Industrial Wash Process Six Sigma

Staticstical Paint Pretreatment Verification

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***Abstract* — The team is working with Parker Hannifin Accumulator and Cooler Division to perform statistical analysis and experimentation on the client's parts wash system to identify variation and sources of defects. Parker Hannifin has a large, planned capital expenditure, an automated paint robot, being installed on the paint line in April 2021. To validate this expenditure, the client needs the parts wash station, which precedes the paint line, to contribute a minimal amount of variation and defects to the post-fabrication process, so that statistical analysis can be done on the paint line without other factors being variable. The parts wash process has not yet been subject to statistical process controls by the client and has instead been operating under specifications recommended by the parts wash manufacturer and the manufacturers of the different chemicals used. To ensure the best manufacturing practices are being met, it is important to the client to have this part of the manufacturing process statistically evaluated using design of experiments and continuous process improvement.**

Keywords- SPC; Concentration; Exposure; Xbar-R; I-MR

I. INTRODUCTION

Paint pretreatment is essential in industrial applications. Painting the metal substrate without pretreating the surface would not enable the hydraulic accumulators to withstand the required environmental conditions experienced in the field. Hydraulic accumulators are highly pressurized vessels that are often essential safety features and must have a highly reliable surface integrity.

Paint pretreatment is the process by which a surface is prepared for paint by chemically cleaning and etching the surface using a system of sprayers. High production volumes dictate that the pretreatment process must remain efficient and should be highly reliable and repeatable. The pretreatment system under observation uses a four-stage method to treat the metal substrate. The first stage of the wash bath is an industrial detergent that strips the metal substrate of pollutants and oils that have been collected during production and assembly. The second stage of the wash bath rinses the metal substrate with DI water and removes any remaining detergent. The third stage of the wash bath bathes the metal substrate in iron phosphate, which is an acid. The acid etches the metal substrate by creating microscopic scratches on the surface. The etching process allows the paint to grab onto the metal substrate and increases paint adhesion. The fourth stage of the wash bath is a DI rinse stage to removes excess iron phosphate not used in the etching process. No scrubbing is performed during the pretreatment process, but instead relies totally on chemical reactions facilitated by spray jets.

II. METHODS

All testing done in this project involved the use of test plates, otherwise known as coupons. These coupons are 4x8x0.032-inch sheets of cold-rolled steel. These test plates simulated the role of the normal Parker Hannifin accumulators, but without the risk of product failure. The sample size of plates used per experiment was determined through the use of Minitab and the team's knowledge of Six Sigma processes. To maximize efficiency and minimize the amount of line spacing needed, the team used the setup displayed in Figure 1 during experimentation.

Figure 1: *Test plate setup used throughout the entirety of the project. This minimized line occupancy and maximized time and efficiency.*

Two experiments were conducted to analyze and confirm the effects of changing concentration and over-exposure to the wash bath and factory atmosphere. Experiment #1 focused on changing the concentrations of the 752 detergent and 758 phosphate [1]. Prior to the experiment, the 752 detergent was kept between 2% and 3% and the 758 phosphate was kept between 3% and 4%. To measure the effectiveness of concentration changes, four "quadrants" were developed that changed the concentration to above or below their current operating standards. After the plates were run through the wash bath and oven, adhesion testing, dry film thickness testing, salt pray testing, and phosphate weight coating testing was performed to test the usability of the plates. Experiment #2 focused on the over-exposure of the test plates to the wash bath and factory conditions. Currently, Parker experiences frequent line stoppages that leave accumulators sitting on the line for an extended period. This experiment verified the negative consequences these stoppages have to the quality of their product.

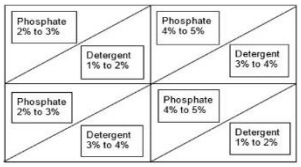

Figure 2: *Chosen concentrations for each "quadrant." 2x2 experimentation allowed the team to explore all possible concentration combinations.*

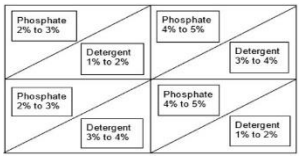

Figure 3: *"Quadrants" for Experiment #2. Long Exposure means the line stopped for approximately one hour and short exposure means continuous line motion.*

III. Results

A. Results from 2 x 2 DOE #1

Results of the 2 x 2 DOE are displayed in 3 forms. Phosphate coating weight, paint adhesion, and salt spray resistance. Data for each of these categories can be seen below:

EXPERIMENT #1							
Quadrant 1				Quadrant 2			
Plate ID	Weight (g/m2)	Plate ID (Replication)	Weight (g/m2)	Plate ID	Weight (mg/ft2)	Plate ID (Replication)	Weight (g/m2)
AVG	0.78	AVG	0.76	AVG	0.69	AVG	0.61
Quadrant 3				Quadrant 4			
Plate ID	Weight (g/m2)	Plate ID (Replication)	Weight (g/m2)	Plate ID	Weight (g/m2)	Plate ID (Replication)	Weight (g/m2)
AVG	1.35	AVG	1.27	AVG	0.58	AVG	1.61

Figure 4: *Phosphate coating weights as determined by independent laboratory.*

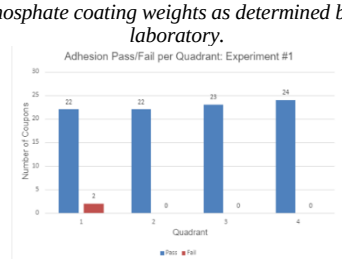

Figure 5: *Paint adhesion passes are in blue and failures are in red.*

RESULTS:

SAMPLE ID	120 Hours	240 Hours	D1654 Method 1
C19 Q1	Very Slight Red Corrosion & Some Blisters	Slight Red Corrosion & Some Blisters	6
C24R Q1	Very Slight Red Corrosion & Some Blisters	Sight Red Corrosion & Some Blisters	7
C13 Q2	Moderate Red Corrosion & Some Blisters	Moderate Red Corrosion & Some Blisters	5
C22R Q2	Intermittent Red Corrosion & Some Blisters	Intermittent Red Corrosion & Some Blisters	5
C18 Q3	Moderate Red Corrosion & Blisters	Moderate Red Corrosion & Some Blisters	5
C24R Q3	Moderate Red Corrosion & Blisters	Moderate Red Corrosion & Some Blisters	2
C14R Q4	Very Slight Red Corrosion & Some Blisters	Slight Red Corrosion & Some Blisters	5
C19 Q4	Very Slight Red Corrosion & Some Blisters	Slight Red Corrosion & Some Blisters	3

Figure 6: *240-hour salt fog exposure results.*

B. Results from 2 x 2 DOE #2

Results of the 2 x 2 DOE are displayed in 3 forms. Phosphate coating weight, paint adhesion, and salt spray resistance. Data for each of these categories can be seen below:

Experiment #2							
Quadrant 1				Quadrant 2			
Plate ID	Weight (g/m2)	Plate ID (Replication)	Weight (g/m2)	Plate ID	Weight (mg/ft2)	Plate ID (Replication)	Weight (g/m2)
B1 AVG	0.88	B1 AVG	0.69	B1 AVG	0.79	B1 AVG	0.61
B2 AVG	0.83	B2 AVG	0.67	B2 AVG	0.85	B2 AVG	0.61
B3 AVG	1.41	B3 AVG	1.34	B3 AVG	0.82	B3 AVG	0.64
B4 AVG	0.9	B4 AVG	0.89	B4 AVG	0.85	B4 AVG	0.65
Quadrant 3				Quadrant 4			
Plate ID	Weight (g/m2)	Plate ID (Replication)	Weight (g/m2)	Plate ID	Weight (mg/ft2)	Plate ID (Replication)	Weight (g/m2)
B1 AVG	0.78	B1 AVG	0.6	B1 AVG	0.88	B1 AVG	0.73
B2 AVG	0.82	B2 AVG	0.66	B2 AVG	0.83	B2 AVG	0.77
B3 AVG	1.41	B3 AVG	1.39	B3 AVG	0.54	B3 AVG	0.59
B4 AVG	0.94	B4 AVG	0.8	B4 AVG	0.79	B4 AVG	0.52

Figure 7: *Phosphate coating weights as determined by independent laboratory.*

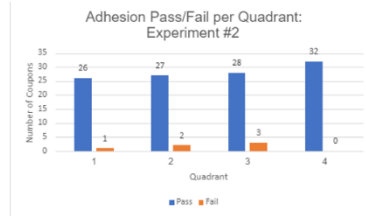

Figure 8: *Paint adhesion passes are in blue and failures are in red.*

SAMPLE ID	ASTM D1564 (Method 1)		
C7 B1 Q1	0	C8 B1 Q3	0
C7 B2 Q1	0	C9 B2 Q3	0
C9 B3 Q1	0	C7 B3 Q3	0
C9 B4 Q1	2	C5 B4 Q3	0
C9R B1 Q1	0	C8R B1 Q3	0
C9R B2 Q1	1	C7R B2 Q3	0
C9R B3 Q1	0	C9R B3 Q3	0
C7R B4 Q1	4	C9R B4 Q3	0
C8 B1 Q2	0	C8 B1 Q4	0
C6 B2 Q2	0	C5 B2 Q4	0
C9 B3 Q2	0	C9 B3 Q4	0
C9 B4 Q2	0	C5 B4 Q4	0
C5R B1 Q2	0	C6R B1 Q4	0
CR9 B2 Q2	0	C5R B2 Q4	0
C9R B3 Q2	0	C8R B3 Q4	0
C5R B4 Q2	0	C7R B4 Q4	0

Figure 9: *240-hour salt fog exposure results.*

IV. Discussion

As seen from the results, the experimental data showed a wide range of phosphate data for both experiments, statistically demonstrating the effectiveness of adjusting the iron phosphate concentrations. Paint adhesion was consistent across all experimental procedure, indicating paint adhesion is less rigorous than a 240-hour salt spray test.

V. Conclusion

The experiments conducted by the team yielded valuable data and root causes that the Parker team will continue to analyze in the near as they implement their new robotic paint system. From Experiment #1, the team was able to determine that the current operational concentrations are sufficient, but there may be underlying issues with the nozzles, pipes, detergent effectiveness, and frequent line stoppages. Experiment #2 further verified the detrimental effects line stoppages have on the parts. From the data collected, even line stoppages as short as ten minutes can have negative effects on the test plates/accumulators. Parker Hannifin will conduct experiments on the underlying conditions found by the senior design team in the near future.

Acknowledgment

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References

[1] "GF PHOS 758 - Iron Phosphate - #1 Supplier Distributor Best Price." Chemicals Global Industrial Chemical Suppliers, 30 Aug. 2019, chemicalsglobal.com/shop/gf-phos-758-iron_phosphate/.