Use of the Potential Drop Technique to Monitor Stress Corrosion Cracking

A short Applications Note

Potential drop methods are ideally suited to the measurement of crack initiation and propagation in the presence of stress corrosion effects. Testing a material in a corrosive environment is vital if valid predictions are to be made of the behaviour in real life or in-service conditions. The presence of even a small amount of an extraneous foreign substance can have a marked effect on the tensile or fatigue properties of a material.

With regard to metallic materials, common corrosive media range from reactive chemicals such as strong acids and strong alkalis to, apparently, benign substances such as sea water. Even fresh water under conditions of high temperature and pressure can become highly corrosive.

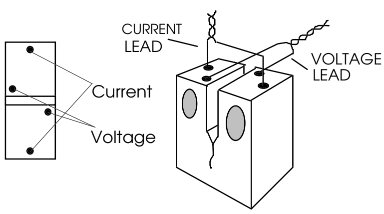
Stress corrosion cracking is the term given to defect propagation that occurs in the presence of both a stress and a corrosive medium. It is also possible for cracks to be initiated in materials due to the joint effect of stress and corrosion. More importantly, such defects can propagate at rates which are significantly greater than those in a benign environment. This can lead to the failure of components well before the expiry of their design life, often with catastrophic con-sequences.

Emulating stress corrosion crack-ing in the laboratory often leads to difficulties in monitoring the initiation and growth of defects. This is because corrosive media are usually gaseous or liquid and, therefore, some means of containment around a test piece is required. Most techniques used to monitor defect propagation need to either contact the specimen or observe it whilst a test is in progress. Thus sealed mechanical, optical, or electrical feedthroughs are required.

Additionally, if sensors such as strain gauges are utilised, both they and their method of fixture have to be able to withstand corrosive attack and retain their integrity of operation throughout the test.

Potential drop methods offer a straightforward solution to the monitoring of stress corrosion cracking. Two methods exist, AC potential drop and DC potential drop. **A**s their respective names suggest, either an alternating or direct current is passed through the specimen under test and the resultant potential developed between two points on the specimen is monitored. If a constant current is used then the initiation or propagation of a defect, sited between the two voltage measurement points, will lead to an increase in the measured voltage. In essence, both techniques, detect a change in the specimen resistance (or the impedance in the case of ACPD) and this can be interpreted as either the initiation or propagation of a defect such as a crack.

The simplest implementation of the potential drop method requires four electrical connections, appropriately placed as shown below and linked to suitable current generation and measure-ment apparatus.



Naturally there are further considerations and subtleties to both the DCPD and ACPD techniques and a knowledge of these is required before any meaningful data can be obtained. However, there is no doubt that both techniques are capable of detecting and measuring crack propagation and they are routinely used throughout the materials world for this purpose.

ACPD offers some advantages over DCPD, not least of which is the greater degree of sensitivity to the presence of a defect. Additionally ACPD requires a constant current supply that is an order of magnitude below that of DCPD, thus permitting a commen-surate reduction in the thickness of the supply leads. ACPD equip-ment tends, however, to be more sophisticated and therefore more costly and the technique is not as conceptually simple to understand as DCPD.

When performing stress corro-sion studies using the PD method it is important not to compromise the integrity of the contacts by the action of the corrosive media. Thus, resistant materials such as nickel, silver or platinum are used as appropriate. Electrical contact can be made either mechanically, for example, by clamping or by using a screwed connection, or alternatively by a bonding method such as spot welding. The latter is better for corrosive environ-ments assuming the bonded metals are electrochemically compatible.

A further electrochemical con-sideration is the fact that traditional DCPD methods can often cause enhanced corrosion both at the point of electrical contact and, more seriously, at the crack site. This is because the DC current causes a potential drop which can drive a corrosive chemical reaction, similar in this respect to electrochemical etching. Unfortunately, this is a prime example of an experimental result being affected by the method employed to observe it.

Such detrimental effects can be countered by using a pulsed direct current technique. Here the exci-tation current is passed through the specimen for a short period of time and then turned off. This is repeated at regular intervals. Measurements of the DCPD are taken during the "on" period. A schematic of a pulsed DC system is shown below.

The fact that the current is pulsed means that, on average, a reduction in the electrochemical effects is observed. By adjust-ment of the "on" with respect to the "off" periods, users can largely eliminate these effects.

A better method would be to reverse the DC current at regular intervals. Reversing DCPD was developed for this very purpose. The technique is not common and the equipment tends to be expensive. More importantly, the pulse widths utilised still give rise to electrochemical effects within each "cycle".

Conceptually, the step from reversing DCPD to ACPD is small and the distinction between the two is, at first, difficult to see. However, a difference does indeed exist. This subtlety is responsible for two further enhancements in the use of PD methods for stress corrosion studies. The reversing frequency of a DC system is very much less than that of an AC instrument. In the latter case, frequencies of 10-100 kHz are usually employed, with research work being conducted at even higher values. Unlike DCPD, at these frequencies, the excitation current flows non uniformly through the specimen with more current flowing in the surface regions than through the bulk. This phenomenon is known as the skin effect and its occurrence leads to several significant advantages of ACPD over DCPD.

Since most defects originate and propagate from the specimen surface, it is sensible to confine the excitation current to these regions, thereby maximising sensitivity to the initiation or propagation of the said defects. This is also the reason why the ACPD technique utilises lower specimen currents - less current is required to obtain a similar defect sensitivity.

Additionally, using alternating currents naturally gives rise to an alternating voltage. Sophisticated electronics can then be employed to lock-in to the frequency of the AC voltage and measure its magnitude. This effectively eliminates other frequencies that usually manifest themselves as noise on the signal of interest.

A reduction in noise further improves the resolution of the potential drop technique. Thanks to its increased sensitivity, ACPD is often used to detect defect initiation in addition to the monitoring of defect propagation.

In conclusion, potential drop techniques offer a highly effective method of obtaining information on stress corrosion cracking. Their main advantages lie in their simplicity of operation, ease of integration and sensitivity to the phenomenon under investigation.

Both DC and AC potential drop techniques can be used to monitor initiation and propagation of defects in electrically con-ducting materials. ACPD offers the highest sensitivity with the minimum detrimental electro-chemical interaction, whilst DCPD equipment tends to be cheaper and still maintains a popular following.

***T**his applications note has been prepared by Matelect Limited who manufacture a range of standard AC and DC potential drop instruments and peripherals.. Please contact Matelect at the address given below for applications information or details of available equipment.*

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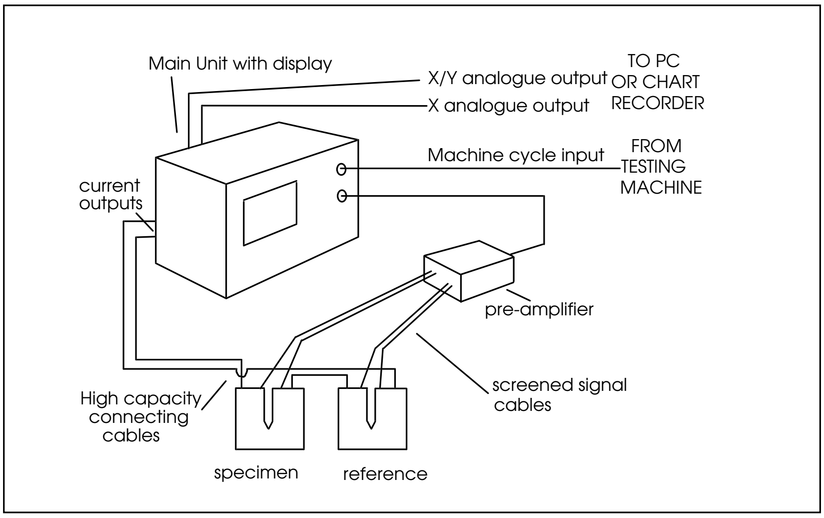

Schematic of a typical DCPD test configuration