suggest mechanical, ecological, and economic advantages of this sealant/coating seal interface in a wide range of applications.

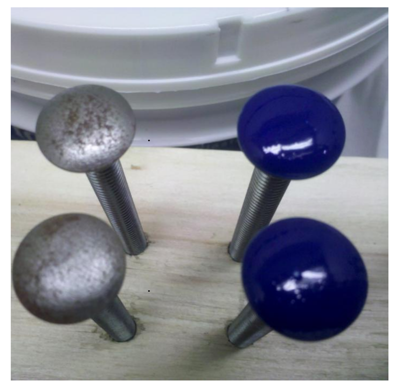
INTRODUCTION & INSPIRATION

Little prior work has been done to elucidate the relationship of seal plate surface properties to the friction and wear of representative sealant formulations during sliding contacts of these articulating materials, or to examine the secondary influence of mineralized debris creating “third body” abrasion at the contacting interfaces.

This project was inspired by a current NYPA problem with seal interface integrity on the main head gates within their facilities. These gates control the flow of water through the intake draft tubes into the turbine chamber.

MATERIALS & METHODS

Experimental material acquisition for this initial investigation was accomplished via industrial and academic collaboration between the NYPA, Sealing Devices Inc., Plastic Maritime Corporation, and the SUNY University at Buffalo Graduate School.



How different is Wearlon®?

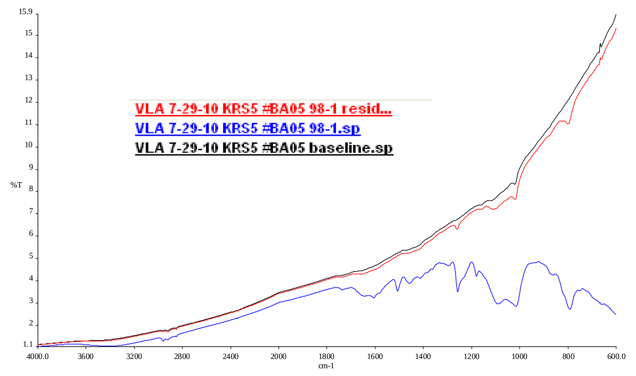
STICK ^	Epoxy Alkyd	P.U.	
NON-STICK	WEARLON	PVF	Silicone PTFE
	HARD	>	SOFT

High-tensile neoprene extrusion was obtained from Sealing Devices Inc (see photograph) and characterized by CA/CST, XRF, and stereoscopic imaging. See *Pilot Surface Analysis Summary* and *XRF Results Summary* tables, respectively. Next, the bulk extrusion was sectioned at 1.5 cm, bulbs removed from the tails, and bulbs notched for mounting in testing apparatus.

WEARLON® 2020.98 coating (parts A and B) was supplied by Plastic Maritime Corporation. This formulation and various other representative WEARLON® versions were also supplied fully cured on aluminum coupons for investigatory reasons. (CA/CST results shown) MAIR-IR spectroscopic analyses also showed spectral differences between coatings, but only a representative 2020.98 spectral series is shown below.

The experimental substrate for coating, ¼” carriage bolt heads had to be carefully selected for its testability in a pre-existing, available rotary testing device (see photograph). Preparation of these bolts consisted of inserting each one into a handheld power drill then pressing the bolt head’s top surface onto a belt sander in an oscillating motion so as to remove all of the zinc coating (see photograph). CA/CST and XRF characterization results are shown on the tables below. The prepared bolt head surfaces were also documented stereoscopically.

MAIR-IR 2020.98-1 Series (baseline, sample, residue)



Pilot Surface Analysis Summary

Surface	CST (dynes/cm)
WEARLON 2020.98-1	24.5
WEARLON 2020.98-2	23.1
WEARLON PM2020-98-1	22.6
WEARLON PM2020-98-2	23.2
WEARLON 711/2020.98	37.5
WEARLON 4545.76	25.5
WEARLON Super F3M	25.8
WEARLON Super F6M	25.9
Steel NEW/RAW	37.9
Steel RUSTED	45.7
Steel WEARLON-1	27
Steel WEARLON-2	27.9
Elastomer (SD)	25.9

Using the PMMA (Plexiglas®) rotary apparatus photographed below, four cyclically driven elastomer samples were tested against one vertically loaded bolt head, the simulated seal plate, in each trial. Consequently, at any number of revolutions, the seal plate experiences four times as much “action” as any one of the four elastomer samples. The pilot experiment included 8 total trials, the first 2 being shortened for investigatory purposes. Loading of the bolt head/seal plate was not varied but the environmental condition of the trial was. Of the 4 dry and 4 wet trials, 2 of each condition tested raw/uncoated seal plates while the other 2 tested WEARLON® 2020.98 coated seal plates. Refer to the *Pilot Wear Testing Summary* table below.

RESULTS

Preliminary results (stereoscopic image analysis) indicate excellent coating adhesion as well as some difference in wear depth and area dimensions between coated and uncoated seal plates. See stereoscopic image matrix and legend below. Some bidirectional material transfer was observed, but primarily elastomer was transferred to the seal plate surface. Elastomer wear area dimensions appear to correlate proportionally with number of revolutions, positively with CST, and also depend heavily on the steel condition, either raw or coated. The initial seal plate contact point on the elastomer is marked by a relatively deeper and darker colored wear area. It appears as though the most seal material was transferred to the raw, uncoated seal plate samples due to rust increasing the roughness within and around the articulatory interface.

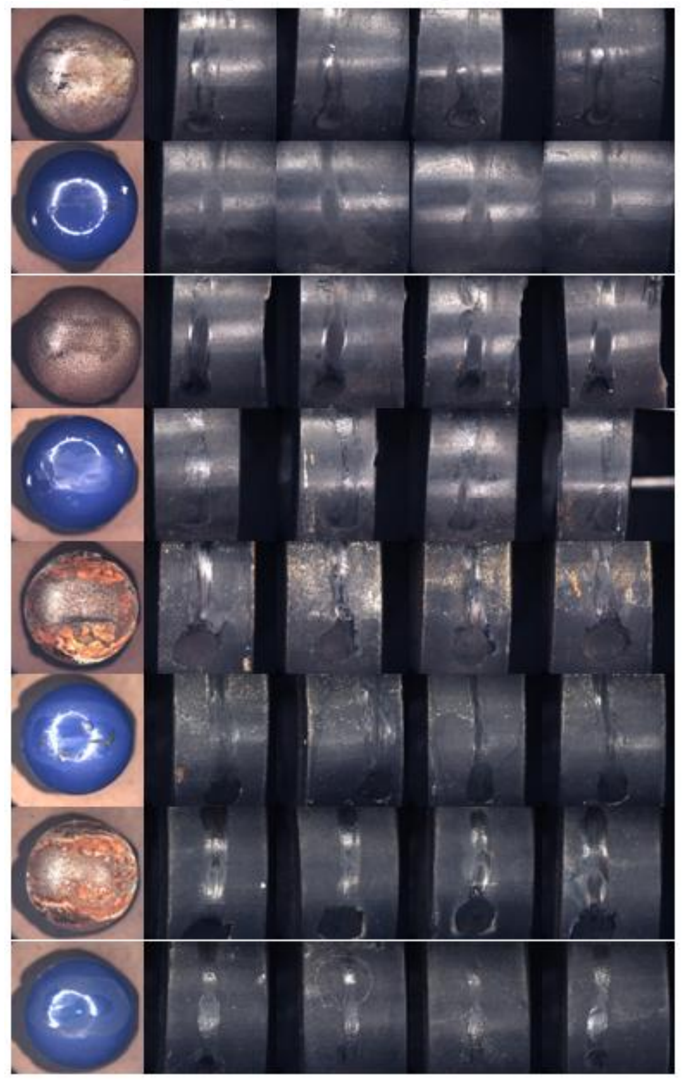
These observations will be further validated by manual area and depth measurements and CA/CST determination, XRF analysis, or MAIR-IR spectroscopy.

XRF Results Summary

Action	Result
Standardization/Calibration	PASS
Zinc-Removed Analysis	Carbon Steel, 100% Fe
Stainless Steel Standard	316 Steel, 17.5% Cr, 1.5% Mn, 68% Fe, 10.5% Ni, 0.5% Cu, 2% Mo
Elastomer Surface Analysis	264 ppm Fe, 20294 ppm Zn, 1356 ppm Ti(+/-)
Elastomer Bulk Analysis	148 ppm Fe, 19930 ppm Zn, 1152 ppm Ti(+/-)
Zinc-Coated Analysis	NO MATCH, 27.5% Fe, 72.5% Zn

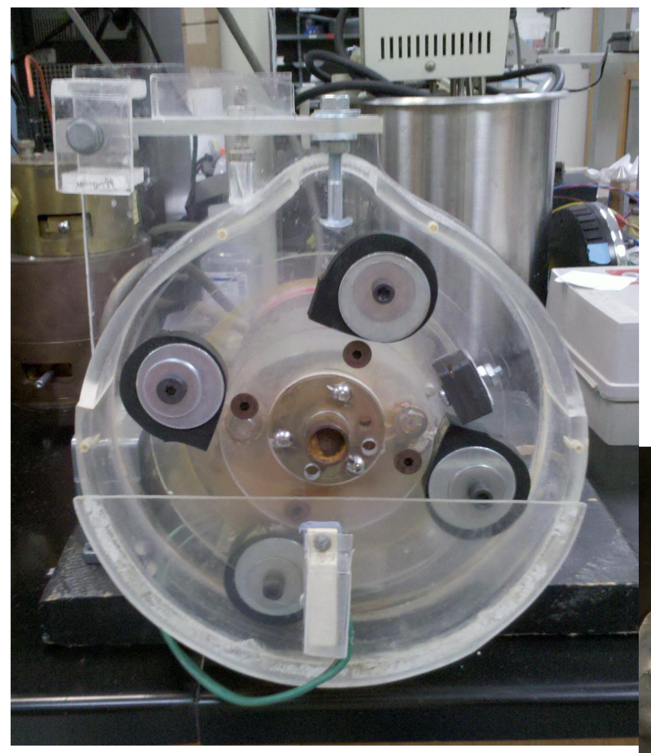
Pilot Wear Testing SUMMARY

Trial #	Env.	Steel Cond.	Revolutions
1	Dry	Raw	150000
2	Dry	WEARLON	180000
3	Dry	Raw	300000
4	Dry	WEARLON	300000
5	Wet	Raw	300000
6	Wet	WEARLON	300000
7	Wet	Raw	300000
8	Wet	WEARLON	300000



DISCUSSION/CONCLUSION

WEARLON® 2020.98 was of particular interest for NYPA intake gate application due to its dual-emulsion fabrication and functionality with epoxy resin for direct adhesion to and modification of the rusted steel substrate, and silicone polymer for the surface characteristics of interest. Possibilities for mechanically, ecologically, and/or economically advantageous use of the WEARLON® 2020.98 coating system now appear to extend beyond foul-release and drag reduction to friction and wear reduction for applications where rigid seal plates are in frictional contact with elastomeric seals. Specific potential applications range from small syringes and implantable pumps used to deliver biological substances for patients to components of diagnostic biomedical equipment, pasteurized milk product transfer lines in dairies, and large sliding head gates in hydroelectric power plants. This WEARLON® coating effectively utilizes a range of chemistries that provide integrated solutions to customer problems concerning asset protection and productivity improvement.



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