The Potential Drop Technique & Its Use In Fatigue Testing

A Short Applications Note

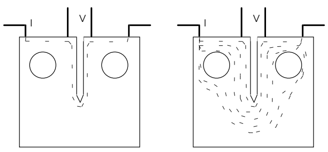
The potential drop technique has been in use to measure and characterise the propagation of defects in metallic specimens for many years. It is one of the few methods that directly measures the depth of a defect or flaw providing this penetrates the surface of the material under test.

BACKGROUND

The potential drop technique relies upon the passage of a constant current through a specimen and the subsequent measurement of the voltage generated across an area (usually the crack site) on the specimen.

Two forms of the technique exist; AC potential drop (ACPD) in which small (ca. 1 amp) alternating currents are passed through the specimen and DC potential drop (DCPD) in which large (ca. 30 amp) direct currents are used.

The techniques essentially measure resistance (DCPD) or impedance (ACPD). The change in these quantities generated by a propagating defect usually results in an increase in the potential drop being measured.



Typical DCPD and ACPD current paths in CT specimens

Both techniques have their protagonists and associated advantages.

ACPD provides a linear increase in voltage with crack depth and hence permits simpler calibrations. It is also theoretically more sensitive than the DC technique since most of the current in the specimen is confined to the surface regions via a pheno-menon known as the skin effect.

These properties have lead to ACPD being used to measure crack depth in the field in addition to its laboratory role. DCPD is usually confined to the materials testing and research applications and is the more traditional, and hence accepted, of the potential drop methods.

The major disadvantages of the DCPD method have been the generation of thermoelectric EMFs at the contact points and the poor noise performance. These effects have been largely overcome by the use of modern electronics and by pulsing the applied currents.

Pulsed or interrupted DCPD units eliminate thermoelectric EMFs by taking two PD measure-ments, one during a current pulse and one after (i.e. at zero current). By subtracting one from the other, the thermo-electric EMFs are removed.

ACPD has always suffered from the effect of pick-up (voltages induced in the signal lead by the current supply lead).

The pick-up signal is super-imposed upon the true ACPD and can dramatically alter measured signal magnitudes.

Pick up is not a problem in itself except for the fact that altering the position of the leads during a test will change the measured PD value.

Although the influence of the AC pick-up phenomenon can be reduced by careful test set-up, it is also possible to electronically remove the offending signal.

FATIGUE TESTING

Both potential drop variants have extensively been used for fatigue testing by industry and academia alike. They are now accepted as methods for the measurement of crack size by the ASTM organisation (ref. 1).

In general, ACPD is suitable for both high and low frequency fatigue studies whereas pulsed DCPD is only suitable for low frequency work.

Modern pulsed DC systems permit the synchronisation of the current pulse to the machine cycle waveform so that measurements can be taken at, for example, peak tension.
Such operation is ideal for the study of crack closure effects in metals.

The rapid response of AC systems makes them ideal for high cycle studies. ACPD has even been used to obtain data during impact testing.

Both techniques suffer from the effect of crack shorting, whereby rough, fresh crack surfaces can exhibit alternative current paths that disappear once the crack is opened after the application of a stress.

This phenomenon is often put to good use to characterise crack closure effects but it can be problematic when static measurement of crack depth in the field is performed since it causes an effective underestimation of the crack depth.

Sometimes regarded as a complicating factor, is the observed dependence of both the DC and AC potential drop on elastic and plastic strain.

The strain effect has been used in ACPD to detect the onset of crack initiation (ref. 2) and has now been used to measure stress within a specimen (ref. 3). In fatigue studies, the change in PD with stress leads to a cyclic variation in the PD signal that mimics the load waveform.

In general, for low frequency fatigue testing it is very important to use equipment that offers high stability and low noise operation.

ACPD systems based on a single channel instrument need to incorporate a high stability current source if sensible long term measure-ments are to be made.

It is possible to use poorer quality sources by using a second measuring channel to act as a reference. The active channel is then normalised using the passive channel.

Increasing the number of signal channels by employing signal multiplexing makes it also possible to obtain information on how a crack profile alters during a fatigue test. For this purpose the ACPD technique is far better than DCPD as the low currents employed in the former permit the current lines to be multiplexed as well. This ultimately leads to greater sensitivity and selectivity - essential if profiling is to be performed correctly.

Multiplexing is, however, confined to low frequency cycling studies where the time delay between readings on any one channel (caused by the necessity of scanning through other channels) is not likely to prove a problem.

For profiling during high frequency fatigue studies, specialist real time multi-channel equipment is required.

Matelect have been established suppliers of potential drop instrumentation for over 10 years with sales extending world-wide.

Matelect supplies both standard single channel ACPD and dual channel pulsed DCPD systems together with multiplexing equipment. Multi-channel, real time (non-multiplexing) ACPD units are also fabricated to customer requirements.

For further information on our products or if you just require advice on any aspect of potential drop technology, please contact our offices at the address below.

References:

1. ASTM E647 Guidlines for electrical potential difference determination of crack size
2. Okumura et al. Application of the AC potential drop technique to the Determination of R curves. Eng. Frac. Mech. 1981(14) 617
3. M Saka et al. Measurement of Stress--intensity factor by means of AC Potential Drop Technique. Experimental Mechanics vol 31 1991(3) 209

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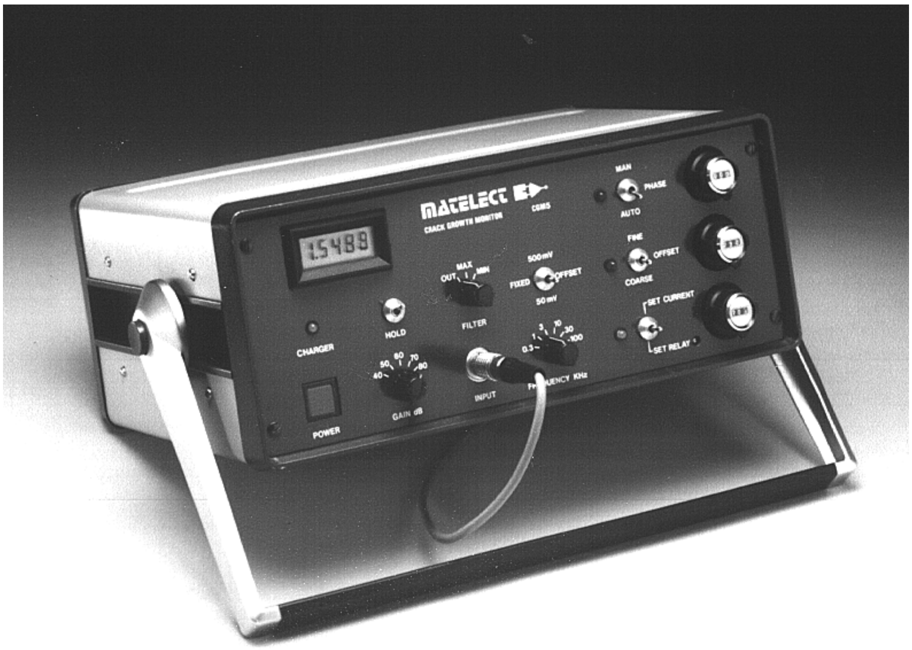

A typical ACPD crack growth monitor