The Surface Analyst:
Gage Repeatability & Reproducibility

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INTRODUCTION

Gage Repeatability and Reproducibility (GR&R) is a valued measure of a gage's appropriateness for use in a specific application. Although this value is assigned to the gage itself, it is imperative to carry out the Gage R&R study on samples that represent the range of what is to be expected from the process being evaluated. Additionally, the measurement/output provided by the gage should be considered in the design of such a study. Because the Surface Analyst is novel device, or gage, little is known about the best way to conduct a Gage R&R evaluation in a meaningful way. This device obtains information about the surface energy of a material by ballistically depositing a microliter water drop on the material's surface. Through image analysis, the contact angle of that water drop is determined and reported to the user. This test is not destructive but taking a measurement in the same location multiple times is not as straightforward as with other gages.

This report details the result of a Gage R&R evaluation of the Surface Analyst for use on grit blast titanium exposed to different surface treatments following grit blasting.

EXPERIMENTAL

Grit blast titanium represents a surface of interest to be measured by the Surface Analyst. Following grit blasting with 240 grit alumina, ten 1" x 3" titanium coupons were rinsed with isopropanol to remove excess grit remaining on surface. Four coupons were set aside to be measured in the as-grit blasted state. Three coupons were placed in a plasma reactor and exposed to a five-minute Argon plasma (100 watts), then set aside to age, undisturbed, in the lab atmosphere.

Approximately four hours following the first plasma treatment, three more coupons were exposed to the same plasma treatment conditions.

Immediately following this final treatment, all samples were used for a Gage R&R study of the Brighton Science Surface Analyst, taking into account within part variation.

Evaluation was conducted using 10 parts, 2 appraisers, and 2 trials. For each trial, 5 measurements were made by each appraiser to get an indication of the range of contact angles over the coupon surface.

Gage R&R was calculated by Average and Range Method of Measurement System Analysis, with and without considering within part variation, based upon 5.15 sigma [1].

RESULTS AND DISCUSSION

Average and Range Method

Table 1 details the variation in the contact angle measurements that is attributable to the equipment, appraiser, and part. The percentages of total variation are shown.

Based on guidelines set forth in the Measurement Systems Analysis reference manual, the Gage R&R for the Surface Analyst indicate the SA "may be acceptable based on importance of application, cost of gage, cost of repairs, etc."

Measurement Unit Analysis		% Total Variation
Equipment Variation (EV)	5.2	19.5
Appraiser Variation (AV)	1.8	6.6
R&R	5.5	20.6
Part Variation (PV)	26.3	97.9
Total Variation (TV)	26.9	

***Table 1**. Results of Gage R&R study of titanium coupons*

The R&R of the Surface Analyst is comprised of both the EV (equipment variation) and the AV (appraiser variation). Because the Surface Analyst measurements are determined by image analysis software and not reliant on an operator's eyes and judgment, the AV is quite low. Information obtained using a Surface Analyst is not influenced by using multiple appraisers.

This is illustrated further by the Part by Appraiser graph and the Appraiser Comparison graph in Figures 1 and 2, respectively.

Average contact angles for each part are shown for each appraiser, along with standard deviations. In most cases, the averages and standard deviations show significant overlap.

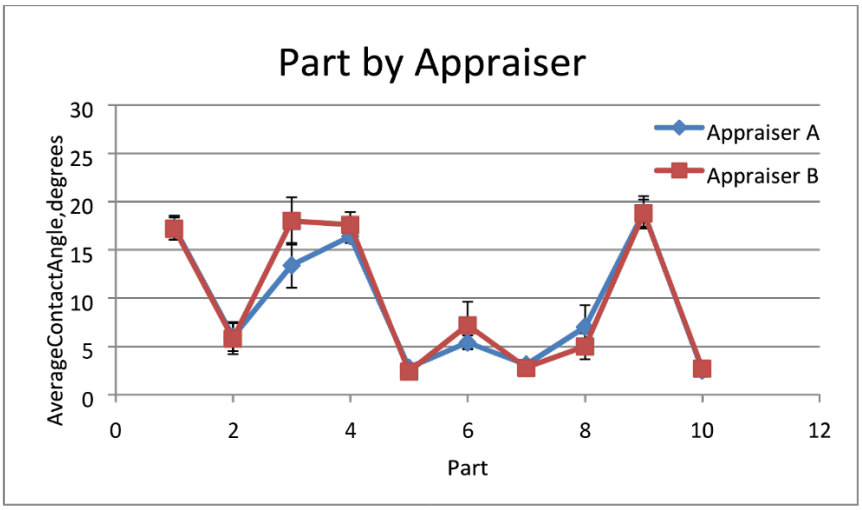

Figure 1. *Contact angle of each part, by appraiser. Standard deviations are also shown for each part.*

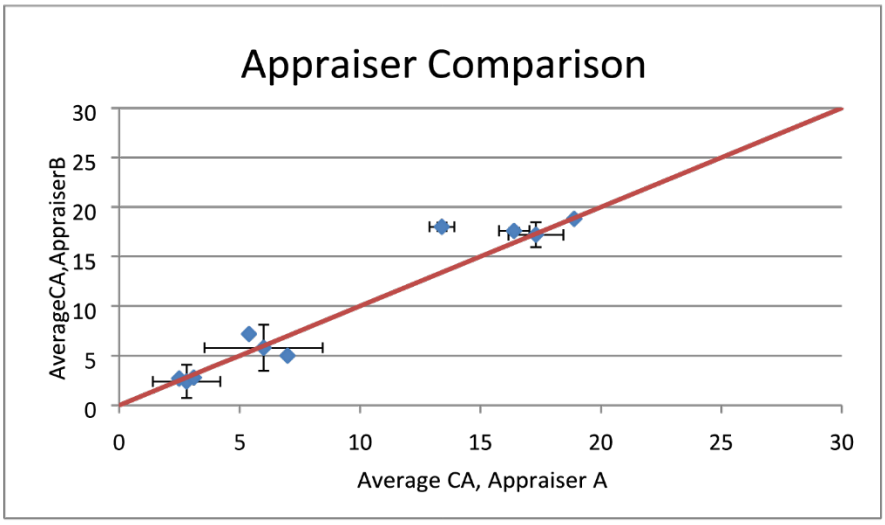

Figure 2. *Appraiser Comparison chart showing Appraiser B vs. Appraiser A. Red line is a 45-degree line, which represents the ideal relationship between appraisers.*

A majority of the TV (total variation) in this study is due to the PV (part variation). Parts were chosen to reflect realistic cleanliness levels. Titanium surfaces that have been grit blasted, freshly plasma treated, and/or plasma treated and aged several hours may all be acceptable surfaces to adhesively bond— separate evaluations would be needed to determine this—but the Surface Analyst was successfully able to discriminate between these treatment levels. Because of the range of contact angles measured on the surfaces of different treatment, the PV was high and made up a large percentage of the total variation.

AVERAGE AND RANGE METHOD INCLUDING WITHIN PART VARIATION

Sufficient data was obtained to allow analysis including WIV (within-part variation). WIV was of interest because of the nature of the Surface Analyst evaluation. The Surface Analyst places a microliter drop of water on a surface to make its measurement. In this study, each coupon was measured a total of 20 times. While the Surface Analyst measurement is not destructive by any means, it is quite difficult to measure the same exact area multiple times. Because of this difficulty, every measurement made on the titanium coupon surfaces was made on previously unmeasured material. Even though these coupons were small, each one may exhibit a slightly different level of cleanliness/treatment over its surface, and it was important to take into account the variation that may be present.

Obtaining all 20 measurements on each Ti coupon was made easier by placing the coupon to be measured between the feet of the Surface Analyst, using two extra coupons (not included in study) as shims to maintain appropriate spacing (Fig. 3)—the spacing is extremely important in allowing the Surface Analyst to make an accurate measurement. Using the two extra coupons alongside the coupon of interest allowed multiple measurements to be made on untouched portions of the coupon being evaluated.

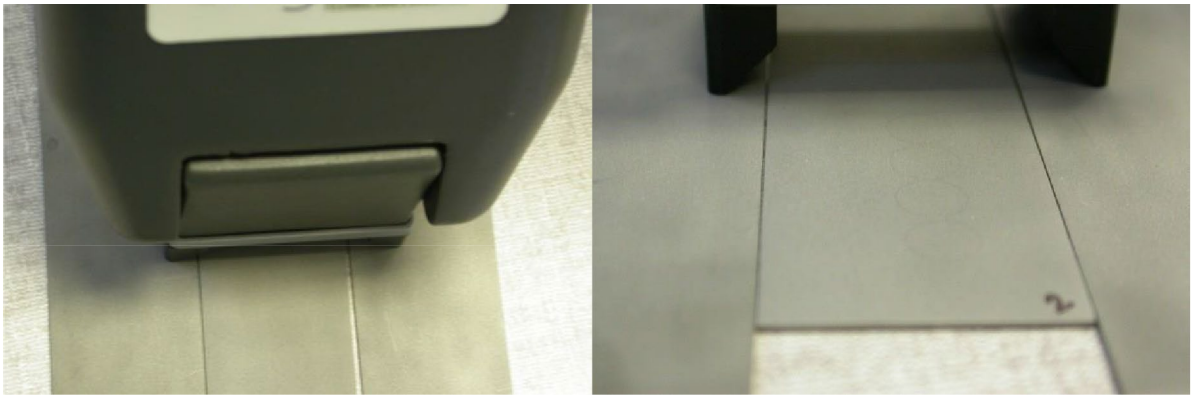

Figure 3. *Images illustrating how two additional coupons were used to control the spacing between the Surface Analyst and the coupon to be measured.*

The results obtained when considering the WIV were not dramatically different from those not considering WIV. Table 2 shows the R&R value is slightly decreased, however the overall result of the SA being “acceptable based on importance of application, cost of gage, cost of repairs, etc.” remains the same.

Measurement Unit Analysis		% Total Variation
Equipment Variation (EV)	5.7	20.4
Appraiser Variation (AV)	1.4	5.1
R&R	5.9	21.0
Part Variation (PV)	26.7	95.7
Within-Part Variation (WIV)	5.5	19.8
Total Variation (TV)	27.9	

Table 2. *Results of Gage R&R study, including within part variation, of titanium coupons*

CONCLUSIONS

When evaluating titanium coupons with a variety of surface treatments (grit blasting, plasma treating), the Surface Analyst yields an acceptable Gage R&R result of 20.4%. Accounting for within part variation increased this slightly to 21.0%, however the acceptability of the gage was unchanged.

These values are subject to change based on the quality of surfaces evaluated. Any future evaluation of Surface Analyst Gage R&R should include the entire range of surfaces the SA would be tasked with differentiating.