TECHNICAL NOTE

Hydrogen-Induced Cracking (HIC) for Electron-Beam Weldments of High Tension Constructional Steels†

Fukuhisa MATSUDA*, Hiroji NAKAGAWA and Sanae TSURUTA*****

KEY WORDS: (Hydrogen-Induced Cracking, HIC) (Electron-beam Welding) (High Tension Steel)

As well known electron-beam welding technique has many advantages for welding of various steels, that is, deep penetration, single pass welding of heavy thick steel, high speed welding, narrow HAZ and so on. Therefore the technique is gradually utilized for welding of large-scale construction using various high tension constructional steels. Moreover it is expected an advance utilization of this technique for the welding of pipelines for gas and fluid transportation on land and under water.

However the heat cycle during welding of electron-beam welding is so rapid that the hardnesses of weld metal and HAZ of hardenable steel show very high. Moreover usually the welded joint is used in as-weld and hardened condition.

The authors, therefore, are anxious about the HIC (hydrogen-induced-cracking) in electron-beam weldment of constructional high tension steel when the joints are exposed in an electrolytic condition under water or well-damped atmospheric environment.

This note has concerned about the risk for the HIC in electron-beam weldments of HT50 and HT80 high tension constructional steels using a technique of electrolytic charge of hydrogen.

Table 1. Steels used, EBW condition and hardness of weldment

Steel	Mark	EBW Condition				Weld Heat Input (kJ/cm)	Penetration (P) (mm)	Hardness (Hv max, 10kgf)		
		Vb (kV)	Ib (mA)	vb (cm/min)	ab			Weld	HAZ	Base
HT50 (SM50C) (50mmT)	50-a	55	450	50	0.7	29.7	64	330	340	170
	50-b	55	450	30	0.7	49.5	48	260	275	170
HT80 (70mmT)	80-a	55	450	50	0.7	29.7	64	370	390	280
	80-b	55	450	30	0.7	49.5	48	350	370	280

HT50:0.17C,0.41Si,1.40Mn,0.022P,0.010S (Ceq:0.41)
HT80:0.12C,0.24Si,0.82Mn,0.014P,0.006S,0.22Cu,0.51Cr,0.83Ni,0.46Mo,0.04V,0.0005B (Ceq:0.51)

Table 1 shows two different steels of HT50 and 80 used, EBW condition, and maximum hardnesses of weld, HAZ and base metals. Two different welding conditions (29.7 and 49.5 kJ/cm) for each steels were selected for bead-on-plate welding. The specimen for the HIC was cut, as shown in **Fig. 1(a)**, from each weldment and hydrogen was charged electrolytically from the right wall of the specimen cut with 0.2 A/cm^2, 24 hrs. The solution for hydrogen charge is aqueous solution of 5% sulfuric acid, to which phosphorus was added.

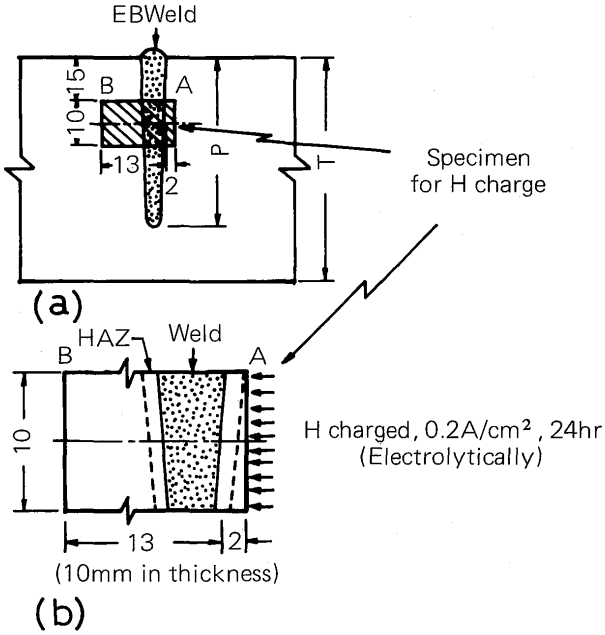

Fig. 1 Specimen size and process for hydrogen charge of EBW weldments
(a) specimen taking out from weldment
(b) hydrogen charge

After charging of hydrogen microscopic investigation was done in mid-thickness of the specimen for verification of the occurrence of the HIC. The results were shown in **Fig. 2(a)** for 50-a, **(b)** for 50-b and **(c)** for 80-a. In (a) and

† Received November 1, 1984
* Professor
** Research Instructor
*** with Tobata Plant, Nippon Steel Corporation

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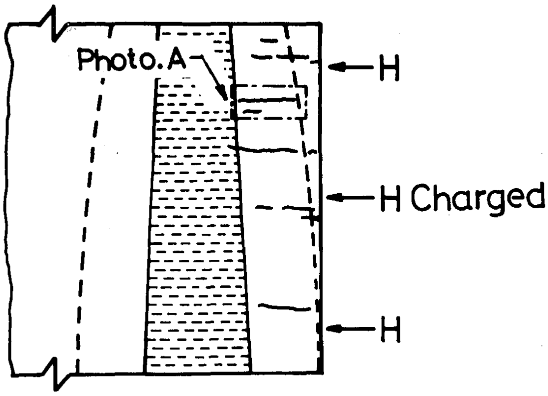


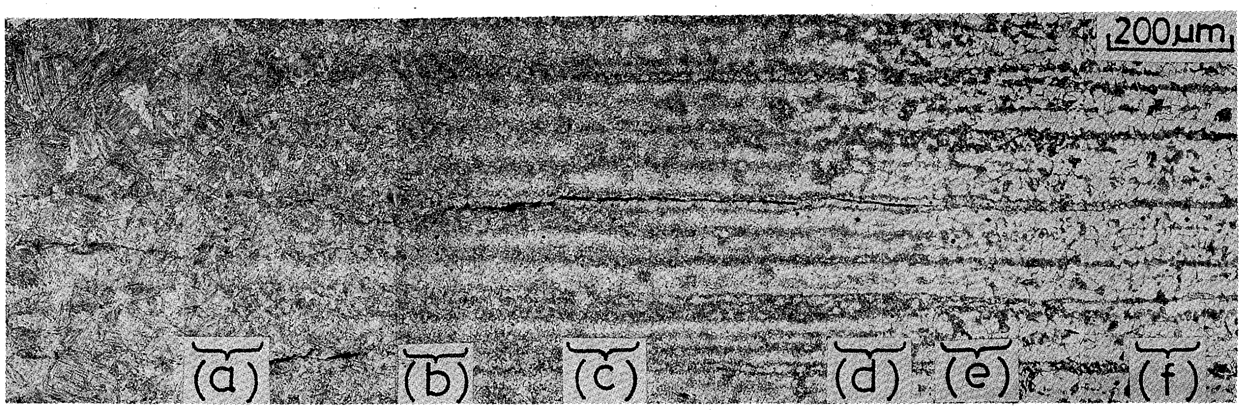


Photo. A

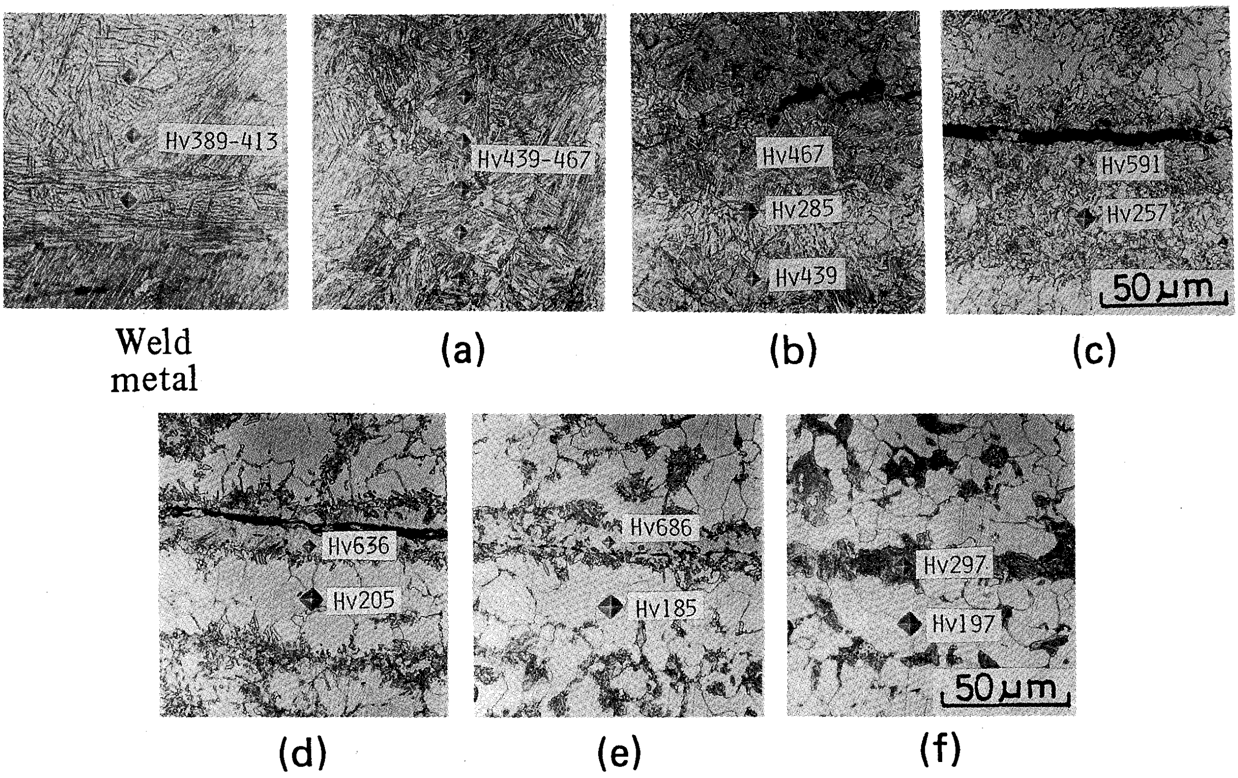
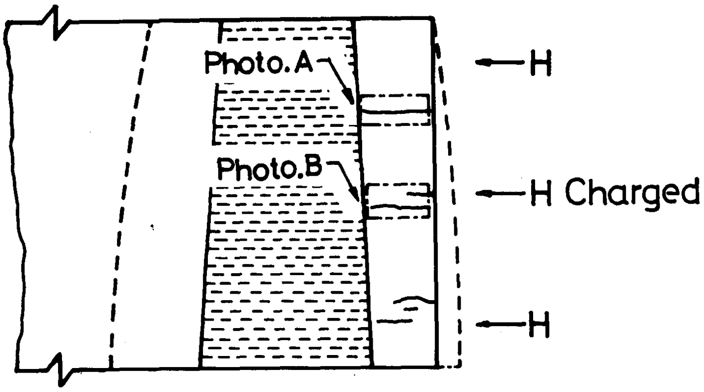


Fig. 2(a) HIC of HT50 Weldment (50-a)



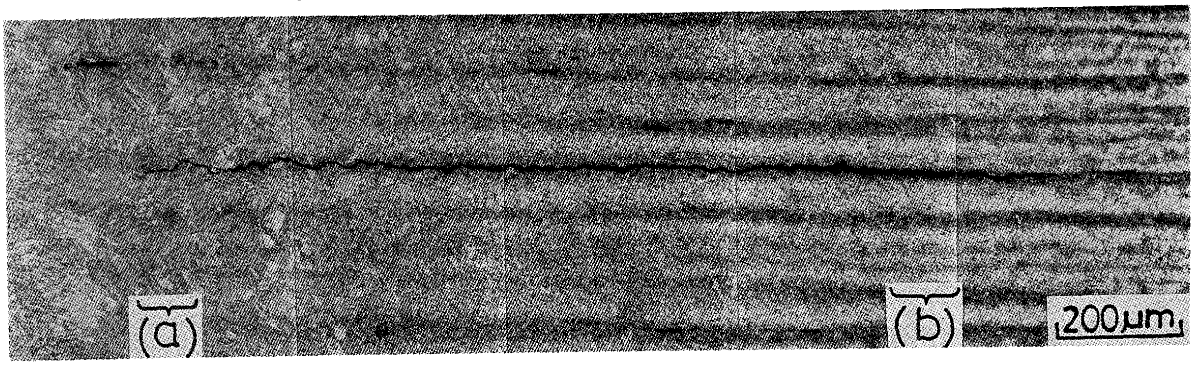


Photo. A

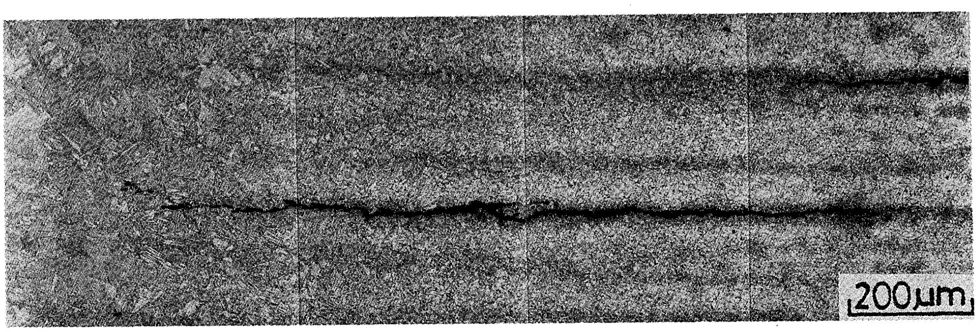


Photo. B

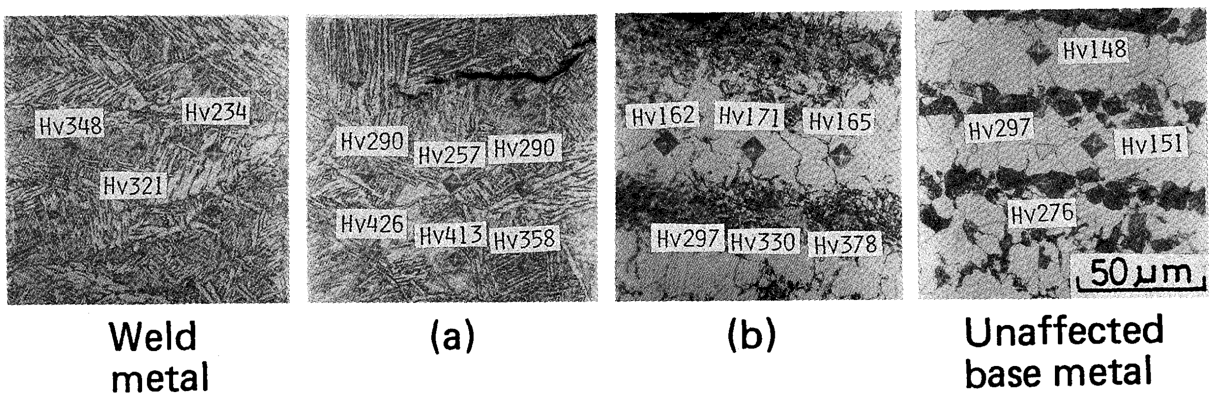


Fig. 2(b) HIC of HT50 Weldment (50-b)

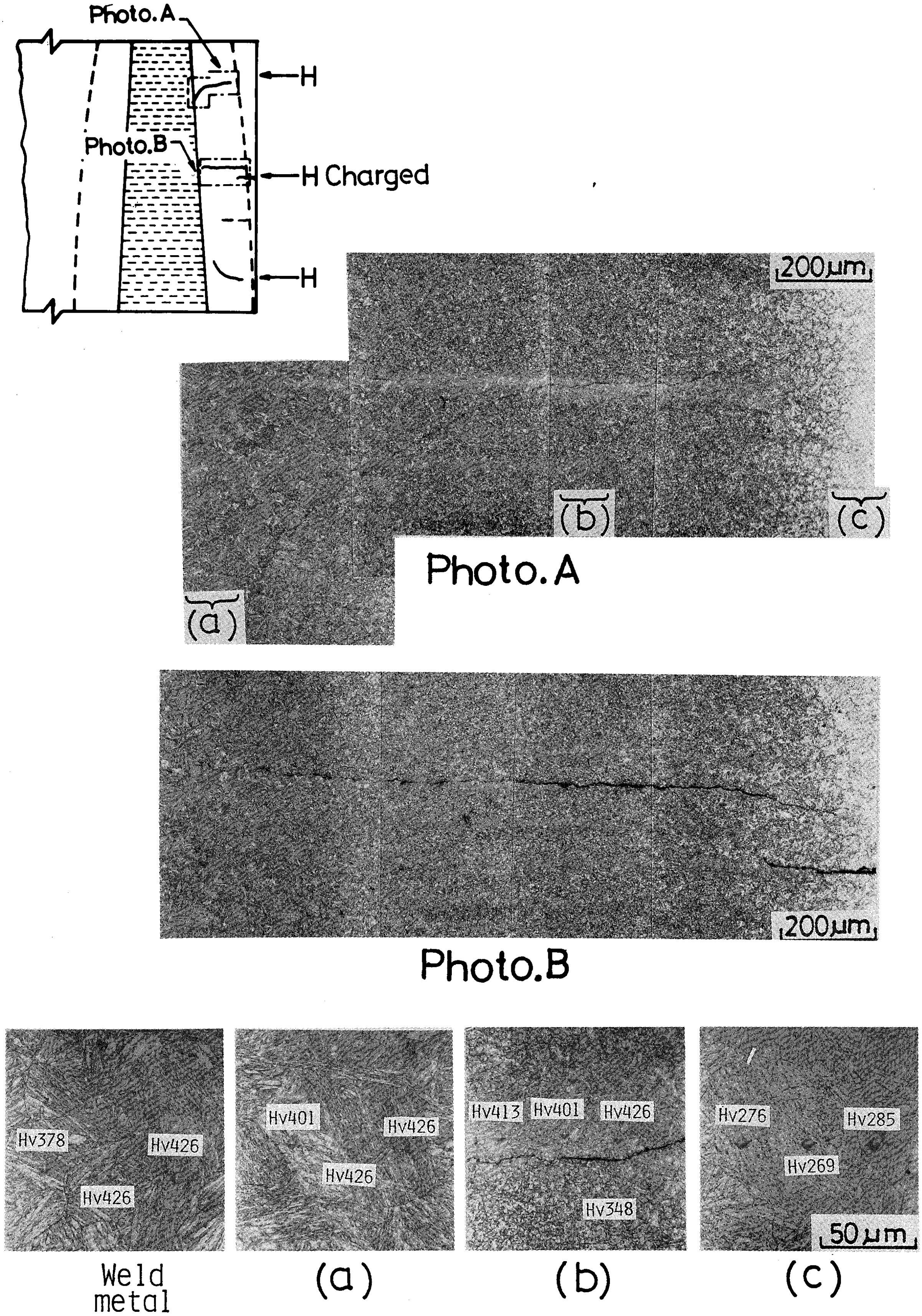


Fig. 2(c) HIC of HT80 Weldment (80-a)

(b) the occurrences of the HIC were apparently seen in macrostructure along banded structures of pearlites in HT50 and propagated to the coarsened prior-austenite HAZ or weld metal zone. In microstructure in the lowest of (a) and (b) it is seen that the HIC occurs in hardened prior-pearlite band which was transformed to austenite and quenched during weld heat cycle. This zone was high carbon martensite due to transformation of pearlite to austenite.

In (c) of HT80 the HIC occurred along a so-called "white band" which generated in the weld heat cycle and has a high hardness. Moreover in welding condition 80-b there were only small cracks within the "white band" zone.

Therefore, as a result the occurrence of the HIC preferentially started in the outer side of HAZ of electron-beam weldment of HT50 and HT80. It is concluded that this crack susceptible zone was heated to between A_1 and A_3 or just above A_3 transformation point of steel during weld heat cycle, and contained partially much hardened structure as high carbon martensite.

It is a future subject whether this HIC originated in the outer zone of HAZ propagates to coarse-grained HAZ and weld metal under stressed condition or not. Moreover it is very important to understand quantitatively the susceptibility of the HIC occurrence in electron-beam weldments which are used in as-weld condition before the rapid advance in application of electron-beam and also laser weldings.