Damage Monitoring by Surface Potential Measurement

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Introduction

The safety control of the atomic energy facility is the most important in using the atomic energy. A large number of research works have been done to prevent corrosion, stress corrosion cracking and corrosion fatigue. However, the existences of corrosion and cracks have been still reported. We have developed a portable surface potential measurement device [1] to monitor the damage caused both by electrochemical and mechanical factors. When materials are fractured, plastic deformation occurs at first stage and the plastic zone expands gradually to lead the crack initiation. Therefore it is possible to prevent the final fracture if we can monitor the early stage of plastic deformation. It is also important to distinguish a new crack or scratch from the old one. Considering these, two different experimental works have been carried out. One is monitoring the new mechanical damage caused by both the plastic deformation and the scratch. The other is monitoring localized corrosion such as pitting and crevice corrosion. The efficiency of surface potential measurement device is discussed.

Surface potential measurement device

Figure 1 shows the schematic representation of the surface potential measurement system.

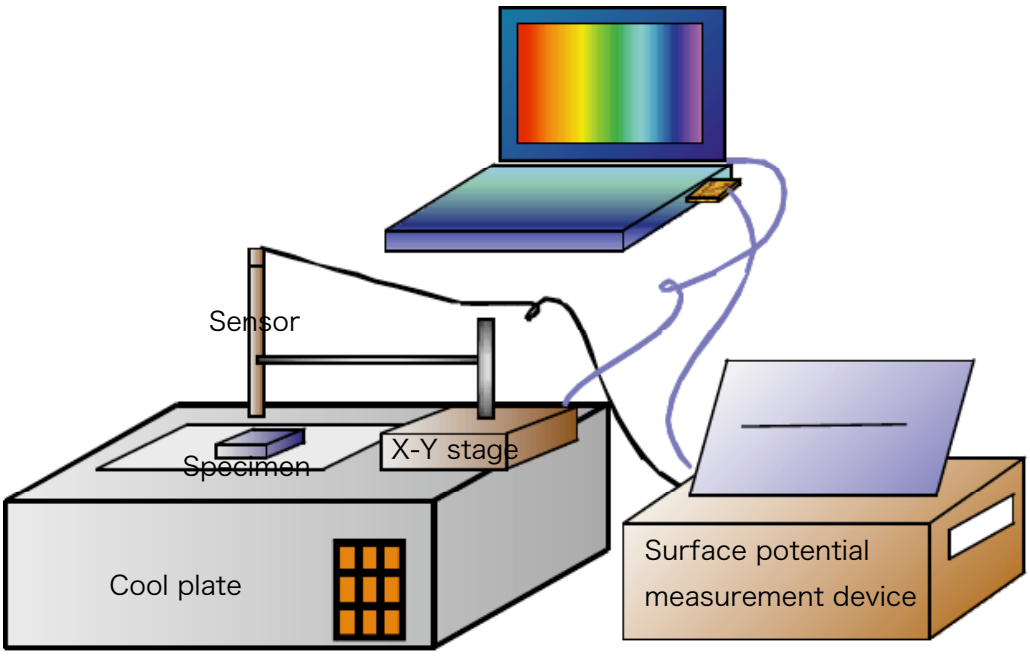


Fig.1 Schematic representation of surface potential measurement system.

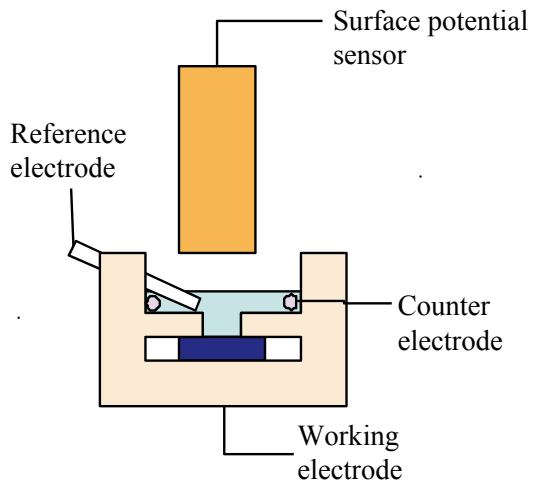


Fig. 2 Schematic representation of test system for investing the relation between the surface potential and the electrode potential.

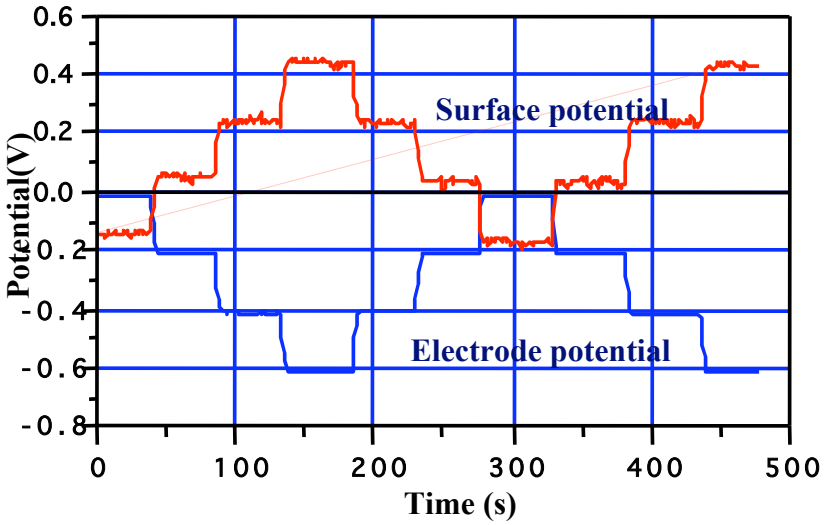


Fig. 3 Relation between surface potential and electrode potential.

The system is composed of the surface potential measurement device, X-Y stage and computer. The accuracy of potential is 10mV and the minimum data acquisition time is 0.5 second. The principle of surface potential measurement is the same as that of Kelvin microscope [2], that is, the surface potential is evaluated from the change of capacitance by vibrating the small metal plate. Fig. 2 shows the schematic representation of test system for investing the relation between the surface potential and the electrode potential. The test specimen used was SUS304 stainless steel and the solution was 3% NaCl. The electrode potential was polarized with 200mV step by the potentiostat and the change of the surface potential was observed (Fig. 3). The amount of potential change was the same, but the

polarity was reverse. The diameter of sensor is 2mm, so the accuracy of this device is 2mm at maximum.

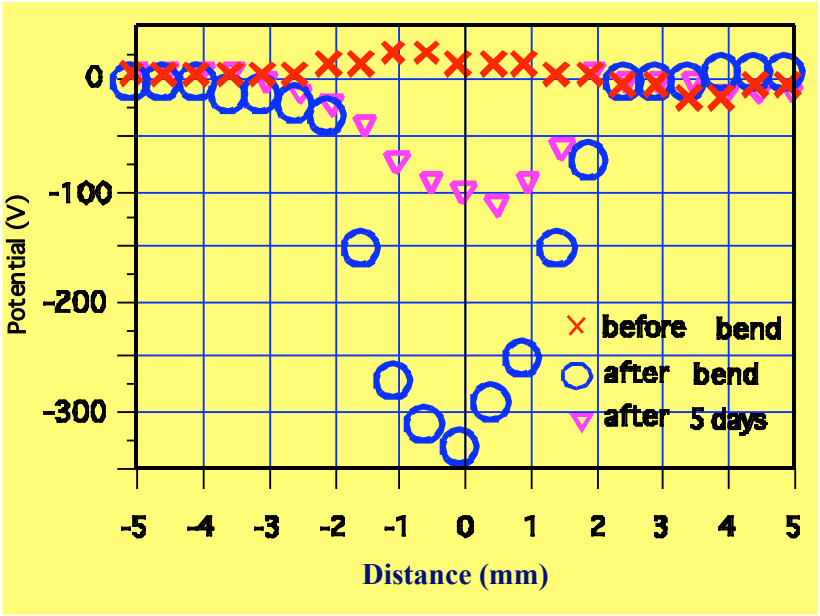


Fig. 4 Surface potential change of aluminum at the bending part with time.

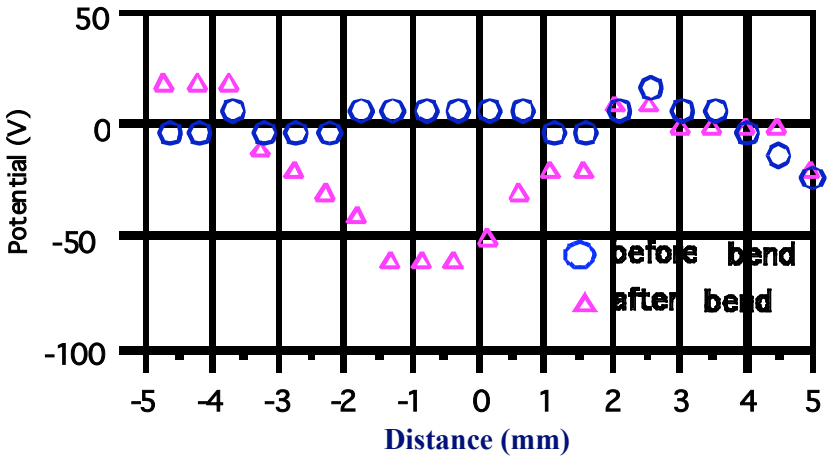
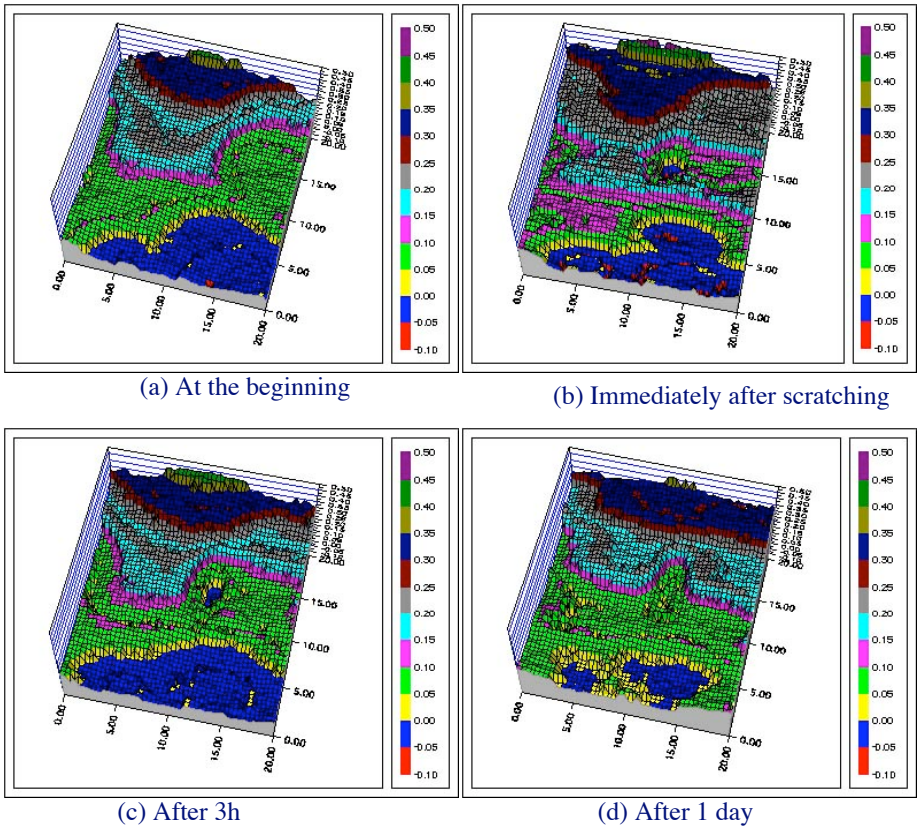


Fig. 5 Surface potential change of 18Cr stainless steel at the bending part with time.

Experimental procedure

The change of surface potential with the plastic deformation was monitored by bending the specimen at 90 degree and bending it again to the reverse direction to be the former shape. The change of surface potential distribution with time was measured after scratching (0.5mm X 3mm) on the surface of 18Cr stainless steel and aluminum by a diamond pencil. On monitoring localized corrosion, the initiation of crevice corrosion on SUS304 under thin vinyl film of 0.2mm in thickness with 1 μl of 1% $MgCl_2$ was monitored by measuring the change of surface potential distribution. On monitoring the corrosion at the defect part of coated metal, a defect was made by a cutter on the iron coated by epoxy resin (defect size: 0.1mm x 2.5mm). 1 μl of 1% $MgCl_2$ was dropped at the defect part and coated part, then the difference of potential change was studied. The differential input system was added on the surface potential measurement device for long term monitoring. The efficiency of the differential input method

was also investigated.



(a) At the beginning (b) Immediately after scratching

(c) After 3h (d) After 1 day

Fig. 6 Change of potential distribution with time on aluminum before and after scratching.

Results and discussion

Fig. 4 shows the surface potential change of aluminum at the bending part with time. The potential of bending part was about 350mV more negative than unbending part immediately after bending. The potential of bending part gradually moved to the positive direction. Fig. 5 shows the surface potential change of 18Cr stainless steel at the bending part with time. The potential of bending part was about 50mV more negative than unbending part immediately after bending. The potential difference between the bending part and unbending part was small. Thus the newly developed plastic deformation can be monitored by the surface potential measurement.

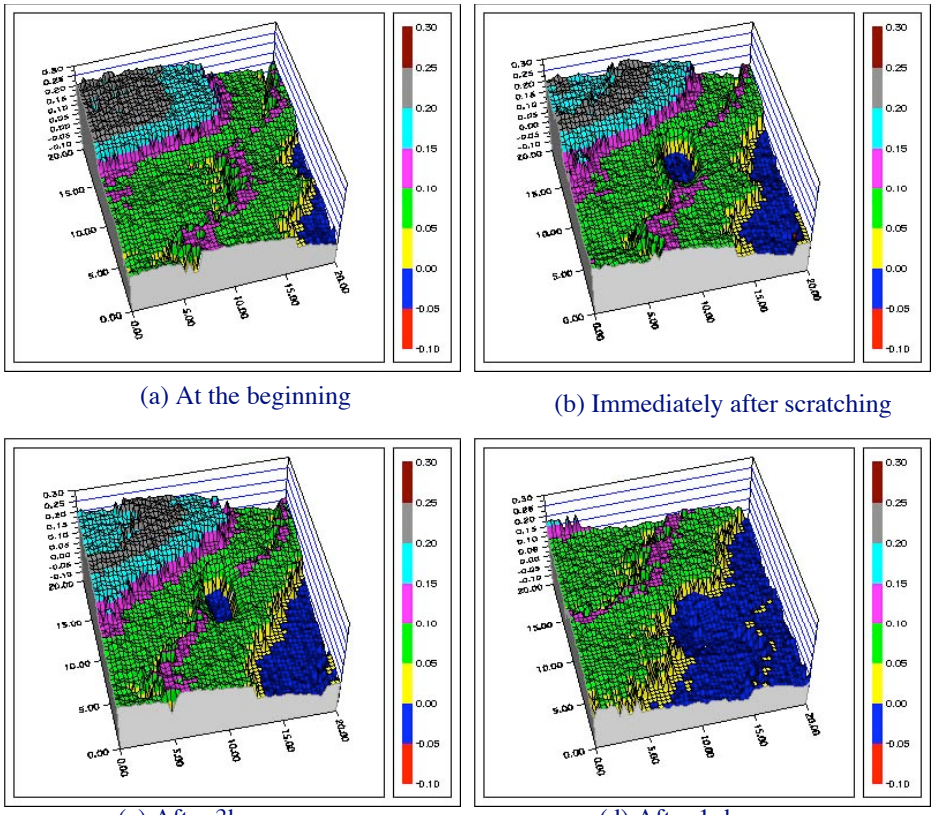
Fig. 6 shows the change of potential distribution with time on aluminum before and after scratching. The potential of scratched part moved more than 250 mV to the negative direction before scratching. The potential of scratched part gradually moved to the positive direction. The scratched part could be detected 3 hours after scratching, but it could not detected after 1 day. Fig. 7 shows the change of potential distribution with time on 18Cr stainless steel before and after scratching. The potential of scratched part moved more than 100 mV to the negative direction before scratching. As it was observed on aluminum, the potential of scratched part gradually moved to the positive direction and the scratched part could be detected 3 hours after scratching, but it could not detected after 1 day. It is clear that the newly created scratch can be monitored by the surface potential measurement.

Before starting the monitoring of the crevice corrosion, the effect of taping on the potential measurement was checked. Fig. 8 shows the potential distribution of Fe-Zn coupled metal with and without taping. The tape used was vinyl tape. The accuracy of potential without

taping was better than that with taping. However the potential distribution of with and without taping were similar to each other, so newly created damage can be monitored with taping on same cases.

Fig. 9 shows the change of potential distribution under thin vinyl film with time. As soon as the crevice corrosion started, the average potential inside of the crevice dropped about 200mV. Corroding part could not be distinguished by the potential distribution at the initial stage of corrosion, but it became clear with time. Fig. 10 shows the optical microscope image of crevice corrosion. The crevice corrosion usually started near the edge of film.

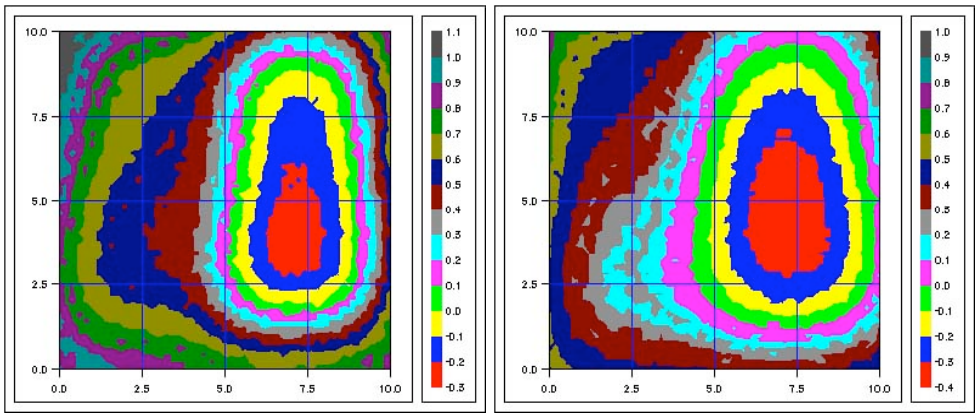
Fig. 11 shows the change of potential distribution on coated iron with time. The potential near the defect part dropped immediately after $MgCl_2$ droplet was attached by corrosion and was gradually recovered as the stop of corrosion. No change of potential distribution was detected on coated iron without defect at the same test condition.



(a) At the beginning (b) Immediately after scratching

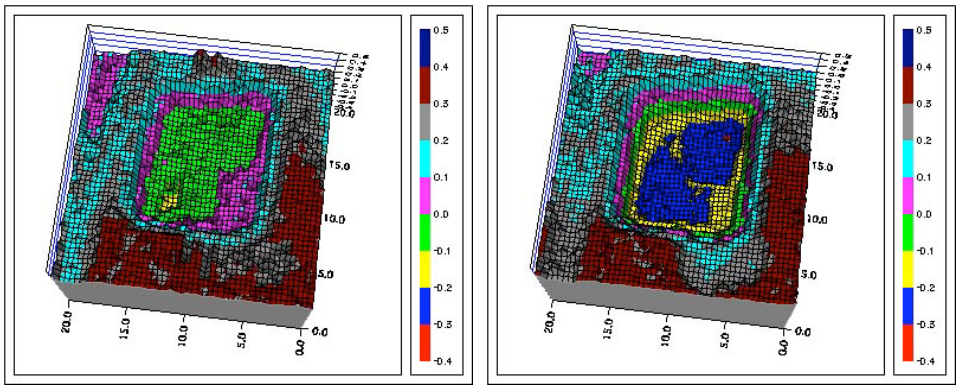
(c) After 3h (d) After 1 day

Fig. 7 Change of potential distribution with time on 18Cr stainless steel before and after scratching.

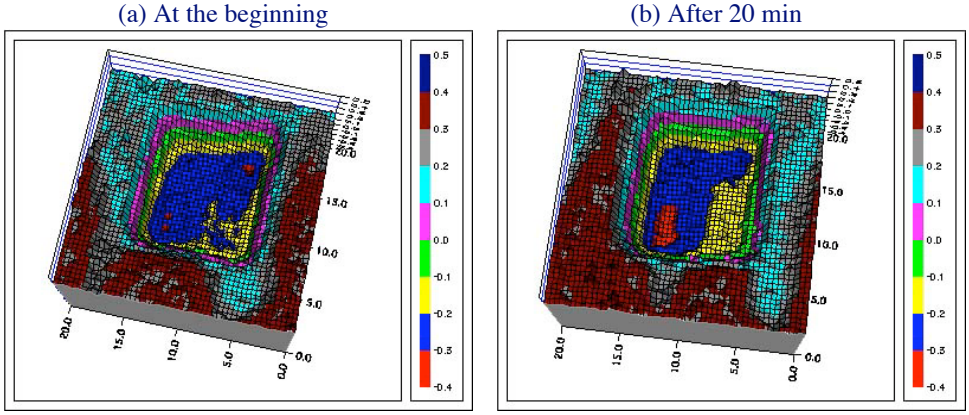


(a) Without taping (b) With taping

Fig. 8 Potential distribution of Fe-Zn coupled metal with and without taping.



(a) At the beginning (b) After 20 min



(c) After 60 min (d) After 100 min

Fig. 9 Change of potential distribution under thin vinyl film with time.

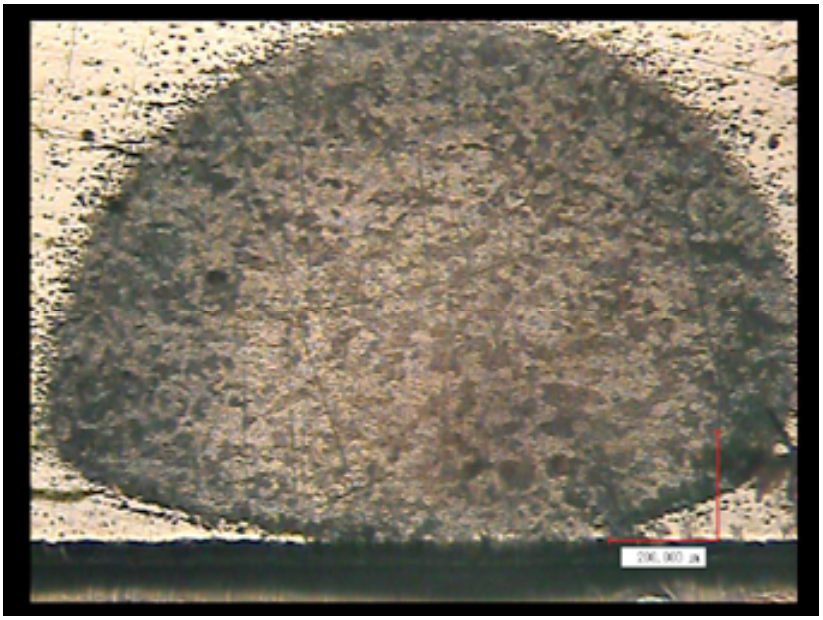
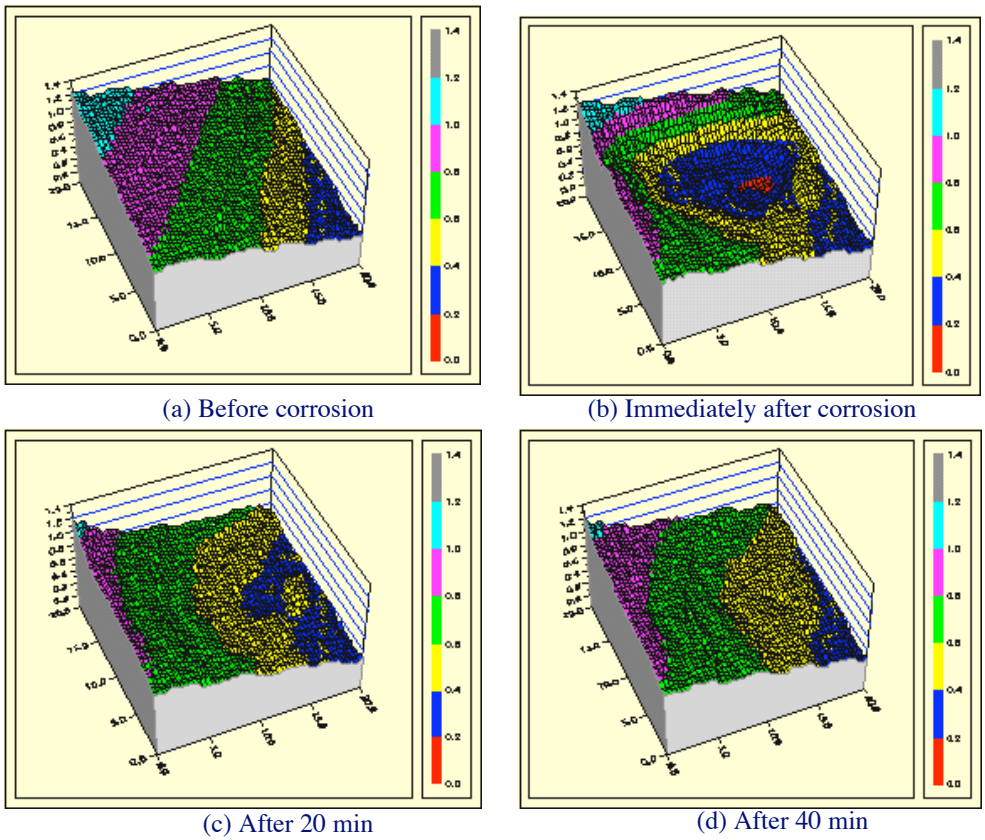


Fig. 10 Optical microscope image of crevice corrosion.

Fig. 12(a) shows the change of potential on stainless steel with time. Two sensors were used for the differential input method. The change of potential was caused by the change of relative humidity. Fig. 12(b) shows the change of potential after correction. The accuracy was increased by using the differential input method.



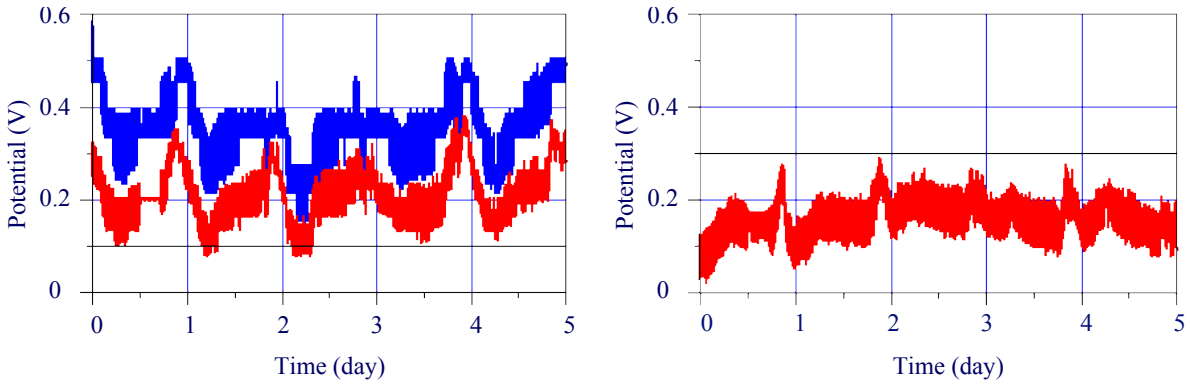
(a) Before corrosion

(b) Immediately after corrosion

(c) After 20 min

(d) After 40 min

Fig. 11 Change of potential distribution on coated iron with time.



(a) Potential change of two sensors with time

(b) Potential change with time after correction by differential input method

Fig. 12 Change of potential on stainless steel with time.

Conclusion

Two different experimental works, one is monitoring the new mechanical damage and the other is monitoring localized corrosion such as pitting and crevice corrosion, were done by using surface potential measurement device. The results show that the newly mechanically damaged part and corroding part can be detected by the surface potential measurement device. The differential input system is useful for long period monitoring.

References

1) Masuda H, "Evaluation of damage on material by surface potential measurement", *Hyoumengijutu*, 2003 54(12) 957-61.
2) Yee S, Oriani R A and Stratmann M, "Application of a Kelvin microscope to the corrosion of metals in humid atmospheres", *J. Electrochem. Soc.* 1991 138(1) 55-60