Improving the Accuracy of Adhesion Testing Results

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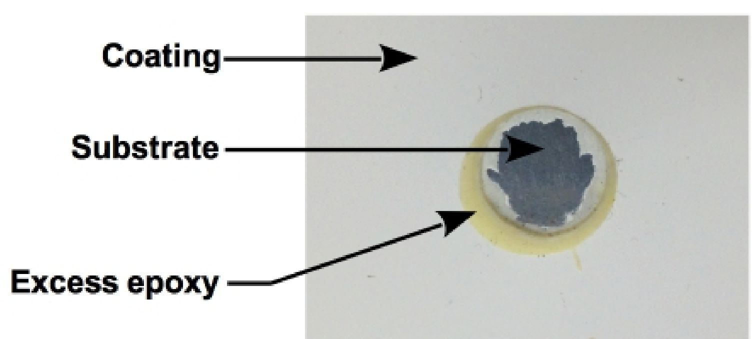
Adhesion testing has become a very popular way to quantify the strength of many different paints and coatings. Two of the most popular methods for investigating adhesion strength are the qualitative cross hatch tape test method and the quantitative pull-off adhesion test method. While ASTM D3359: Standard Test Method for Measuring Adhesion by Tape Test has largely remained the same over the last 50 years, the instruments used to perform pull-off tensile strength calculations have become smaller and increasing portable. Manufacturers of these instruments are now including advanced features, such as visual verification of standards compliance and software analysis packages. Even with all of these advances, instrument manufacturers seem to have overlooked a glaring problem at the core of the tensile strength calculation. By taking the steps necessary to improve the results of pull-off adhesion tests, the same technology can be used to drastically improve the results from more qualitative methods, such as the cross hatch tape test method mentioned above.

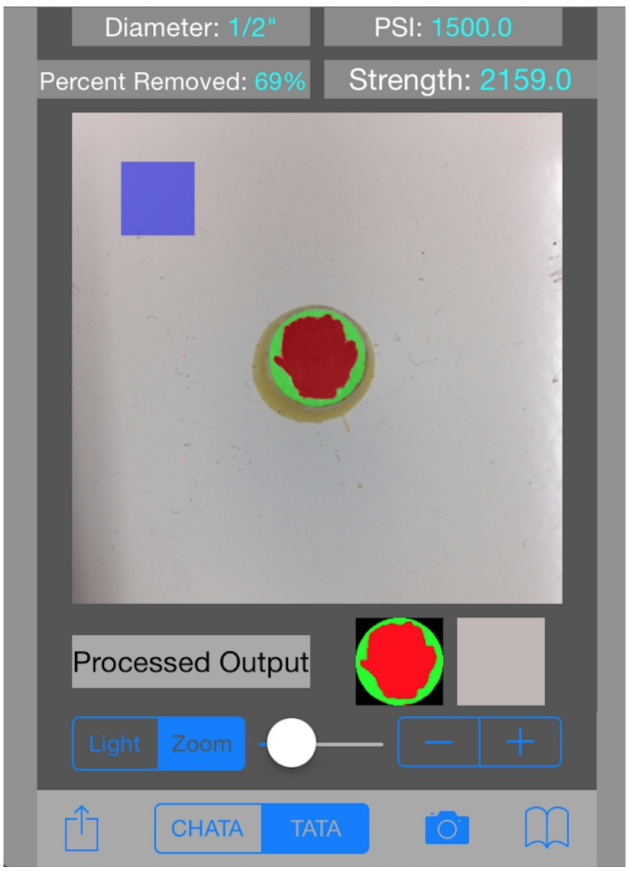
All portable pull-off adhesion testers operate in a similar manner. First, a loading fixture or pull stub is bonded to the coating using a strong glue or two-part epoxy. A force is then applied to the stub, normal to the surface, until the pull stub is pulled from the surface. At this point, the adhesion testing instrument displays a value which is supposed to represent the tensile strength of the coating. This value is calculated by taking the force that was applied to the stub and dividing it by the contact area between the between the stub and the coating. The main difference between the different portable adhesion testing instruments is the type of force applied to the stub: pneumatic, hydraulic, or mechanical.

The problem with the approach described above is that the calculation assumes that the force acts on the entire contact area between the stub and the coating. Anyone who has performed pull-off tensile testing would admit that partial pulls are very common and in fact, it is rare that the area pulled from the surface is an exact match to the contact area of the stub. This might happen for a number of reasons, including small bubbles in the epoxy bonding the stub to the surface, substrate flexing or even improper surface preparation of the coated substrate or pull stub. So how does this discrepancy affect the adhesion testing result? To investigate this question consider the following image of a real-world pull off adhesion test:



Most technicians performing pull-off adhesion testing would consider the test above a 'good' test. As a matter of fact, in the last round robin session administered by ASTM to develop precision and bias data for D4541, there were so many partial pulls that a pull test was only thrown out if less than 50% of the coating was removed under the stub. The adhesion testing instruments that are on the market today all assume that the entire area within the excess epoxy circle above was pulled, and that is the area used to generate the tensile strength value.

One problem with trying to use the actual pulled area rather than the contact area of the pull stub is the amorphous shape of the actual pulled area. It would be very difficult to accurately estimate the area pulled by visual means alone and without the aid of a camera and computer program. Fortunately, today many people carry a camera and computer in their pockets in the form of a smartphone. A patent-pending smartphone application will soon be available from SEMicro Division in Rockville, Maryland to accurately calculate the area pulled and the corresponding tensile strength of the coating based on the results obtained by commercially-available tensile testing instruments. To illustrate the utility of this system, examine the sample smartphone screenshot below:

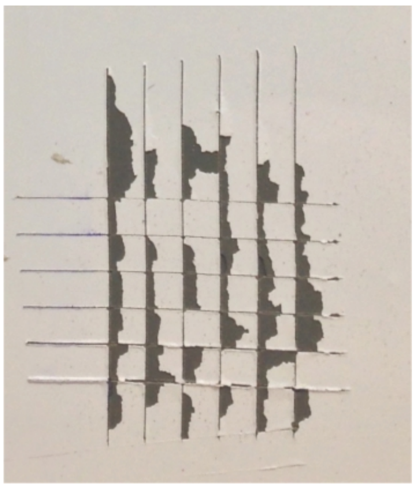


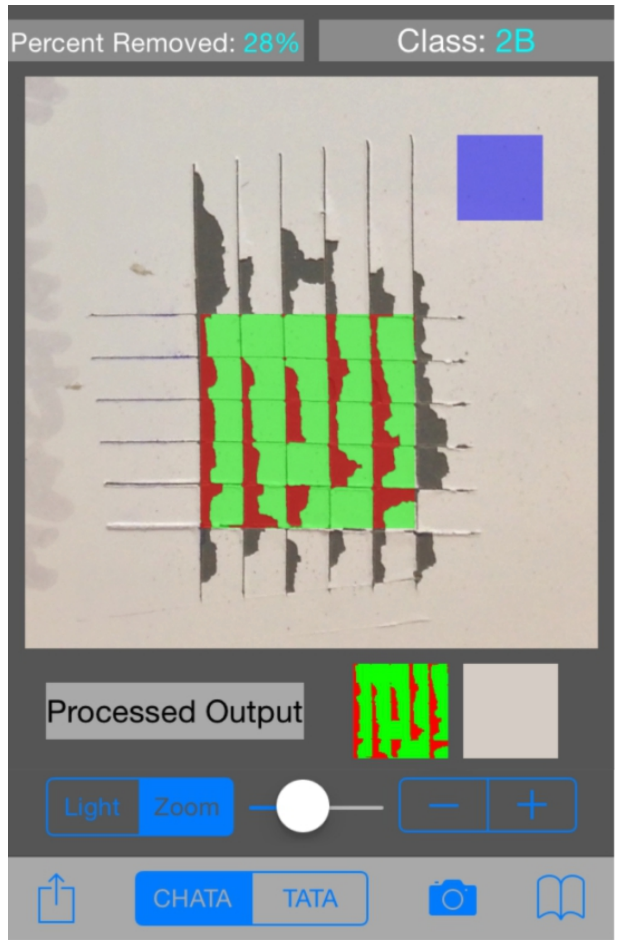
As you can see, using the smartphone's camera and an application the user can properly calculate the tensile strength of their coating using the actual area pulled rather than some ideal, perfect world case. After using the app to obtain an image via the smartphone's camera, the user would then input such parameters such as the diameter of the pull stub and the value returned by the adhesion tester to obtain the true tensile strength of the coating.

The area in blue in the image to the left can be moved so that it represents an unblemished sample area of the topcoat. This helps the app to distinguish between the different coating layers in the system. The area in red represents the area that was actually pulled and the area in green that surrounds the pulled area represents the difference between the actual and assumed areas.

The bottom line is that although the adhesion tester returned a value of 1500.0 psi in the example above, the actual tensile strength of the coating was 2159.0 psi. Thus, the coating is actually **43.9% stronger** than reported by the instrument! Since many pull tests are less than the assumed area, those adhesion test results are significantly lower than the actual strength of the coating. So, if you need to show that a coating is adhering to some *minimum* value, you are doing yourself a disservice if you do not take the actual pulled area into account at the completion of your adhesion test. But how can this technology be used to improve the results obtained by the cross hatch tape test method?

The cross hatch tape test method, also known as ASTM D3359, is a simpler, more qualitative means of classifying a coating's adhesion. In essence, a multi-toothed blade is used to score parallel lines through a coating to the substrate. The same blade is used to score the coating again but at 90 degrees to the first set of lines to produce a cross-hatched pattern. A section of specialty tape is then applied to the hatched area and subsequently pulled from the coating to remove any loose paint. The hatched area is then examined and compared to a set of images to determine the classification rating of the coating. The problem with this method is that if some amount of coating is removed from the substrate after the test it can be difficult to properly estimate the percentage removed and the resulting classification rating. This is because whole squares may not be removed from the grid and there may be some amorphous shape to quantify. To illustrate this, consider the following images:





Without the use of software, it would be very difficult to estimate the percentage of coating removed from the image above. However, using a smartphone and a special application, the area removed can be automatically calculated and discovered to be 28%, making the classification rating of this coating a 2B. Also, since the test site has been digitized in order to calculate the amount of coating removed, it is easy to share electronically with interested parties.

In summary, adhesion testing is a popular way to assess how well a coating was applied and if it meets the specifications set by the client. Using traditional adhesion testing techniques alone frequently results in inaccurate tensile strength values, especially considering that many pull-off adhesion tests are partial pulls. In extreme cases, this could lead to the coating being rejected and may even result in a very costly stripping and repainting of the surface. However, using the smartphone application described in this article, this discrepancy can be greatly reduced to produce consistently accurate adhesion testing data, even using older instruments. As the technology becomes more accepted by industry, perhaps a NIST reference standard could be developed to verify that the application is performing as advertised, giving interested parties even more confidence in the results. For more information about this technology, contact me via email at r.hester@semicro.org.