What is the Alternative to the Salt Spray Test

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Abstract

The basic idea of corrosion testing is to simulate and accelerate the corrosion performance of a component in service by enhancing the corrosion test parameters. By this way the corrosion mechanism may change and further on the test itself may not be suitable for the system under test. This is partly valid for the neutral salt spray test, widely used in practise and keeping always too much time.

The strategy to overcome this dilemma will be no longer to simulate and accelerate natural corrosion processes but to switch over to other, especially combined electrochemical techniques where the parameters and therefore the corrosion reaction itself can be fixed easily.

However for long term corrosion assessment the correlation between the electrochemical data and the actual corrosion performance in service has to be evaluated - in a first step by help of the artificial corrosion climate tests. This can be possible by combining the salt spray test with optical and electrical techniques, reducing the test duration and increasing its reproducibility and accuracy.

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Introduction

Much progress has been achieved during thr last decades in the field of corrosion protection however corrosion tests are still on the level of the past. This has been evident again as the automobile industry has to develop new hexavalent chromium free systems being demanded by the EU “End of Life Vehicle Directive”. The background is that most of the manufacturer give an antirust guarantee for more or less ten years which of course could be a problem while introducing new anticorrosion systems in the production not knowing their longtime behaviour. The frequently used corrosion test is still the neutral salt spray test (DIN 50021 SS, ASTM B 117) and especially in Germany some similar tests like the 3-phase-corrosion-changing-test with long phases VDA-621-415 (German Automobile-Association) [1] or with short phases PV 1210[2].

Every artificial corrosion test aims to present the longtime corrosion performance of a system under service conditions in a very short time .As indicated in Fig.1 the relevant test parameters like temperature, pressure, concentration of chemicals, pH-value and other more are increased from value ^{1} to ^{2} in order to reduce the life time of the system t^{1}down to the the test duration t^{2}. A dramatic change of the parameters –as sometimes practised- however is risky as the test result will be less reproducible and accurate and the corrosion mechanism itself may be different from what is happening under real application conditions.

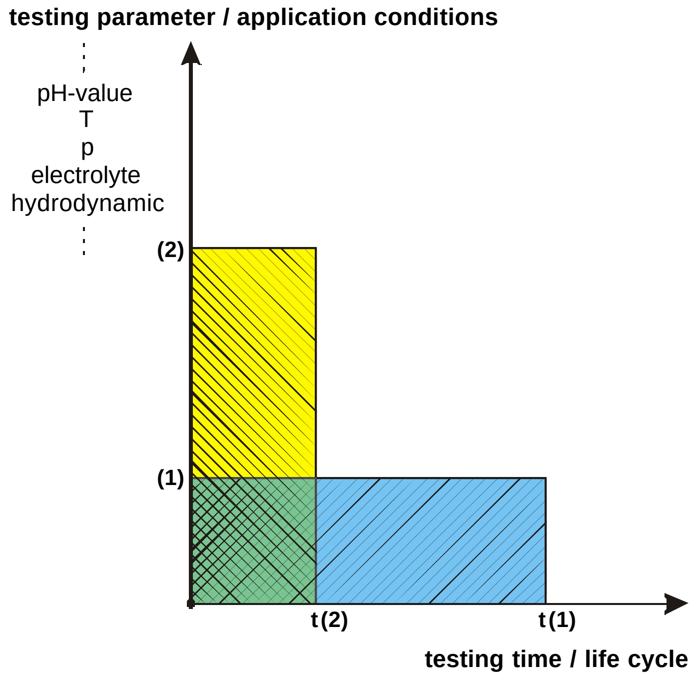

Fig.1: Principle of artificial corrosion tests

Why is the salt spray test criticized

The main argument is the long duration of the test. An average test duration of 1000 hours, which means almost 50 days, is very unconvenient for the development of new products and for controlling the production as well. On the other hand the tremendeous practise with that test and the well known correlation of the test result with the longterm behaviour for many systems is of big advantage.

The reproducability and the accuracy of the test have already been mentioned. In many cases the salt spray test is no longer a real corrosion test but a simple quality test representing a "good-bad" result and decision. Further on the test is often used for systems like anodic oxide layers or organic coatings, where quite different impact would be necessary. For the last it is well known that irridiation and simultaneous humidity are necessary as used in the Q-UV-test (DIN 53384) or in the Xenon-test (DIN EN ISO 11341). More over it is a point of discussion whether new developed systems for cathodic protection as conducting polymers, ormoceres or self assembling molecules (SAM) can be reliable tested by the salt spray test and whether these results can be compared to the well known systems used in the production line. The situation is quite clear, as the test cannot be used to predict service life on a part that has no previous salt spray/service correlation.

Alternative test procedures

The most promising alternatives are physical-chemical methods and more specific electrochemical procedures probably in combination with optical methods. Not in the discussion up to now are techniques widely used in nondestructive testing and characterization as radiologic, acoustic, electrical and magnetical techniques. Overall there are a lot of possibilities to characterize and identify a system with respect to corrosion.

If the correlation to the long term behavior is known – and this is of course the essential problem – using this techniques the corrosion protection of a system can be evaluated within minutes. Thus the original idea of simulating the corrosion process in a time-lapse is no longer of importance: The aim is the characterization of a system under definite impact conditions in the sense of the system theory and the correlation to the corrosion behavior in service. Of course research and development are necessary to overcome the difficulties on that way and in the meantime the salt spray test will still be needed. Further on some ideas in that direction will be discussed.

Corrosion-potential-measurement

Measurement of the corrosion potential is often not very reliable with respect to the corrosion behavior of a system. This however can be quite different if the measurement is combined with a second process as indicated in Fig.2. A system being in a stable passive condition will be attacked by a corrosion stimulating agent as e.g. chloride ions. After a definite concentration and therefore adding-time the passivity is broken and the system becomes active [3]. Investigation of filiformcorrosion of differently pretreated and polymer-coated aluminum alloys using conventional filiformcorrosion tests and the above discussed corrosion potential measurement gave same results. Remarkably the artificial corrosion test takes several weeks whereas the result of the electrochemical technique is available within hours.

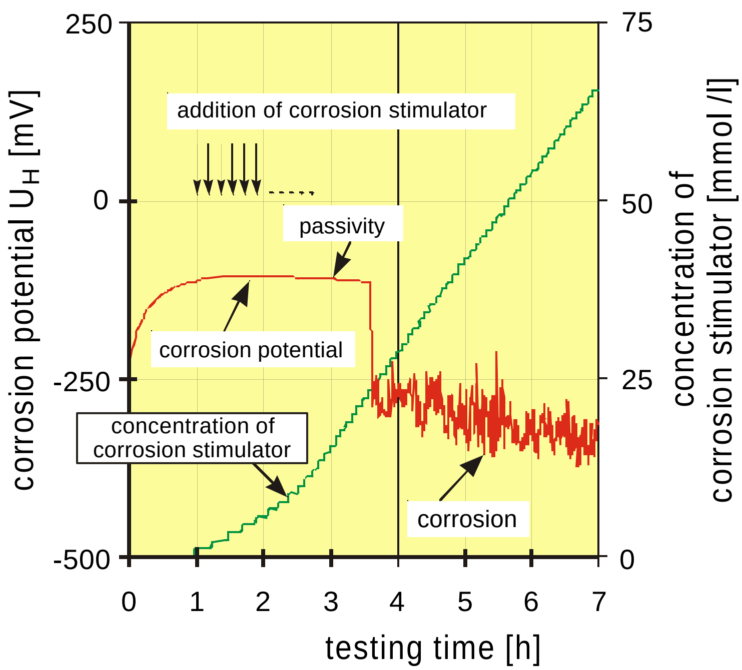

Fig.2: Measurement of the corrosion-potential as a corrosion test

Potential measurements under definite conditions

Cathodic corrosion protection of steel by chromated electroplated zinc can be evaluated under short cut conditions in a double cell betwenn the sample under test and an electrode of the steel base material [4]. The potential time dependence of the electrodes under stationary conditions before and after the short cut is shown in Fig.3. The potential difference under short cut conditions is characteristic for the corrosion protection of the chromate conversion layer and can be achieved within minutes – in contrast to the salt spray test. Similar the corrosion protection of chromate films can be determined by measuring the time dependence of the potential of the chromated zinc or zinc alloy during a galvanostatic pulse in a suitable solution. The height of the measured potential maximum corresponds to the corrosion protection abilities of the chromate layers, which is confirmed by the results of the neutral salt spray test of different chromate films. Again the result can be achieved within seconds [5].

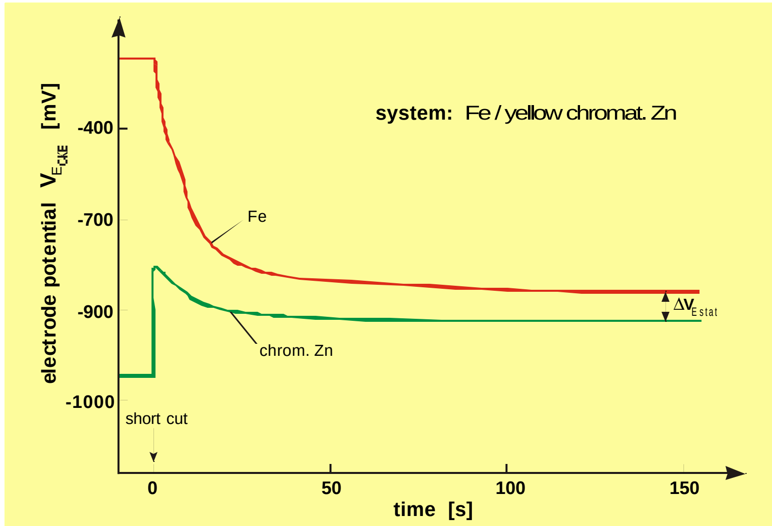

Fig.3: Potential-time-dependence of a chromated zinc electrode in a double cell under short cut conditions

Current-density-potential-characteristics

Galvanic corrosion can be juged by current-potential-characteristics. Fig.4 shows the quasistationary diagram of the automobil-magnesium alloy 91AZhp and of fastner materials with respect to galvanic corrosion [6]. The current density of the magnesium alloy in contact with the ZnNi-alloy, normally used for aluminium alloys, and a deposited AlMg alloy clearly shows that the last one represents the optimum problem solution. The decision and quality control can be achieved within minutes and is confirmed by a longtime salt spray test [7].

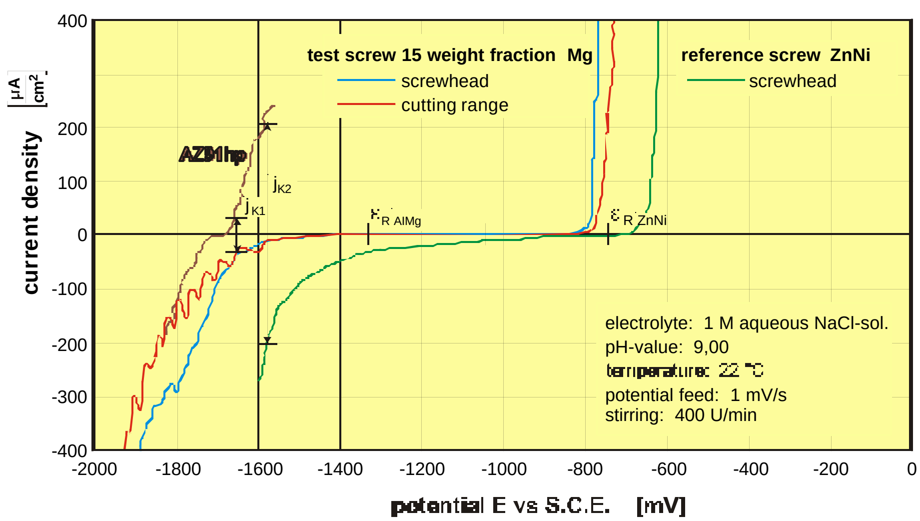

Fig.4: Current-potential-characteristic of a Mg-electrode in comparison to a ZnNi- and AlMg-alloy

Impedance and noise measurements

The dynamic behavior of a corroding system can be characterized by impedance spectroscopy in a wide frequency range [8]. Well known is the quality control of anodised and sealed aluminum for architectural applications by measuring the imaginary part of the impedance and the phase angle (DIN 50949, DIN 50920). Especially the quality of organic coatings including the influence of pretreatment procedures can be evaluated by impedance spectroscopy. Very similar the potential of this technique as well as for noise measurements [9] has not been used sufficiently up to now for the development of corrosion test techniques.

Other techniques

Besides the methods discussed above further techniques should be mentioned. Using the Kelvin Probe [10] by measuring the work function the delamination of organic coatings can be detected in an initial stadium. The quarz microbalance (QMB) enables to measure weight losses or the formation of layers during corrosion processes within an accuracy of nano- grams [11]. The great number of non destructive testing techniques of radiologic, acoustic, magnetic, electric and electromagnetic nature is already used in the field of sensors and actuators but has not been applied up to now in corrosion testing.

The instrumentally improved salt spray test

As already mentioned it seems to be very difficult to replace the salt spray test in the near future as we have tremendous experience and knowledge about the correlation of the data with the long time behaviour in service. However for better reproducibility and accuracy of the test results there is need for better data acquisition and evaluation. Progress has been achieved in using imaging and ranking techniques already used in other areas and giving more accurate results [12].

Further improvement of the salt spray test is possible in a simultaneously analytical investigation of the corroding sample in the test. One possibility is monitoring the sample surface by IR-spectroscopy. Comparing the spectra with the data of samples being tested for long time and knowing the time dependence or time law of surface modifications by the test it will be possible to predict the long term behaviour in a short time. This will reduce the testing time significantly enhancing the accuracy of the result as well. The schematic set up for the measurement and evaluation of IR-spectra during the corrosion test is shown in Fig.5.

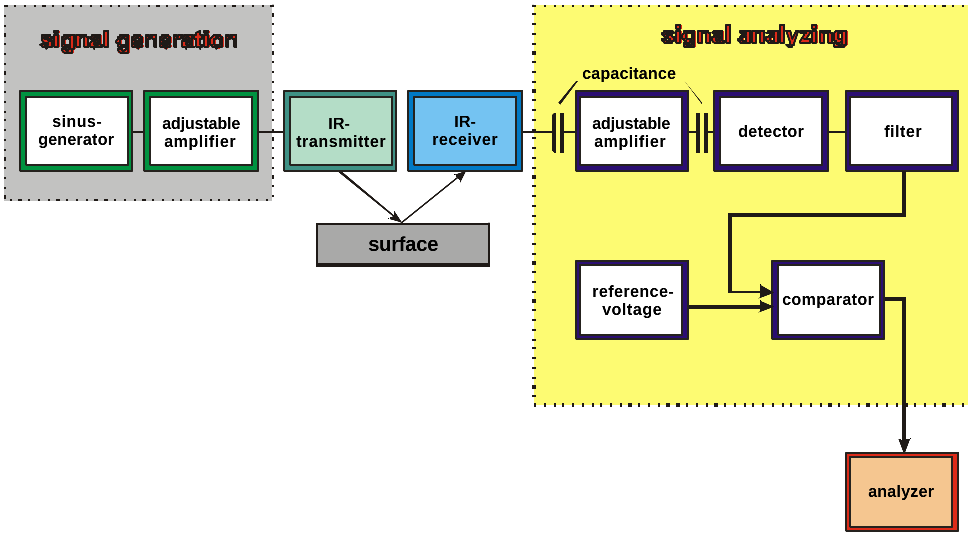

Fig.5: Set up for measuring and evaluating IR-spectra in a salt spray cabinet

Especially the Fourier-transformed IR-spectroscopy (FT-IR) is very sensible and useful in characterisation of corroding surfaces [13]. However a lot of other techniques can be used to monitor the corrosion process in the salt spray test. A high-sensitive technique for measuring electrical resistance has been tested with electrodeposited zinc coatings. In comparison with weight loss measurements, impedance spectroscopy and the neutral salt spray test the corrosion rate for the uniformly corroding zinc coatings was almost identical [14]. In another measurement of the electrical resistance using a special geometric device the efficiency of corrosion inhibitors for crevice corrosion of automobile bodies was successfully tested in the salt spray test [15].

Conclusion

Corrosion assessment of protection systems by the neutral salt spray is supposed to be too time consuming giving the same time generally less accurate results. In order to simulate the corrosion conditions in service it would be more useful in future to develop test methods on the basis of electrochemical, optical, acoustical, electrical and other effects. The main problem however is, to evaluate the correlation between these test methods and the long term corrosion behaviour in service. As enormous experience exists for the neutral salt spray test being the same time part of numerous technical standards however it will not be possible in the near future to replace that test. A first step will be to combine the test with e.g. suitable optical and electrochemical techniques to reduce the test duration and to improve its reproducibility and accuracy.

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