Dynamic Observation with Scanning Electron Microscope (SEM) of Hydrogen-Induced Cracking in High Strength Steel Weldments†

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KEY WORDS: (Hydrogen Embrittlement) (Cold Cracking) (High Strength) (Electron Microscope) (Plastic Deformation)

In a previous note[1)] the authors studied dynamic observation of cold cracking in weld metal of high strength steel utilizing Nomarski differential interference microscope. This technique could reveal minute plastic deformation prior to and around the cracking. A disadvantage of Nomarski microscope, however, is difficulty to distinguish the cracking from portions undergoing extremely large plastic deformation. Therefore the authors have been trying dynamic observation with SEM which has a very large depth of focus and enables us to observe in far higher magnification in order to improve the disadvantage in observation with Nomarski microscope.

Thin sheets, the dimensions of which were 17.5 mm in length, 12.5 mm in width and 3 mm in thickness were sliced mechanically from T-1 type high strength steel HT80 whose ultimate strength was 80 kg/mm^2 class. They were gathered in two rows through end tabs with cramp jig as shown in **Fig. 1 (a)**. Then, TIG-arc welding was done without filler metal in the condition of 300A, 17V and 150 mm/min, where Ar-1%H_2 mixing gas was used as the shielding gas in 20 l/min of total amount of gas flow. The specimen was quenched in water immediately after the welding, and soon transfered into liquid nitrogen. Then, they were wedged to obtain the test specimens for dynamic observation as shown in **Fig. 1 (b)**. The test specimen was metallographically polished as soon as possible and set to a testing device shown in Fig. 2 (b) in the previous note[1)], although the device in this note was an improved one. The bending strain was selected to 0.5% perpendicular to the root face. The test specimen set to the testing device as shown in **Fig. 2** was put into a scanning electron microscope HITACHI

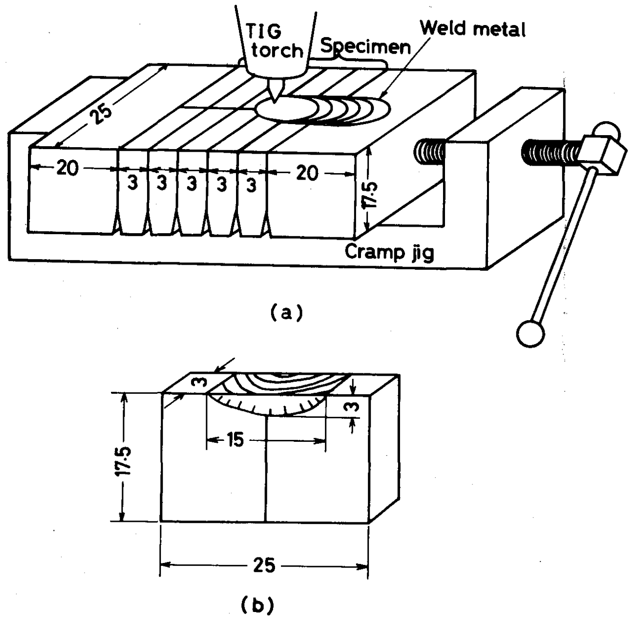

Fig. 1 Illustration of (a) welding procedure and (b) test specimen

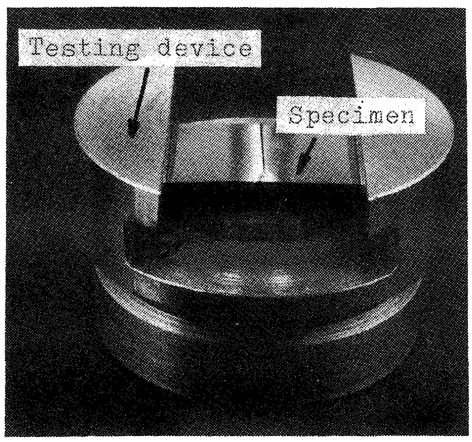

Fig. 2 Close-up view of setting of specimen into testing device

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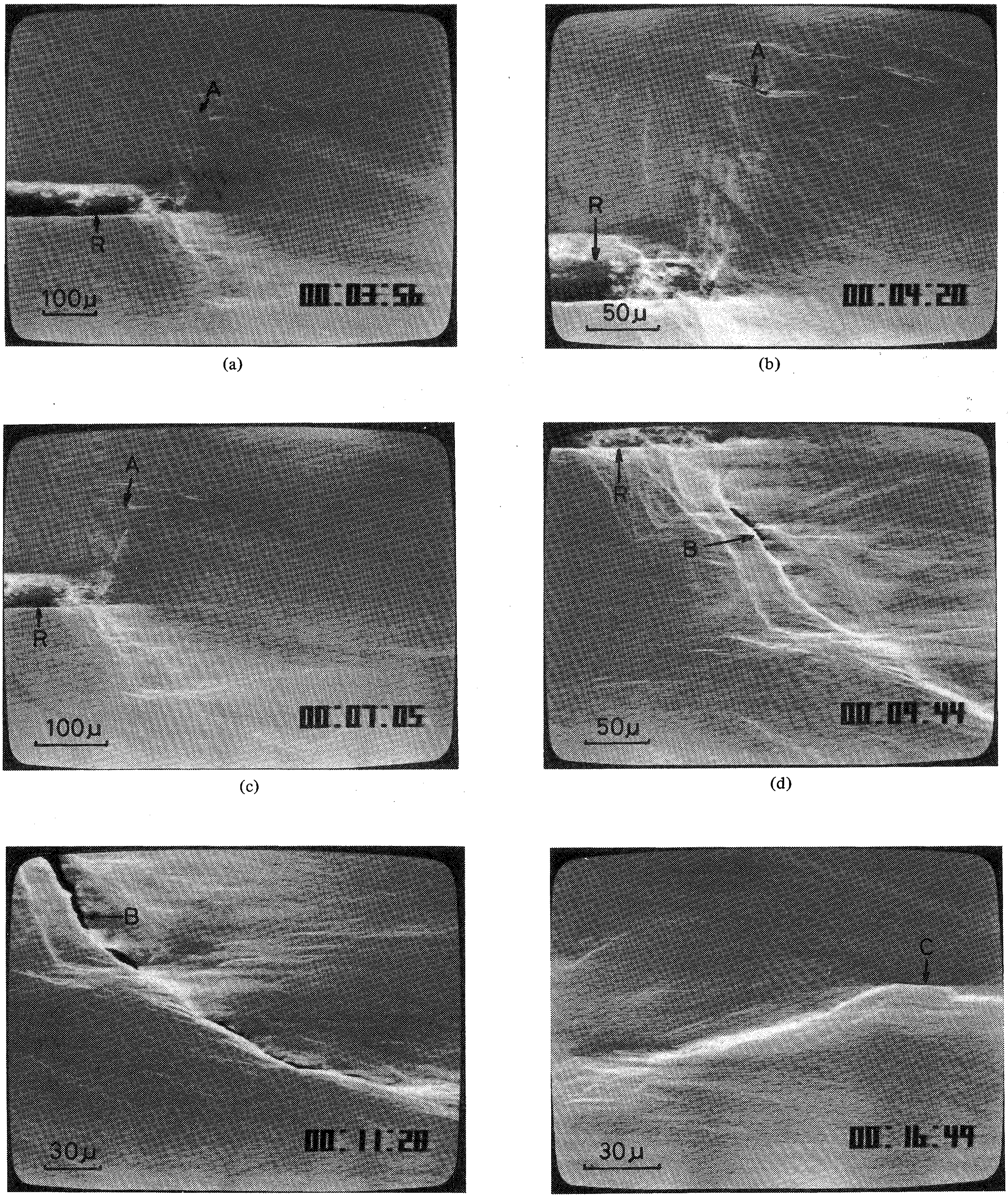
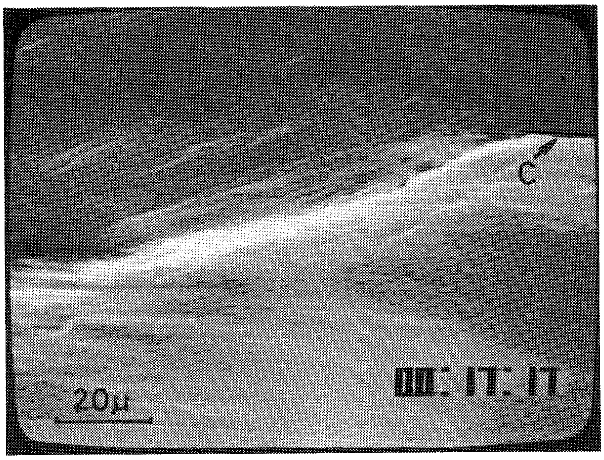
HSM-2B where TV scanning equipment HITACHI S5010 was especially supplemented. Then the change in plastic deformation and cracking was recorded with a video tape recorder.

An example of sequence of video pictures during the testing is shown in **Fig. 3**. The six letters at lower right

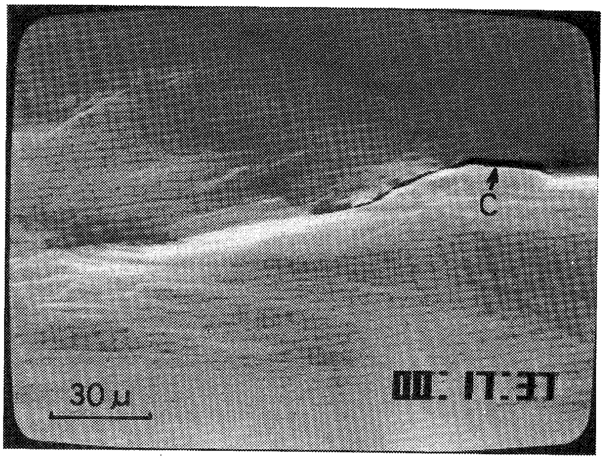


(a) (b) (c) (d) (e) (f)

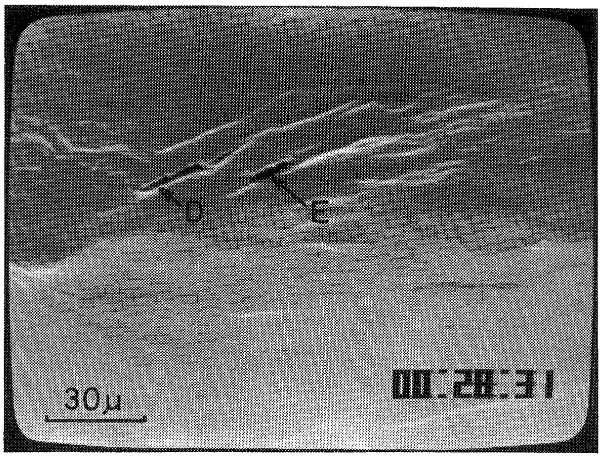
Fig. 3 Change in plastic deformation and cracking vs. time site in each picture show the time after the straining in a manner as XX(hr) XX(min) XX(sec). At 3 min 56sec, Fig. 3 (a), two regions deformed plastically are observed in two directions from the edge of root (R) which were formed at the same time of the straining, and a micro crack (A) was formed in one of the regions deformed plastically. This micro crack hardly grew thereafter. Then the region deformed plastically which lay on opposite side of the micro crack grew a little in Fig. 3 (c), and then a micro crack (B) was formed in Fig. 3 (d). After a



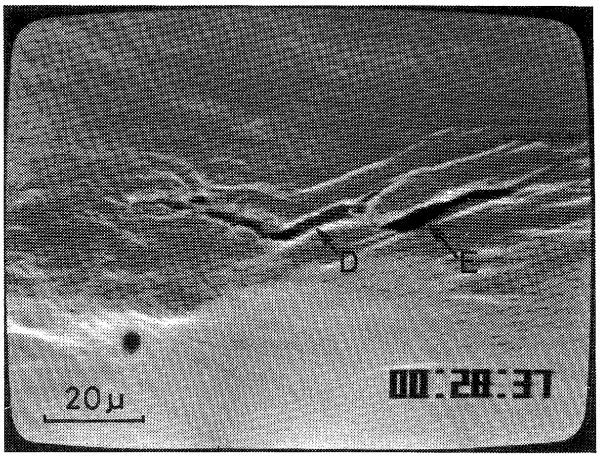
(g)



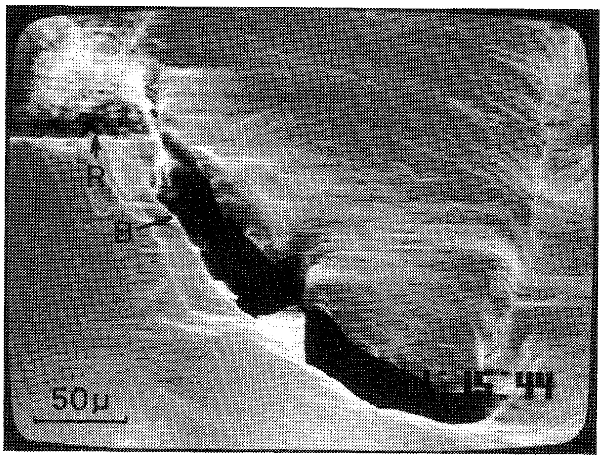
(h)



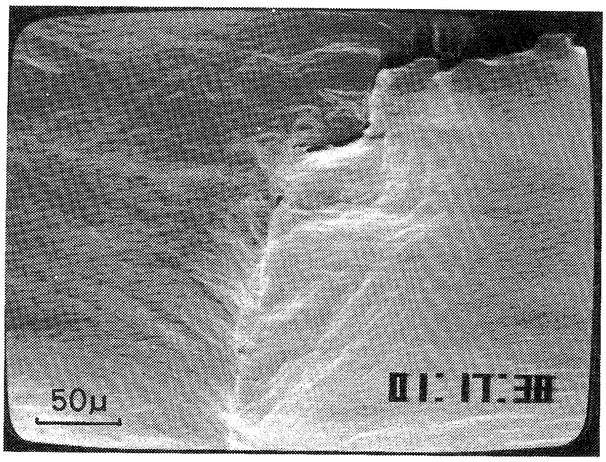
(i)



(j)



(k)



(l)

Fig. 3 (continued)

while, other micro cracks were formed in front of B along the deformed zone in Fig. 3 (e). In Fig. 3 (f), (g) and (h), a micro crack (C) was growing at a place in far front of the micro crack (B). Figure 3 (i) and (j) show other micro cracks (D) and (E) growing, which are considered to occur along martensite laths. The growth of these cracks stopped by about 30 min, when they had grown to macro-cracks as seen in Fig. 3 (k). Figure 3 (1) shows the upper right area of Fig. 3 (K).

It is noticeable that a micro crack in Fig. 3 (b), (d), (e), (f), (g), (h) and (i) always occurred along very large slip bands which were seen brightly. Consequently SEM observation is suitable to reveal the relation between large plastic deformation near and just before the initiation of crack and the cracking site. The detailed studies are planned by the authors.

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Reference

1) F. Matsuda, H. Nakagawa, T. Sugimoto and H. Kihara: Trans. JWRI, Vol. 8 (1979), No. 2, pp. 129 - 131.