OPTIMIZING THE DRY FILM LUBRICANT PERFORMANCE ON STEEL

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Abstract: Appendix A of MIL-PRF-46010 and MIL-PRF-46147 recommends pretreatments for various structural metals. However, the use of zinc or manganese phosphate on steel as a pretreatment for dry film lubricant can prevent various problems. The variability of steel hardness, abrasive size and hardness, phosphate type, coating weight, crystal size and coverage, and thickness of dry film lubricant will all affect the expected lubricity and corrosion resistance of the applied coating. A series of case histories are used to demonstrate the issues.

Background: Optimizing your dry film lubricant coating for lubricity and corrosion resistance on steel hardware requires paying attention to the details. These details include knowing the hardness of the steel as carbon steels are much softer than steels that are heat treated or carburized/nitrided (surface hardened). The size of the abrasive and the hardness of the abrasive will affect the blast profile on the different hardened steel surfaces. The phosphate type may be iron, zinc or manganese and the coating weights may vary significantly within each type of phosphate coating. Iron phosphate coating weights can range from a minimum of 0.35 to in excess of 1.0 g/m^2. Zinc phosphate coatings can vary from 1.5 to more than 30 g/m^2. Manganese phosphate coatings can range from 10 to 40 g/m^2. The real variable with all phosphate coatings is crystal size and coverage. This variable can result in phosphate coatings with complete coverage compared to areas that may be completely bare in certain areas while adjacent areas may contain very large crystals (See Figure 2 below). The final variable is the actual thickness of the dry film lubricant which could range from 0.2 mil minimum as stated by the specification to as much as 2.0 mils if you are trying to cover a heavy phosphate coating.

Case History #1. Two sets of panels (three each) were supplied for testing in the ASTM B117 5% salt spray with two different dry film lubricants. Along with the panels for salt spray testing there were included three panels as blasted and three panels that were blasted and manganese phosphate coated. Testing of the blasted panels with an electronic blast profile gage showed a blast profile of 0.7 mil. Testing the blasted and manganese phosphate coated panels with a magnetic thickness tester showed the phosphate thickness to average 0.7 mil. Testing of the blasted, phosphate and dry lubed panels with the same magnetic thickness tester showed a total dry film thickness of 0.7 mil. Salt spray testing of the two dry lubed sets (one Teflon based and the other molybdenum disulfide based) for 100 hours showed the exact same results on both sets. One panel each had no rust spots, one panel each had one rust spot and one panel each had two rust spots after the testing. Since the failure criteria for 5% salt spray testing is three rust spots less than 1.0 millimeter in diameter, both sets of panels passed the minimum requirement. However, the actual thickness of the dry film lubricant that was tested given the measured blast profile and the manganese coating was essentially unknown. Dry lubed parts with a minimal coating thickness over manganese phosphate do not perform well in the outdoor environment as is shown in Figure 1 on the next page. The photo shows the results of four years outdoor exposure

of a part that had a 0.5 mil dry lube coating applied over a heavy manganese coating. A number of years ago, a chart was generated that attempted to correlate
the coating weight of a phosphate coating with thicknesses measured with a magnetic thickness tester (See Figure 6). The chart shows that a minimum thickness of the manganese phosphate coating would be approximately 0.5 mil. Thus, a combined thickness of 0.5 mil for phosphate and dry lube results in a poorly performing coating for outdoor exposure. (It is noted that good epoxy primers on steel need to be around one mil in thickness over a light phosphate coating to achieve any significant corrosion resistance.)

Figure 1. Outdoor exposure of 0.5 mil dry film lubricant over heavy manganese phosphate after 4 years .

Case History #2. Three panels that were phosphate coated and three panels that were phosphate coated with an application of dry film lubricant were evaluated for corrosion resistance. Thickness testing of the phosphate coating with a magnetic thickness tester showed the coating was 1.5 mils thick. Thickness testing of the phosphate coating with the dry film lubricant showed the combined thickness to be 1.5 mils. Prior to salt spray testing, the surfaces of the panels were photographed on the scanning electron microscope (SEM). The results of the 5% salt spray testing showed the phosphate and dry lubed panels were significantly rusted after only 24 hours of corrosion testing. An examination of the SEM photos was invaluable in determining the reason for the poor performance in salt spray. The phosphate crystals shown in Figure 2 were very large with incomplete coverage of the steel surface. This also explained the elevated thickness reading on the bare phosphate. Thus, the corrosion testing was essentially being performed with dry lube over bare steel. Figure 3 shows the surface after the dry film lubricant was applied and appears to have just filled in the low areas of the phosphated surface (The dry lube did not even cover the phosphate crystals). Since the coverage of the phosphate coating may not be obvious to the naked eye, the results of the corrosion testing lets you know there is a problem with the overall process. (The preproduction approval process required by the phosphate coating specification has provided these case histories which enabled these process variations to become known.) It is also noted that the phosphate specification requires a coating weight determination which does not insure coverage or thickness indications of the actual applied coating.

Figure 2. Photo shows large crystals with voids in the phosphate coating.

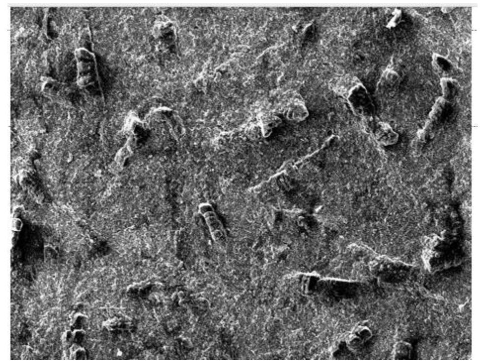

Figure 3. Photo shows dry lube in the valleys of the phosphate crystals.

Case History #3. A 9mm magazine coated with heavy phosphate and oil was having a problem with jamming during sand and dust test firing. Particles of sand were adhering to the oiled surface and being embedded into the heavy phosphate as the cartridges were moving through the magazine. As the sand particle wedged itself between the cartridge and the magazine, the jamming would occur. It was suggested that a light phosphate (Figure 4) and dry lube be used in lieu of the previous requirement. Subsequent sand and dust testing showed a significant improvement in the resistance to jamming. A light phosphate with good coverage at 4 g/m^2 and a total film thickness of 0.7-0.8 mil of a solvent-based dry lube resulted in a finish that exceeded 2500 hours of 5% salt spray testing as shown in Figure 5. This change is now the standard finish on the 9mm magazine. It is known that the solvent-based products generally show

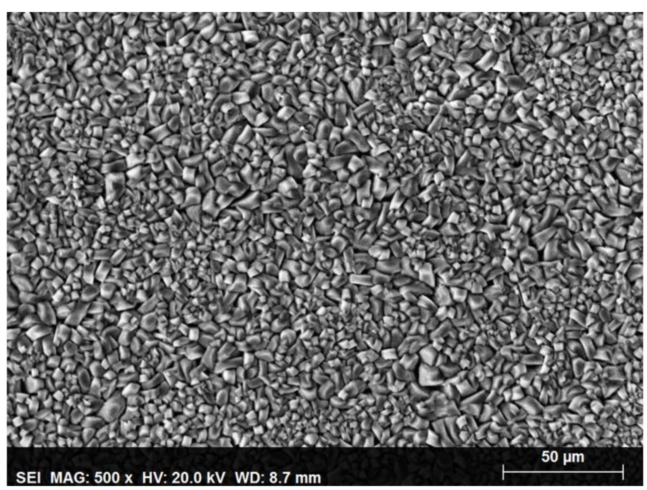

Figure 4. Photo shows fine grained calcium modified zinc phosphate (4 g/m^2) on carburized steel magazine for 9 mm pistol.

better performance in corrosion testing than do the water-based products. For example, testing at Sandstrom Products shows that the water-based 099 product provided around 1000 hours to failure while the solvent-based LC300 provided about 3000 hours of corrosion performance in the 5% salt spray test. Thus, if corrosion resistance is an important aspect of performance, a solvent-based product should be considered. Solvent-based products are available under the SAE AS5272 specification.

Figure 5. Photo of dry lubed magazine after 2500 hours salt spray testing. Coating defects on the center specimen were evident after 24 hours and did not increase in size.

Case History #4. As previously mentioned, a chart that compares coating weight of phosphate with thickness was generated using a magnetic thickness tester and is shown in Figure 4. It should be noted that the thickness readings were taken with very light pressure on the phosphate crystals. Medium pressure to heavy pressure resulted in a decreasing thickness until a zero reading was attained due to the ease at which the phosphate crystals can be crushed. The ease with which the phosphate crystals can be crushed is one of the reasons for the coating weight requirement in the MIL-DTL-16232 specification rather than using a thickness requirement. It must also be noted that the coating weight can be misleading because it does not indicate the type of coverage that may exist as shown in Case History #2. While the dry lube specification requires the coating thickness range of 0.2 to 0.5 mil to qualify the material in the can, the dry lube thickness applied to the hardware must be optimized to enhance the end item performance. As a result, process control for the hardware should consider dry lube thicknesses up to 1.0 mil or more to enhance corrosion performance in the field. Light phosphate coatings mentioned in Case History #3 have a coating weight range from 1.5 to 5.0 grams/meter^2 and are thus too thin to be accurately measured. The thickness of these coatings is determined after the paint or other supplemental coating has been applied and cured as abrasive blasting is not required for these coatings.

Case History #5. Even though there is no military specification for a Teflon based dry film lubricant, it is necessary to include its wear load and corrosion properties in this discussion. Teflon is capable of loads in the 2000-3000 psi line contact pressure range compared to molybdenum disulfide's 50,000 psi line contact pressure loads. If Teflon products will meet the load carrying performance for the particular application, it needs to be considered as an option depending on the duration of the loading requirement. The corrosion resistance of Sandstrom's Poxylube 887 product is capable in excess of 1000 hours of salt spray performance. One of the nice things about Teflon products is that they are capable of being colored if necessary and still provide lubricity. Graphite is capable of 20,000 psi line contact pressure loading but it corrodes all iron-based materials. Therefore, graphite products are not an option for use on steel substrates if any kind of corrosion resistance is to be expected. This is also why molybdenum disulfide based "black dry lubes" are not functionally possible. The only current way to "blacken" molybdenum disulfide is by using graphite or some other material like carbon black. Both these approaches destroy the corrosion resistance of the molybdenum disulfide based products.

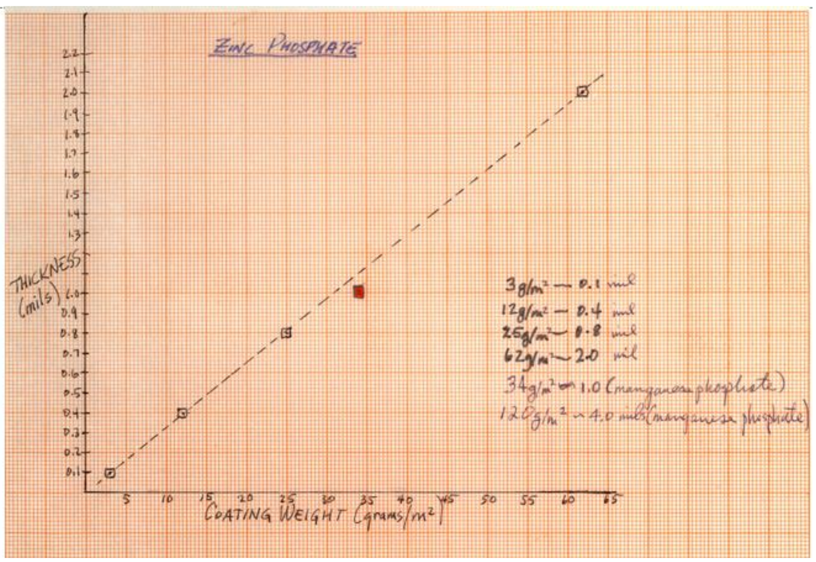

Figure 6. Chart shows the relationship of phosphate coating weight with respect to thickness.

Conclusions: It is concluded that:

1. The total finish system must be considered when evaluating the performance of coated hardware. Knowing the blast profile and phosphate thickness/coverage are essential to optimizing the finish. The thickness requirement in the dry lube specification was used to qualify the product in the can, it does not ensure a quality coating. The surface preparation and proper application technique does that.

2. The coverage of the phosphate coating is essential to good performance of the dry lube finish. Proper cleaning and blasting are essential to getting uniform coverage of the phosphate coating.

3. The proper application of a phosphate pretreatment and inhibited dry film lubricant on steel is an excellent application to prevent collection of abrasive residues on operating surfaces in various operating environments. It also provides significant corrosion protection and wear/load performance.

4. The chart (Figure 6) can be used to assist in optimizing the thickness of the dry film lubricant for the best wear and corrosion resistance of the hardware.

5. Other applications of dry film lubricants, like the Teflon based products, can also benefit from these optimization processes for coating steel substrates.

6. For all structural metals, graphite is not an option as it can corrode all the metals it comes in contact with. Most galvanic corrosion series show graphite as a cathode with respect to all metals except platinum and gold.

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