A STUDY ON CHARACTERISTICS OF SCC PROPAGATION
da/dt FOR WELDED JOINT

Song Jiayin (宋甲荫) Wang Zhengfang (王正方) Chang Xiuying (张秀英)
Meterials Dept. Beijing Polytechnic University, China

ABSTRACT

Characterictics of transverse propagation (T.P.) and longitudinal propagation (L.P.) of SCC on parent metals, welded metals and heat affected zone (H.A.Z.) of steels of 16Mn, 09MnTiCuRe I and II, using constant displacement WOL specimen[1,2] were demonstrated in this paper. Micro and macro fractographs were carefully observed and analyzed. Two kinds of heat simulated specimen of fusion line were used and it is proved that the stress corrosion resistance of the fusion line is the lowest. The front of longitudinally propagated crack at the fusion line presented a "Concave" shape and the curve da/dt-K_1 of T.P. appeared in "Saddle" pattern.

MATERIALS AND SPECIMENS

1. Parent metals: 16Mn(35kg), 09MnTiCuRe I(35kg), 09MnTiCuReII (40kg).
2. Electrode: T507A(6_b 50kg)
3. Specimens and heated conditions

No.1,3,5	Parent metal as rolled.	No.6 Weld metal.
No.5	Parent metal normalized	No.4 T.P.
No.2,9	Fusion line heat simulated.	No.8 L.P.

Heat circulation curves of specimens were shown in Fig. 1.

EXPERIMENTAL PROCEDURE AND RESULTS

1. Sampling

The ways of sampling were shown in Fig. 2-a, 2-b, 2-c, for specimen

No.4,6,8 respectively.

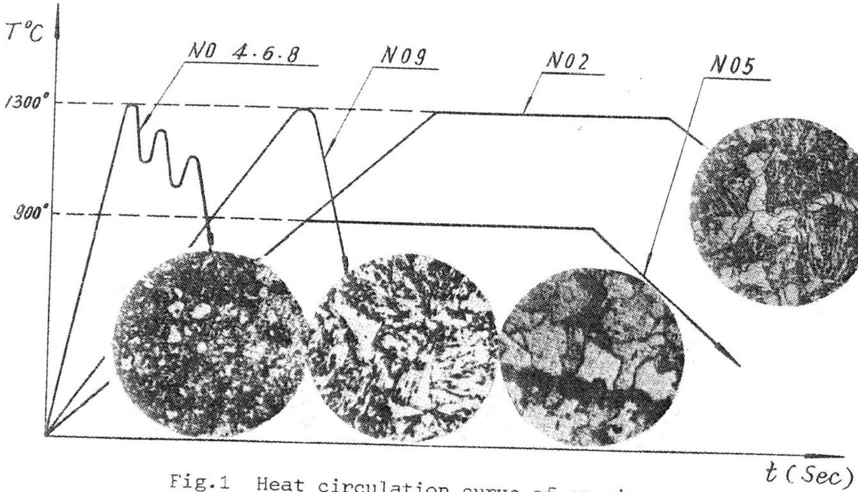

Fig.1 Heat circulation curve of specimens

2. Experimental Method[3]

WOL specimen was used for both da/dt and K_{1scc} to determine da_i/dt_i by means of compliance equation i.e. $EBV/P = C_6$, and then to work out $da_i/dt_i - K_{1i}$ curve. Standard solution NACE, T-1 and F-9 was used.

3. Results[4,5]

$da/dt-K_1$ curves of specimens No.2,3,4 were shown in Fig. 3 and Fig.4 respectively. The results were shown in the following table.

4. Discussion

(1) Comparing specimen No.3 with No.5, it can be seen that the crack propagation in No.3 is very fast, while in No.5 no propagation at all.

(2) From specimen No.1,2,6,7, it was shown that anti SCC capacity of the weld is the best; parent metal the next; while fusion line is the worst.

(3) Specimen No.2 and No.3 are of homogeneous materials. Therefore,

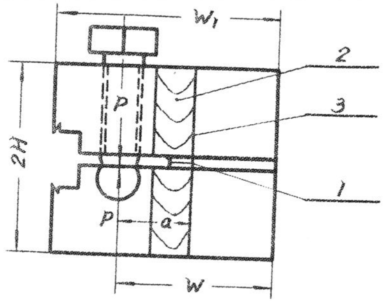

Fig. 2-a

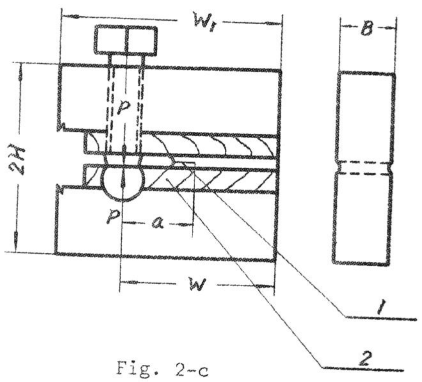

Fig. 2-c

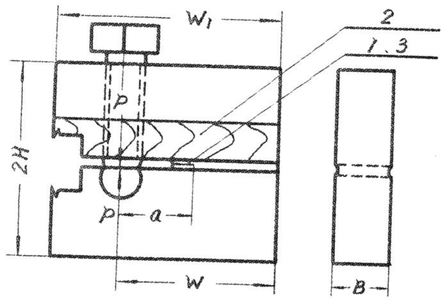

Fig. 2-b

Fig.2 The way of sampling. 1 Fatigue crack. 2 Weld metal. 3 Fusion line.

Fig.2-a Transverse propagation.

Fig.2-b Longitudinal propagation-weld metal.

Fig.2-c Longitudinal propagation-fusion line.

the $da/dt-K_1$ curve appears in a "Reverse S"pattern. Spcimen No.4 is of T.P., and the curve appears in a "Saddle", in which $(da/dt)_I=AK_1$ i.e. linear relationship, and $(da/dt)_{II}=BK_1^2$ i.e. in "Saddle" pattern. A and B are constant. The formation of "Saddle" pattern is due to the different and non-homogeneous microstructure in the H.A.Z.

FRACTOGAPHIC ANALYSIS

Fractures must be cleaned by ultrasonic in advance. The macro fractograph of parent metal is shown in Fig.5. The front of propagation presents a "Convex" shape. Because the center part of the plate is restrained three-dimensionally. The front of propagation of the fusion line shown in Fig. 6 is in "Concave" shape. This is because the surface part of the plate has high hydrogen concentration, coarse grain and high hardness. On the other hand, though the center part of the plate is under plane strain

Table

No.*	Type	Heated Condition	** Microstruture	K_{1scc} ($kg\text{-}mm^{-3/2}$)	da/dt ($\times 10^{-5}$ mm/s)
1	B	09-I, as rolled	Banded, F+P	145±15	0.1—0.5 "Reverse S"
2	B	09-I, heat simulated (T_{max} 1300°C)	PF+W+B	125±10	1.53 "Rev.S"
3	B	09-II, as rolled	F+P	85±15	5 "Rev.S"
4	A	09-II+T507A, T.P.	Fusion line-Coarse grain-Normalized-Partially transformed	127—227	1 "Saddle"
5	B	09-II, Normalized	Fine grain F+P	190±30	No. propagation
6	B	Weld metal, 16Mn+T507A. L.P. along weld.	Dendrite F+P	150±5	0.2 "Rev.S"
7	B	16Mn, as rolled	F+P	140±10	0.3 "Rev. S"
8	A	Fusion line, 09-II+T507A. L.P. along fusion line.	Surface: fusion line; Center: H.A.Z.	118—238	/
9	B	09-II, heat simulated. (T_{max} 1300°C)	W+S+B	107--186	/

* TypeA(20mm), B(25mm). ** F: Ferrite, P: Pearlite, B: Granular Bainite, W: Widmanstätten, PF: Preeutectoid Ferrite, S: Sorbite

condition, yet it has fine grain and being multi-tempered by the upper layers. Therefore, center part has a good toughness, and propagation is lower than that in the surface part.

S.E.M. micro fractogaphs are shown in Fig.7, where initiated location in Fig.7-a, DR, propagated location in 7-b, QC+SC, arrested location in Fig.7-c, IG, and Fig.7-b, $(IG)_{SC}$.

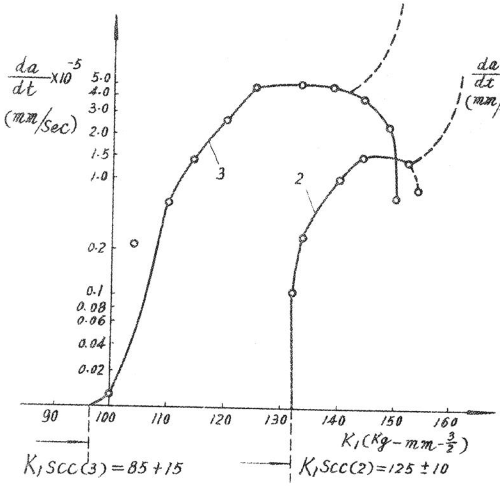

Fig.3 da/dt-K_1 curve of specimen No.2 and No.3.

--- Continuous loading curve.

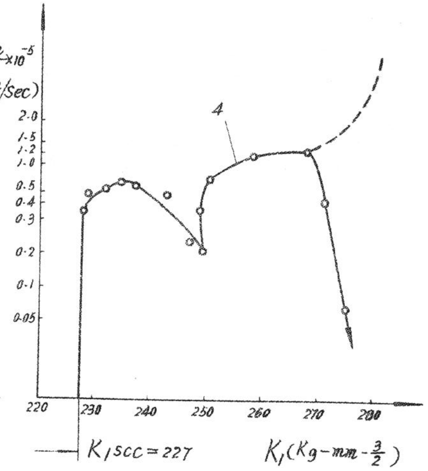

Fig.4 da/dt-K_1 curve of specimen No.4.

—— Experimental curve

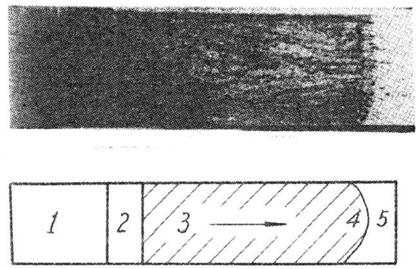

Fig.5 Macro fractograph of parent metal(Convex)

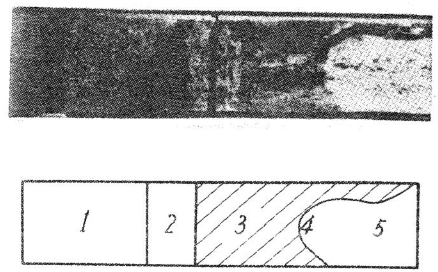

Fig.6 Macro fractograph of L.P. fusion line

1 Linear cutting 2 Fatigue crack 3 Propagated region

4 Arrested region 5 Tear region

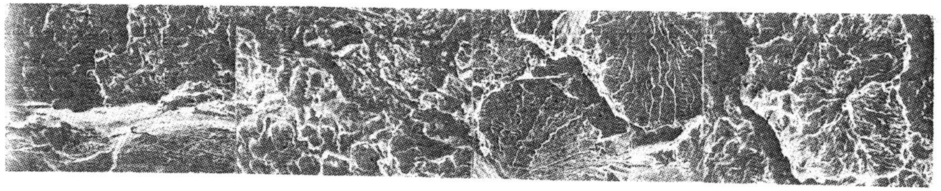

Fig.7-a Fig.7-b Fig.7-c Fig.7-d

Fig. 7 Micro fractographs

CONCLUSIONS

1. Precipitation hardening steels containing Ti, Nb, should be provided in normalized condition.

2. da/dt-K_1 curve of T.P. of the welded joint presents "Saddle" pattern. There exist 2 maximums and $(da/dt)_{min}$=10–20% $(da/dt)_{II}$, therefore T.P. could be controlled and eventually might be arrested.

3. K_{1scc} of fusion line is the worst, which is about 60–70% of the parent metals.

4. The shape of the front position of propagation may be either "Convex" or "Concave". It depends on hydrogen concentration, stress condition and metallogaphic structure.

5. The essential fracture is QC, but $(IG)_{SC}$ appears while hydrogen concentration is high.

REFERENCES

[1] Brown B.F, A New Stress-Corrosion-Cracking Test for Strength Alloys, Materials Research and Standard, Vol.6, No.3 (1966).

[2] Novak S.R. and Rolfe S.T, Modified WOL Specimen for K_{1scc} Enviromental Testing, Journal of Materials, JMLSA, Vol.4, No.3, Sept. (1969).

[3] X.M. Yao, Measurement of Propagation Rate in Enviroment, Beijing Polytechnic University (1981).

[4] Z.F. Wang, Evaluation on K_{1scc} of Welded Joint of Low Alloyed Steels, 4th Session of National Welding Society (1981).

[5] Z.F. Wang, Summary on K_{1scc} and da/dt of Steel 09MnTiCuRe-II, Beijing polytechnic University (1982).