Utilizing Water Contact Angle Measurements to Predict Surface Preparedness for Dye Penetrant Application

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ABSTRACT

Reliably predicting dye penetrant wettability for fluorescent crack inspections hinges on understanding surface cleanliness prior to penetrant application. Validating the efficacy of a parts washer using water contact angle measurements is a non-destructive method for quantifying surface cleanliness and can ensure complete wetting of the penetrant across a substrate. For this study, surface energies of washed and un-washed aluminum parts were characterized via water contact angle measurements and subsequently correlated with dye penetrant wettability. Penetrant was applied to the surface via cotton swab and allowed to wet the surface for 15 minutes before obtaining a visual inspection of wetting pattern; a smooth, uniform distribution of penetrant indicated sufficient wettability while a blotchy, non-uniform distribution indicated insufficient wettability. Freshly washed samples displayed low contact angles and yielded acceptable penetrant wettability while unwashed parts displayed high contact angles and displayed unacceptable penetrant wettability. Water contact angle can be used to determine surface readiness prior to penetrant application.

Keywords: surface energy, water contact angle, contact angle, fluorescent dye penetrant, surface cleaning, wettability

INTRODUCTION

Aluminum wheel houses were analyzed via water contact angle and penetrant wettability assessments. Analyses were performed on surfaces before and after wiping with various cleaners to investigate the efficacy of each cleaner using surface energy as well as on parts before and after a parts wash. Areas of interest on the part include the stress roll, machined well and inner wall.

Water contact angle analysis: Contact angle measurements provide an estimation of surface energy that can be related to surface cleanliness. This type of analysis is sensitive to the top few molecular layers of a surface [1]. Gilpin [2] shows that a high-energy molecule—water—with a large polar component can be used as a direct estimation of total surface energy. A clean surface with high energy will display a low contact angle: the surface tension of the water droplet will be overcome by the energy of the surface and spread out (i.e. the water molecules are more attracted to the high-energy surface than themselves). Conversely, a surface that is contaminated will display low surface energy and produce a high contact angle: the water molecules are more attracted to themselves than the surface, and the droplet will bead up.

EXPERIMENTAL

Water contact angle measurements were taken on surfaces of interest before and after wiping with one of three cleaners: 1) customer specified parts washer detergent (FPI) 2) isopropanol (IPA) and 3) DS-108 (a common aerospace industry solvent, a blend of XXX and YYY). Wipe method involved saturating a clean KimTech wipe with desired cleaner and applying to the surface unidirectionally, followed immediately by a unidirectional dry wipe with a clean KimTech wipe. Cleaned surfaces were allowed to dry for 10 minutes before performing measurements. Surface wettability tests were performed using customer specified fluorescent penetrant. A Qq-tip was dipped in penetrant and lightly applied to analysis surface. Penetrant was allowed to wet test surface for 15 minutes, to allow penetrant to wet completely. “Good” and “bad” wettability results were defined by the shape and uniformity of the applied penetrant. A smooth, uniform distribution of the penetrant indicates “good” wettability while a blotchy, non-uniform distribution of the penetrant indicates “bad” wettability (see Figure 1).

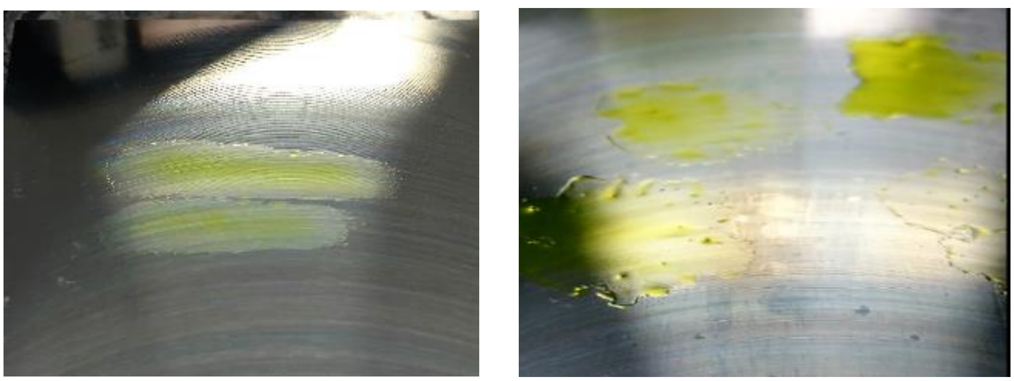

Figure 1: Images above display both modes of penetrant wettability. The left image displays “good” wettability and is defined by the uniform distribution of the yellow penetrant across the surface. The image on the right displays “bad” wettability and is defined by the non-uniform, blotchy distribution of the yellow penetrant across the surface.

RESULTS

Penetrant wettability assessments: As received and FPI cleaned surfaces yield a wide range of contact angles (~60-110°) and display insufficient (bad) penetrant wettability. Surfaces cleaned with DS-108 display contact angles ~40-65° and display sufficient (good) penetrant wettability. Cleaning with IPA yields contact angles ~60-70˚ and displays mixed mode penetrant wettability.

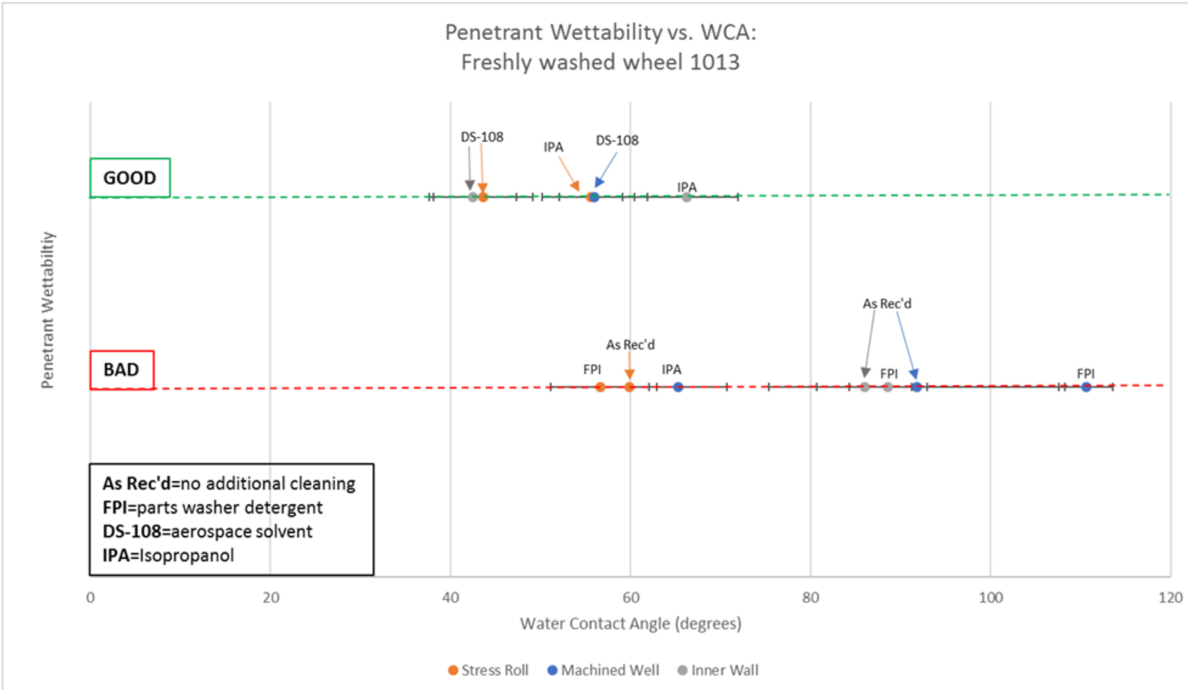

Figure 2: Contact angle measurements obtained on three areas of interest (stress roll, machined well and inner wall) post cleaning. Measurements are an average of 10 data points per series. Error bars represent +/- standard deviation, penetrant wettability test is represented as a binary test (good or bad).

Analysis of washed and unwashed parts from factory line: Exposing aluminum wheels to parts washer yields an average contact angle of ~50°. Data obtained from penetrant wettability tests suggest this would most likely yield sufficient (good) penetrant wettability. Wheels that were not parts washed yielded contact angles ~70° and displayed a high standard deviation consistent with a non-uniform, unclean aluminum surface. Previously obtained data suggests these surfaces would most likely yield insufficient (bad) penetrant wettability.

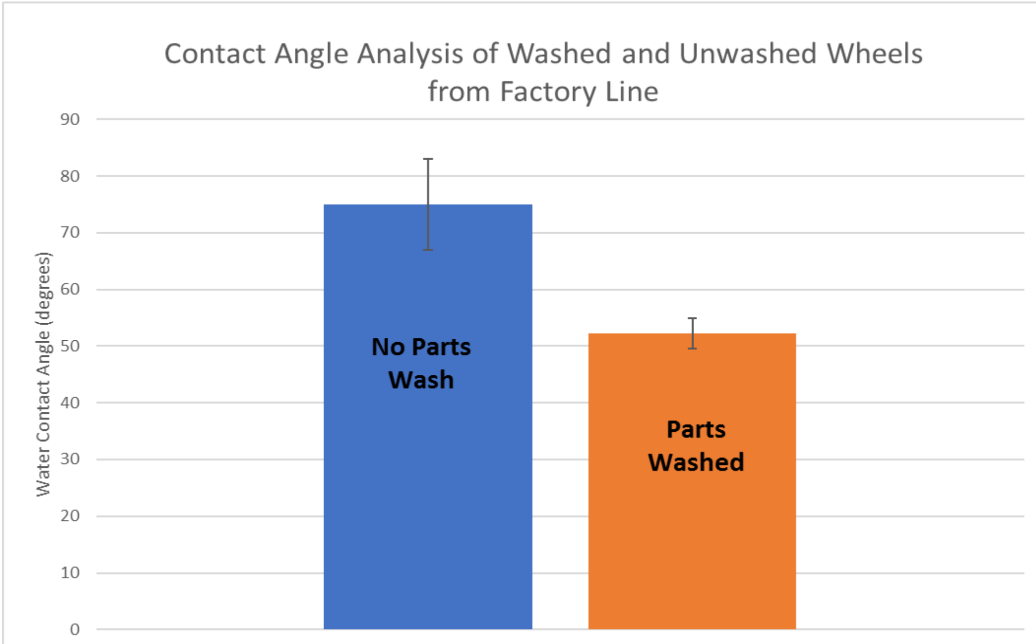

Figure 3: Contact angle measurements obtained from washed and unwashed parts directly from factory line. Measurements are an average of 10 data points per series. Error bars represent +/- standard deviation in the spread of contact angle measurements.

CONCLUSIONS

Water contact angle measurements directly relate to fluorescent dye penetrant wettability and the ranges established in this study can be used to predict surface preparedness prior to penetrant application. For this study, water contact angles <50˚ are indicative of sufficient (good) penetrant wettability, 50-70˚ yields marginal penetrant wettability and >70˚ indicative of insufficient (bad) penetrant wettability. Unwashed aluminum wheel houses display contact angles ranging ~75° and will most likely yield marginal or insufficient penetrant wettability while parts washed wheels yielding average contact angles ~50° will most likely yield sufficient (good) penetrant wettability.

REFERENCES

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