Effect of Oxygen Content on Diffusible Hydrogen in Weld Metal in Inert-Gas Arc Welding for High Strength Steel†

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After the fractographic investigation[1] the authers already reported that weld metal cracking of HY-130 steel (5Ni-Cr-Mo-V) was easy to occur in intergranular fracture mode affected by hydrogen embrittlement in the TRC test with shielded-metal arc (SMA) welding. Furthermore there were many oxides on the fracture surface.

On the other hand, it is known[2] that HY-130 steel is much susceptible to weld cracking of hydrogen delayed type even in gas metal arc (GMA) welding with argon-oxygen mixture shielding gas.

Judging from the above, oxygen may affect the weld cracking of HY-130 steel, so the effect of oxygen in weld metal on diffusible hydrogen content has been investigated as one of investigations about the effect of oxygen on weld cracking.

Chemical compositions of HY-130 steel of 100 kg/mm^2 tensile strength level and filler metal F 130 used for GMA welding are shown in **Table 1**. The yield strength and the tensile strength of F130 weld metal well match those of HY-130 base metal.

Table 1 Chemical compositions of HY-130 steel and F130

Material	Composition (wt.%)										
	C	Si	Mn	P	S	Cu	Ni	Cr	Mo	V	O
HY-130	0.11	0.31	0.83	0.004	0.008	0.04	4.92	0.50	0.47	0.059	0.0021
F130	0.09	0.37	1.92	0.003	0.002	0.21	2.64	1.15	0.66	–	0.0049

Experiment A

The two different types of experiment were undertaken.

The experimental procedure shown in **Fig. 1** was undertaken in order to investigate the effect of oxygen in base metal on diffusible hydrogen content. A gas

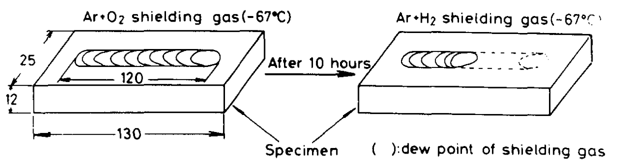

Fig. 1 Welding procedure to examine the effect of oxygen in weld metal on diffusible hydrogen content

tungsten arc (GTA) welding without filler metal was done on the specimen as shown in Fig. 1 using argon-oxygen shielding gas in which oxygen content was changed 0, 1.0, 3.0 and 5.0%. The oxygen content in weld metal was 5, 50, 300 and 600 ppm respectively according to LECO analyser. The specimen was left for 10 hours at room temperature after welding in order to release the diffusible hydrogen. Then a GTA welding was done again on the previous weld metal using argon-hydrogen shielding gas by the same welding condition. Hydrogen content in shielding gas was changed 0.3, 1.0 and 2.5%. Then the diffusible hydrogen content was measured.

Diffusible hydrogen content was measured by modified JIS method in which mercury at 45°C was used as a confining liquid instead of glycerine. The specimen was

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maintained for 48 hours and then the volume of hydrogen was measured. The diffusible hydrogen content was represented in mℓ/100g fused metal in GTA welding.

The welding conditions were 300 amp, 16-18 volt, 150 mm/min and bead length was about 120 mm. Total gas flow was 20 ℓ/min.

Experiment B

The experimental procedure shown in **Fig. 2** was

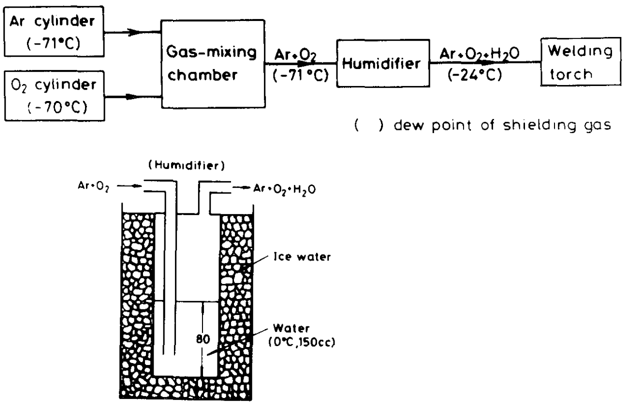

Fig. 2 Mixing process of argon, oxygen and water vapor in shielding gas and inner construction of humidifier

undertaken in order to investigate the effect of oxygen content in shielding gas. A GTA welding without filler metal and a GMA welding were done using argon-oxygen-water vapor mixing shielding gas. Argon and oxygen gases were mixed with a mixing chamber and water vapor was mixed with a humidifier, the inner construction of which is shown in Fig. 2. The dew point of argon-oxygen mixing gas was -71°C and that of argon-oxygen-water vapor mixing gas was -24°C.

The welding conditions were 300 amp, 16-18 volt, 150 mm/min in GTA welding and 280 amp, 33 volt, 330mm/min in GMA welding. Total gas flow was 20 ℓ/min in both weldings.

Diffusible hydrogen content was measured by the same technique as discribed already in Experiment A and was represented in m ℓ/100 g fused metal in GTA welding and m ℓ/100 g deposited metal in GMA welding.

Results

The relationships between oxygen content in weld metal of the second GTA welding in Fig. 1 in experiment A and diffusible hydrogen content are shown as broken lines in **Fig. 3**. An increase in oxygen content in weld metal increases diffusible hydrogen content in three different levels of hydrogen content in shielding gas. The same tendency was also observed in high tensile strength

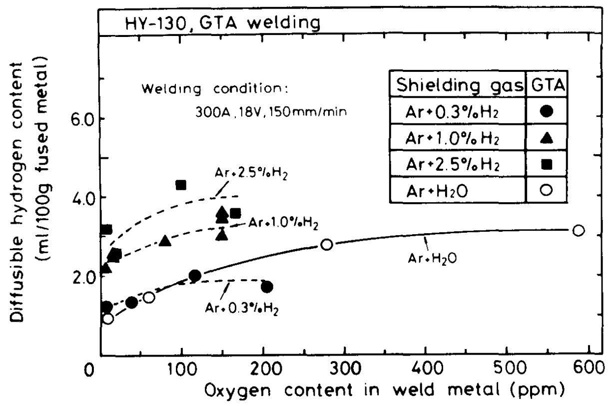

Fig. 3 Relationship between oxygen content in weld metal and diffusible hydrogen content with GTA welding

steel of 80 kg/mm^2 tensile strength level.

The relationships between oxygen content in shielding gas and diffusible hydrogen content in GTA and GMA welding are shown in **Fig. 4**. The increase in oxygen

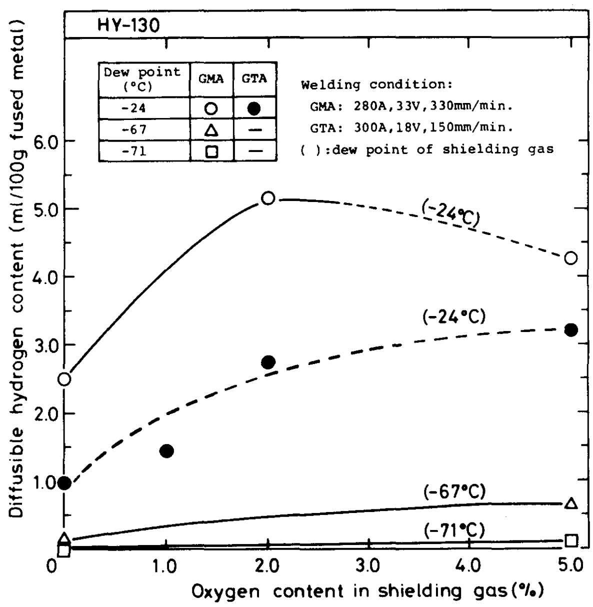

Fig. 4 Relationship between oxygen content in shielding gas and diffusible hydrogen content for various dew points of shielding gas with GMA and GTA welding

content in shielding gas increases diffusible hydrogen content in both GTA and GMA welding, though the degree of the increase depends on the dew point of shielding gas. Moreover the diffusible hydrogen content in GMA welding is more than in GTA welding in comparison with the two weld metals which were welded with the shielding gas of -24°C dew point. Moreover, lowering the dew point, namely the partial pressure of water vapor in shielding gas decreases the effect of oxygen on diffusible hydrogen content. Then, if the dew point of shielding gas during GMA welding is below than about

–70°C, the diffusible hydrogen content will be not increased in the weld metal regardless of addition of oxygen gas in shielding argon gas.

The data in GTA welding in Fig. 4 were transferred into Fig. 3 in open marks with a solid line. Thus, it is understood that the data nearly agree with that in argon–0.3% hydrogen shielding gas. This means that comparing the effects of oxygen with the content in the weld metals for the two experiments A and B shown in Fig. 3, the oxygen in shielding gas has comparable effect with that in the weld metal.

It is briefly summarized as follows;

An increase in oxygen content in shielding gas or in weld metal increases the diffusible hydrogen content, if the shielding gas contains hydrogen or moisture. Lowering the partial pressure of water vapor in shielding gas decreases the effect of oxygen. Therefore, for GMA welding high sensitive steel to hydrogen-induced cracking as HY-130 the dew point of argon-oxygen mixture shielding gas should be kept as low as possible, for example, below than –70°C. In order to keep this recommendation, we must deeply give attention to the selection of the material of gas leading hose from gas cylinder to welding torch. Within the authors' experience polyethylen hose is preferable to rubber hose for GMA welding.

References

1) F. MATSUDA, et al.; Fractographic Investigation on Root Crack in the TRC Test of HY-130 Steel, Trans. JWRI, Vol. 6 (1977), No. 2, pp.59-73
2) Private communication