Simulation Test of Disbonding between 2$\frac{1}{4}$Cr-1Mo Steel and Overlaid Austenitic Stainless Steel by Electrolytic Hydrogen Charging Technique†

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Disbonding meaning separation-type cracking which occurs at the transition zone between 2¼Cr-1Mo steel and overlaid austenitic stainless steel of oil refining vessel in its shutdown period has been serious problem at the present. The disbonding is considered to be attributed to hydrogen accumulation at the transition zone, and has been generally studied with autoclave in laboratory scale[1,2].

On the other hand, electrolytic hydrogen charging technique has been widely used for the study on hydrogen embrittlement because of the simplicity of apparatus. Therefore, the authors has been studying to apply electrolytic charging technique for the study on the disbonding phenomena and its direct observation.

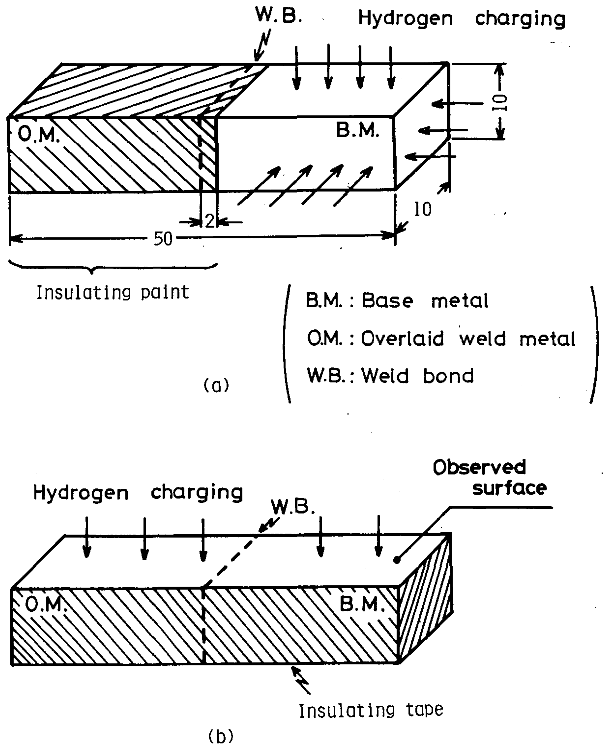

Fig. 1 Specimen configuration for hydrogen charging
(a) general type
(b) special type for direct observation

Type 309 filler metal of 75 mm width and 0.4 mm thickness was overlaid on 2¼Cr-1Mo steel of 80 mm thickness with submerged-arc welding. Welding conditions were; welding current of 1350 ± 50(A), arc voltage of 27(V), welding speed of 16 ± 1 (cm/min), preheating temperature of 100(°C) and interlayer temperature of 150(°C). For the special purpose of direct observation mentioned later, eight layers were deposited.

Hydrogen was charged electrolytically to the specimen shown in **Fig. 1(a)**, cut from the weldment, where shadow region means insulating paint used during the charging. The paint covers all the overlaid weld metal and HAZ region within 2 mm from the weld bond, and thus hydrogen was charged to only the base metal. Consequently hydrogen accumulation was expected to occur at the transition zone in overlaid austenitic weld metal because of the higher solubility and the lower diffusibility in its austenitic structure. At about 24 hr after the charging, the specimen was cut along the longitudinal middle section, and crack was inspected with optical and scanning electron microscope.

Table 1 shows the effects of current density and charging time on the occurrence of the disbonding. Generally high current density or long charging time promotes the

Table 1 Effects of current density and charging time on occurrence of disbonding

Material	Charging time (hr)	Current density (A/cm^2)			
		0.01	0.03	0.05	0.1
As welded	6	o	x	x	x
	12	o	x	x	x
	24	o	x	x	x
PWHT*	6	o	o	o	o
	12	o	o	o	x
	24	x	x	x	x

o: no crack, x: crack , *: 690°Cx26hr

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disbonding. Interestingly the specimen as welded gives higher susceptibility to disbonding than the PWHT specimen, the reason of which is not understandable now.

Microscopic observation revealed four types of disbonding location, namely Type A, B, C and D as shown schematically in **Fig. 2**, and their actual examples are shown in **Fig. 3**. In Fig. 2 martensite zone is classified into two zones, namely brown colored and black colored zones according to the etching by Marble's reagent. The black colored zone is considered to correspond to so-called carbide precipitation layer, and gave about 280 – 350 H_V in microhardness. The brown colored zone gave about 350 – 400 H_V. Type A disbonding occurred along the grain boundary in austenitic weld metal near the weld bond. Type B disbonding occurred nearly along the saw-toothed border between the austenite and the martensite phases. Also Type B crack generally occurred along grain boundary. Type C disbonding occurred in the brown colored martensite zone, and Type D disbonding occurred in the black colored martensite zone. By varying the charging time from 6 to 24 hr, it was guessed that the disbonding first ocurred as Type B, and then propagated as Type A, C and D.

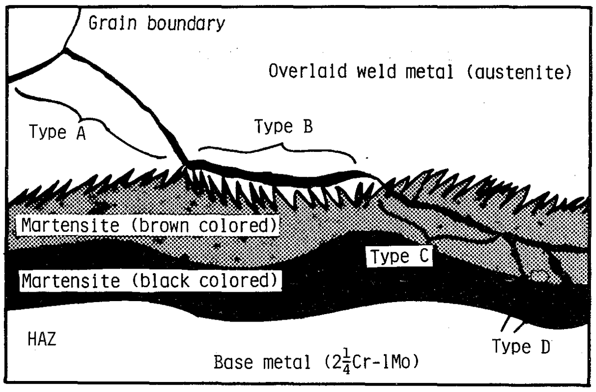
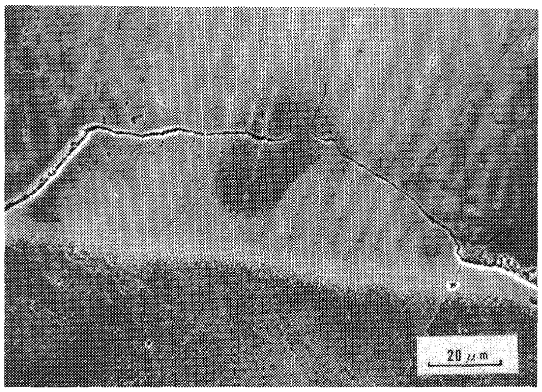
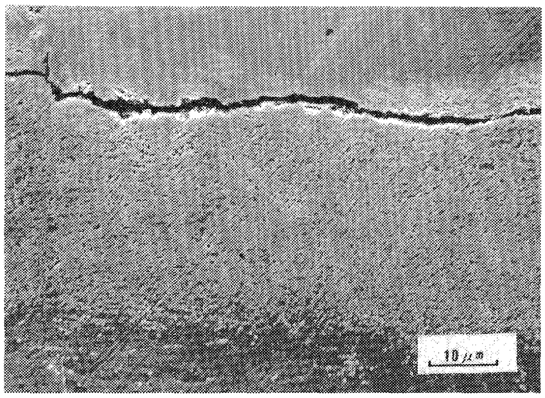


Fig. 2 Illustration of four types of disbonding location

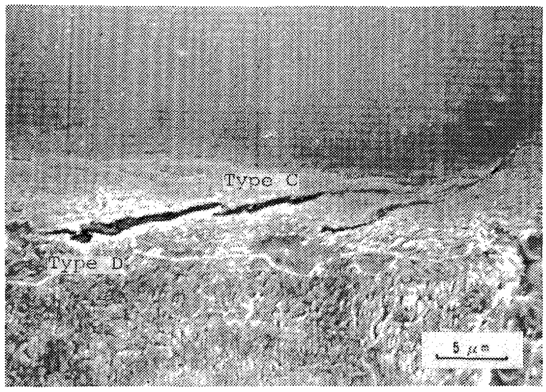
Nextly, direct observation was tried to confirm the initiation site of disbonding. Hydrogen was charged to only one side including both base metal and overlaid weld metal as shown in **Fig. 1 (b)**. Current density was 0.04 (A/cm^2) and charging time was 6 (hr), under which there was no disbonding. After the charging, the specimen was soon polished and etched electrolytically, and set to a four point bending apparatus combined with an optical microscope. The surface stress was gradually increased by a step of 5 (kgf/mm^2) in each holding time of 2 (min). Typical example of direct observation is shown in **Fig. 4**, where disbonding first occurred as Type B at the stress of 20 (kgf/mm^2), and propagates as also mainly Type B with occasional case as Type A and C.



(a) Type A



(b) Type B



(c) Types C and D

Fig. 3 Actual examples of four types of disbonding location

Consequently, it is concluded that electrolytic hydrogen charging technique is useful for the study on the disbonding. In the future subject, correspondence between this technique and actual case should be established.

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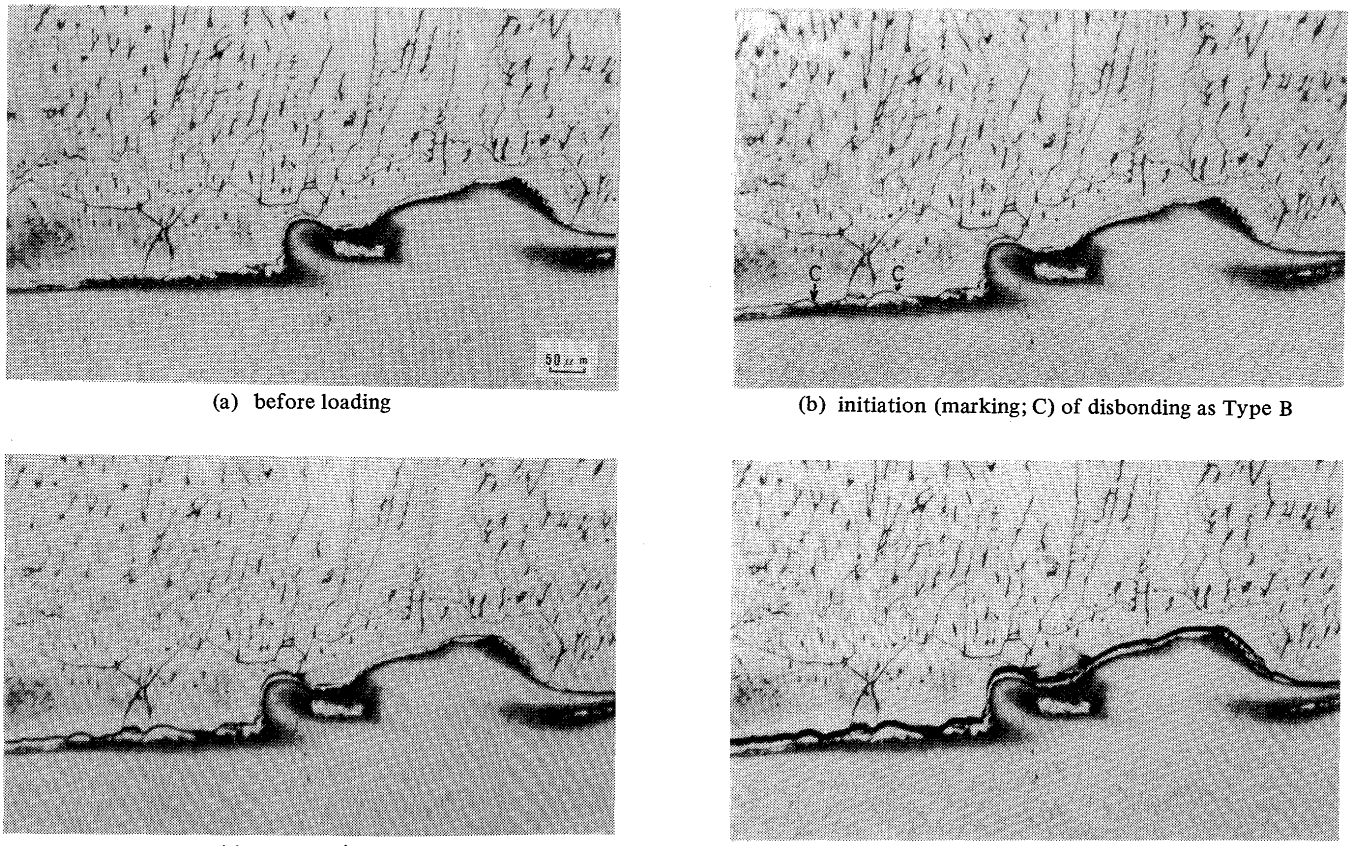

(a) before loading

(b) initiation (marking; C) of disbonding as Type B

(c) propagation

(d) propagation

Fig. 4 An example of direct observation of disbonding

References

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2) K. Ohnishi, et al.: Quarterly J. Japan Weld. Soc., Vol. 1 (1983), No. 3, p. 377. (in Japanese)