Monitoring Passivation on Stainless Steel with Open Circuit Potential Technology

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ABSTRACT

Passivation of stainless steel parts is of crucial importance in order to maintain its corrosion protection properties. Most specifically, heat affected zones on welded stainless steel are vulnerable areas that require specific care and should be thoroughly tested for passivation in order to avoid corrosion issues. The optimization of the passivation on stainless steel parts depends largely on our knowledge of the passivation process itself and the methods used to test the manufactured parts. A suitable test method is instrumental in validating proper passivation of parts for various industries such as food & beverage, pharmaceutical and other industries using stainless steel components for their specific needs. Several existing methods are currently available and are well known to most manufacturers, but do they really meet their specific needs?

Over time, other methods have been developed to meet the growing needs of manufacturers. Particular attention will be given in this document to the Open Circuit Potential technology and the added value of this new test method that offers flexibility, a clear economic advantage and accuracy that was previously unattainable.

PROBLEM STATEMENT

Often microscopic cells are present on the surface of the delivered work piece, but cannot be located and detected visually prior to shipment. These later spread and become visible, creating a phenomenon known as pitting and corrosion. That is why it is important for a manufacturer to ensure that the work piece is properly passivated before it is put in service. On site repair and refurbishment is costly for the manufacturer and the need exists for a clear diagnostic tool capable of monitoring the state of the passivation before it leaves the shop.

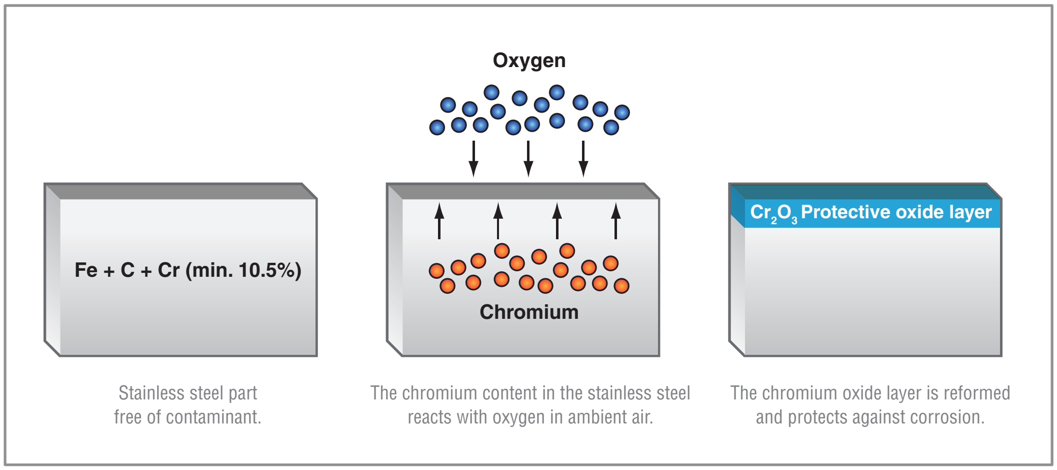
PASSIVATION

Stainless steel is an alloy that contains iron and at least 10.5% chromium. Other elements such as nickel, molybdenum, and many more may also be present depending on the grade of stainless steel. Stainless steel gets its amazing corrosion protection properties from the presence of chromium in the alloy. The chromium present reacts with oxygen to form a thin chromium oxide layer on the surface of the workpiece, thus preventing the reaction of iron with oxygen which forms iron oxide: rust. The thin chromium oxide layer acts as a barrier between the iron rich bulk alloy and the oxygen rich ambient air.

To passivate, the surface of stainless steel must be completely free of contaminants. Heat tint from welding as an example is a major contaminant that must be removed from the surface, not only for aesthetic reasons, but specifically to allow the stainless steel to passivate itself.

The passivation process begins immediately after the contaminants are completely removed from the surface of the material. The chromium content in stainless steel at the surface of the material then reacts with oxygen in ambient air to form a passive layer of chromium oxide on the surface of stainless steel. It takes between 24 to 48 hours to achieve a uniform and stable passive layer.

PASSIVATION PROCESS



The chromium oxide layer can be damaged by:

- Thermal treatments such as welding
- Mechanical abrasion
- Galvanic corrosion
- Strong acids

Several methods are available for restoring thermally damaged (from welding) stainless steel:

Grinding and polishing

Grinding the welds off completely removes the heat tint. However, there might be traces of free iron left behind which can cause pitting and corrosion. To ensure that this free iron is removed, a post chemical treatment with an acidic product is required. The situation is different for mirror finishes where the corrosion resistance of the stainless steel parts are greatly enhanced due to the uniformity of the material itself after the polishing process. The drawback of this method is that it is labour intensive and will alter the surface fininsh.

Sand blasting

Sand blasting will remove the heat tint, but will embed a plethora of other contaminants into the stainless steel, which could hinder and limit the self passivation of material. This method is not considered ideal for repairing damaged stainless steel.

Pickling pastes and gels

Pickling pastes and gels will remove the heat tint and every other inorganic contaminant from stainless steel parts. However, these pastes and gels usually contain mixtures of nitric and hydrofluoric acids. Nitric acid vapours are very harmful to the human respiratory system and hydrofluoric acid will cause severe damage to the skin. Not only are the pickling pastes and gels very toxic to human beings, but they also alter the surface of stainless steel.

Electrochemical cleaning and polishing

Electrochemical cleaning and polishing is by far the safest and most efficient method of removing heat tint and other contaminants from stainless steel surfaces. Electrochemical polishing removes more iron and nickel, leaving the surface rich in chrome. Walter offers a weld cleaning and polishing system known as SURFOX which will remove heat tint from surfaces at a speed of 3 to 5 feet per minute. This system uses food grade acids and electricity to remove the heat tint. SURFOX is certified ASTM A967-05/A380* for passivation.

* ASTM A380 Standard provides definitions and describes best practices for cleaning, descaling and passivation of Stainless Steel Parts, Equipment and Systems. ASTM A967 Standard provides tests with acceptance criteria to demonstrate that the passivation procedures have been successful.

As per ASTM International Standards; “passivation testing is the process by which stainless steel will spontaneously form a chemically inactive surface when exposed to air or other oxygen containing environments. Passivation testing involves the removal of exogenous iron or iron compounds from the surface of the stainless steel, by means of a chemical dissolution, most typically with an acid solution that will remove the surface contamination but will not significantly affect the stainless steel itself.”

EXISTING PASSIVATION TEST METHODS

Any steel or iron that comes in contact with stainless steel is a potential source of contamination. Tools such as grinding wheels and wire brushes previously used on steel or iron parts are susceptible to transfer iron to stainless steel surfaces. One of the most difficult sources of iron to avoid is the atmosphere itself. Industrial areas have a surprising amount of iron in the air. This iron falls onto exposed items, including previously cleaned stainless steel parts. To ensure proper passivation of stainless steel components, the surface must be free of contaminants such as free iron. Test methods exist to determine the presence of free iron on stainless steel surfaces.

Stainless steel manufacturers need to select a test method which fulfills all of their needs. One important selection criteria is how quickly the test can generate results; quicker is normally better. The accessibility and the ability to perform the test on site are also important considerations. The fact that most of the known tests will damage and stain the stainless steel parts also reduces the range of solutions offered to manufacturers.

The following tests will detect free-iron on parts and will provide pass or fail results:

Water immersion test

This test may seem attractive at first sight since water is often easily accessible. However, it may take several hours before being able to see any results. Not to mention that if the part is improperly passivated, it will have a tendency to rust and will probably need to be reworked before being tested again.

It is also important to ensure that the water is clean. The water used for the test should not contain iron (from plumbing for instance) or chemicals, otherwise the test result may falsely indicate that iron is present on the surface the part.

Humidity test

The humidity chamber test requires specific equipment and a capital investment. Unless the manufacturer is properly equipped, stainless steel parts will be sent to an external laboratory. It may be easy to outsource humidity testing for small stainless steel parts, but larger parts may be problematic. Obtaining the results will also take time and failed parts will require a rework.

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Salt spray test

The inconveniences of the salt spray test are similar to the humidity chamber test.

Copper Sulfate test

This test is rarely accepted in the food industry because of its toxic nature. Moreover, this test will leave undesirable marks on the stainless steel parts.

Potassiunm ferricyanide – nitric acid test

This last test is very sensitive. The potassium ferricyanide solution must be made fresh every day. The reaction is highly visible as it turns blue in presence of free iron, but will often give false positives.

ALTERNATE METHOD

Open Circuit Potential Testers

Walter Surface Technologies has recently launched a compact and portable testing device which is capable of qualifying the stability and thickness of the passive chromium oxide layer of stainless steel. This device works on the principle of Open Circuit Potential. Open Circuit Potential is the difference of electrical potential between two terminals. The tester measures the interface potential of the chromium oxide layer versus the underlying steel. A numeric value of the quality of the passive layer will then be read in about 20 seconds. This tester can also be used to monitor the evolution in time of the passive layer. The passivation tester will indicate a positive reading within a couple of hours of properly cleaning and decontaminating the stainless steel surface.

The thin profile of the test probe allows for the collection of readings in small and very specific areas. Multiple readings can be taken in order to maximize reliability and reproducibility. A negative value will indicate that the part being tested is not passivated. A positive value will indicate that the part is passivated. The higher the value, the thicker and more resistant the passive layer.

Walter's new generation of passivation testers are also supplied with a software and USB cable in order to record data from the tester and upload data to a computer. This feature can be used to implement quality control procedures at the manufacturing location.

To summarize, the Open Circuit Potential method offers the following advantages:

* Qualifies the quality and thickness of the protective chromium oxide layer
* Provides a numeric value instead of a pass and fail result only
* Provides fast and accurate readings (about 20 secs.)
* Will not damage the surface being tested
* Allows for onsite measurements
* Allows recording and uploading of measured data

CONCLUSION

Passivation of stainless steel parts and structures are unquestionably a concern for welders and manufacturers in many industries. For economic reasons, manufacturers want to minimize rework costs of rusted parts and structures in the field. Fortunately, new techniques are being developed to help manufacturers ensure the quality of their parts. The Open Circuit Potential method is a reliable, effective and accurate method to measure passivation and minimize rework costs.

About Walter Surface Technologies

Walter Surface Technologies has been a leader in the surface treatment technologies for 60 years, and has been providing high productivity abrasives, power tools, tooling, chemical tools and environmental solutions for the metal working industry. Founded in Montreal in 1952, Walter Surface Technologies is now established in multiple countries in North America, South America and Europe. For additional information, visit us at walter.com. Visit surfox.com for more information pertaining to the Surfox line of products.