Journal of Power Sources, *20* (1987) 81 - 85

MATERIALS TESTING PACKAGE FOR BATTERIES AND ENERGY CONVERSION SYSTEMS

M. I. ISMAIL

Faculty of Engineering and Petroleum, Kuwait University (Kuwait)

Summary

A novel testing technique is described in which the material is subjected to fast heating. An aggressive medium or special environment may be used to contact the material under test, while extreme conditions evaluate materials. Such testing programs are safe and reliable. A research and development package is commercially available which permits the simultaneous assessment of various materials by a multi-electrode tester using continuous or pulsed electroheating in the media of interest. The signals in mV (or mΩ) are measured manually or by a microprocessor at various stages of the test. The amplitude and frequency of the reversed polarity is controlled by a "Reversalyzer" power supply which is utilized in the package to generate various d.c. pulses.

Introduction

The components of electrochemical cells are different, depending on the overall chemistry of the cell. However, the principles of operation of all galvanic cells (batteries) are fundamentally the same. In the main, battery failure problems are related to materials' characteristics, irrespective of whether such materials are active or inert components.

The object of this work is to introduce promising accelerated test techniques that might be used for the selection/evaluation of battery materials, particularly inert materials such as steels or non-ferrous alloys.

Tests for composite materials are similar to those used for single and multi-phase alloys. This report is of importance for the testing of materials used in the manufacture of battery components, both for primary and secondary cells of low or high energy density.

The accelerated tests, whether of a destructive or a non-destructive nature, are useful for the initial screening of battery materials. However, in the end result, long-term tests are essential for the selection of cell components. Such procedures must involve both field and simulated cell testing.

0378-7753/87/$3.50

Experimental

The package used for component assessment (Fig. 1) includes a power supply ("Reversalyzer") which is capable of reversing the polarity at preselected periods (144 selections) ranging from one second to a few minutes. A multi-cell testing device [1] allows the independent examination of various cells under different loads. The cells could also be tested using an external power supply. For example, by changing the arrangement and circuit connection, the cells could be changed from a series to a parallel arrangement by the single push of a button switch. The data include open-circuit voltage (OCV), and electrode potential with a single, common (outside) reference electrode or a reference electrode incorporated in the cell. The data are manually recorded or the apparatus is connected to a microprocessor. The package also includes a tribology testing device which has a d.c. power-supply connection and is capable of causing pulse electrolysis during rotation of the specimen in contact with a corrosive/erosive medium. Finally, the package has a monitoring gun that generates heat pulses of suitable duration and is capable of differentiating between various media through measurement of their response to short-duration heat pulses. Multiphase and porous media were found to exhibit different behaviours according to their overall heat-transfer coefficients [2].

Fig. 1. Materials R & D package: (a) Reversalyzer power supply; (b) multi cell tester; (c) battery tester; (d) tribology tester; (e) monitoring gun (heat pulse tester). (Courtesy of CanReactor Materials, Inc., Canada.)

Standard techniques, such as the tensile test, are most useful for specimens tested in contact with an electrolyte or during electrolysis when the polarity is kept steady or is periodically reversed. This technique could be used to examine the effect of H_2 or other parameters on the performance of materials. Electrochemical studies undertaken on pre-strained metal are helpful in material evaluation, particularly when various strain rates and levels are involved [3].

Results and discussion

The package described above has been tested in different applications [4 - 6]. Figure 2 shows OCV data obtained from mild steel after determination under various strain rates and strain levels. The environment contacting the mild steel was either air, LiCl-saturated solution or gelled LiCl in carboxymethyl cellulose (CMC). It can be seen that there is a difference in the OCVs or the electrode potential of the tested steel specimens. This difference is large under extreme conditions, *i.e.*, when the material is deformed at high strain levels and low strain rates and is in contact with an aggressive environment (LiCl).

Heat pulse tests were carried out on the fractured materials after the tensile test; the results are given in Fig. 3. There is a correlation between the

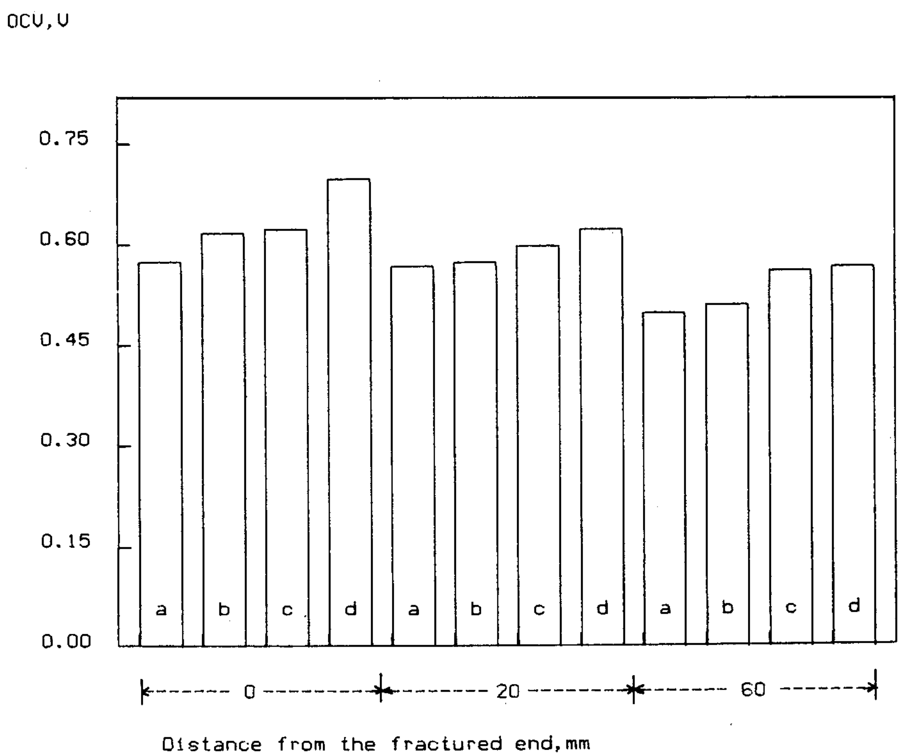

Fig. 2. Open-circuit voltage of mild steel specimen strained to failure at various strain rates in air or LiCl solution: a, 3.3×10^{-4} s^{-1} LiCl solution; b, 3.3×10^{-4} s^{-1} LiCl gelled with CMC; c, 3.3×10^{-4} s^{-1} air; d, 8.3×10^{-5} s^{-1} air.

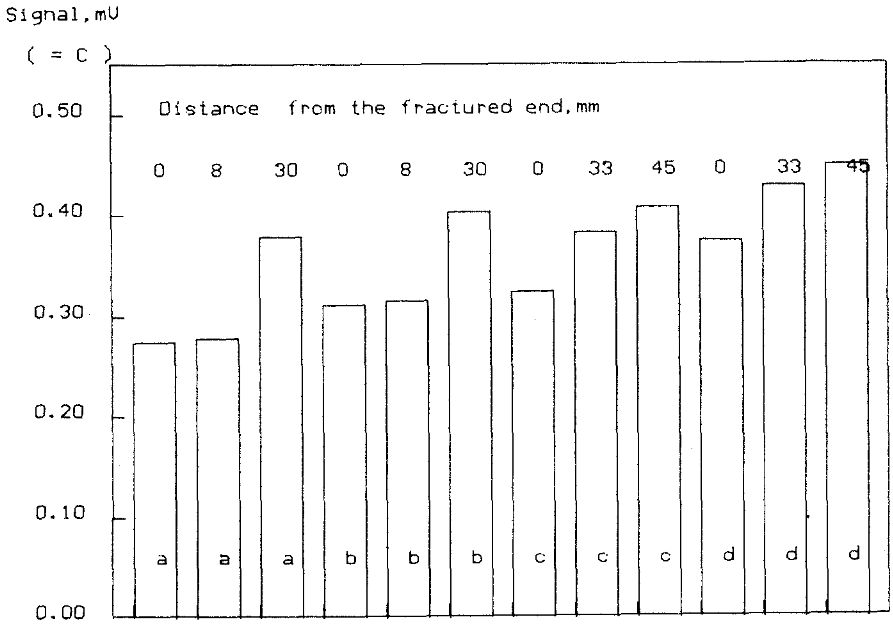

Fig. 3. Monitoring the transient thermal response of deformed steel: response signal measured after: a, c, 10 s; b, d, 15 s. Strain rate: a, b, $8.3 \times 10^{-5}\ s^{-1}$; c, d, $3.3 \times 10^{-4}\ s^{-1}$.

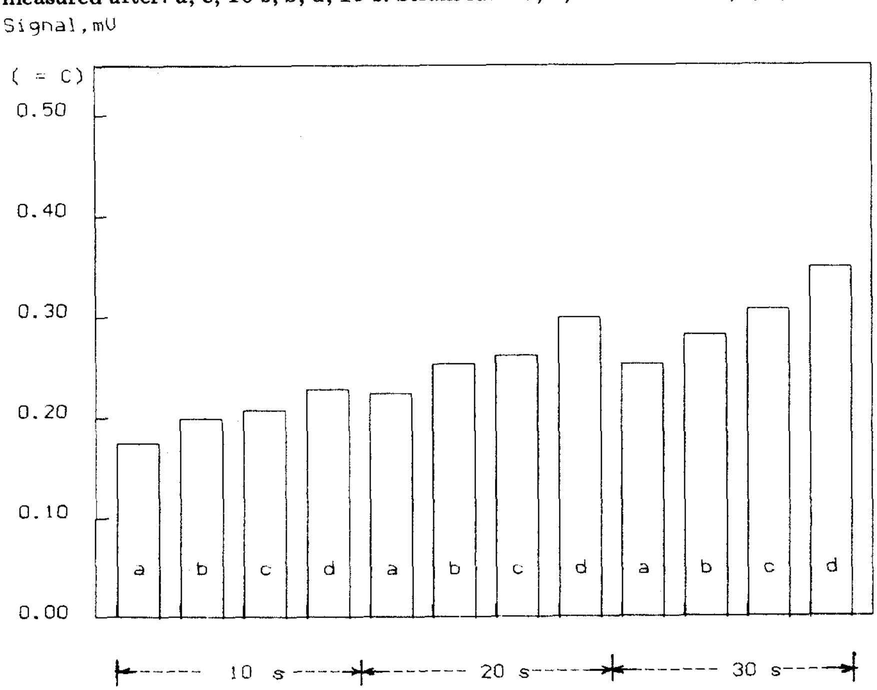

Fig. 4. Monitoring the transient thermal response during deformation (tension) of steel: a, d, strain rate of $3.3 \times 10^{-4}\ s^{-1}$; b, c, strain rate of $8.3 \times 10^{-5}\ s^{-1}$.

deformation level and the response to the heat pulse. The value of the transient response to the heat pulse increases with decrease in deformation level and increase in deformation rate. Further details on the application of this monitoring system to materials with differences in metallurgical condition/treatment are available elsewhere [7]. Heat-pulse responses during tensile tests are shown in Fig. 4. The strain rate exerts an effect on the measured transient thermal response. The response signal increases both with decrease in the strain-rate level and with increase in the transfer time (10, 20 or 30 s). The stress/strain diagram shows variations in the yield as well as in the ultimate tensile strength when the tested specimen is in contact with air or with a solution of saturated LiCl. Such accelerated testing can help to predict the behaviour of materials during various manufacturing processes involving aggressive chemicals or severe operational conditions.

The data obtained from the measurement of heat-pulse response and those obtained by the conventional methods are in full agreement depending upon the application [8 - 10].

Acknowledgements

The financial support of CanReactor Materials Inc. (Box 189, Mississauga, Ontario, L5M 2B8, Canada) and Kuwait University (EDC 017) is gratefully acknowledged.

References

1 M. I. Ismail, Electrolytic Multi-Cell Testing Apparatus; *Patent Can.CA 1,201,479* (Cl. GO1N26/46), 04 Mar. 1986, Appl. 454,224, 14 May 1984.
2 M. I. Ismail, F. J. Farquhar, and T. Prasad, *167th Meeting Electrochem. Soc., Toronto, May, 1985*, 85-1, pp. 510 - 511.
3 M. I. Ismail and N. Sato, *Hokkaido Daigaku Kogakubu Kenkyu Hokoku, 75* (1975) 181 - 192.
4 M. I. Ismail and R. Wason, *4th Asian Pacific Corrosion Control Conf., Tokyo, May, 1985*, Vol. 2, pp. 393 - 401.
5 M. I. Ismail, *4th Asian Pacific Corrosion Control Conf., Tokyo, May, 1985*, Vol. 2, pp. 1095 - 1102.
6 M. I. Ismail and M. H. Attia, *167th Electrochem. Soc. Meeting, Toronto, May, 1985*, pp. 10 - 11.
7 M. I. Ismail, *Proc. 3rd World Congress of Chem. Eng., Tokyo, Sept. 1986*, Vol. IV, No. 11a-307, pp. 477 - 480.
8 M. I. Ismail, *Proc. 3rd World Congress of Chem. Eng., Tokyo, Sept. 1986*, Vol. IV, No. 11a-203, pp. 446 - 449.
9 M. I. Ismail, S. A. Alkhapery, E. C. Albert and A. Langer, Monitoring drug release by thermal and d.c. pulse technique, *9th Int. Congress CHISA '87, Praha, Aug. 30 - Sept. 4, 1987.*
10 M. I. Ismail, G. J. Farquhar, T. Prasad and E. A. McBean, *Proc. Electrochem. Soc.*, 85-8 (1985) pp. 184 - 192.