Fracture Toughness Testing of Maraging Steel Weldments

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ABSTRACT

Evaluation of fracture toughness of 18 Ni M250 grade maraging steel weldments has been made by resorting to 'R' curve method as per ASTM E561 standard. Fracture toughness of HAZ was found to be higher than that of weld-metal. Most of the weldments passed the minimum specified value.

Introduction

Materials selected for weight sensitive structures are of high strength alloys. They must withstand high stresses during certain phases of operation. In the overall design they should be able to tolerate not only the maximum design loads, but also the maximum crack that can develop in the structure over a specified period. Because of this trend there is an increasing need for fracture mechanics based data on high strength materials.

M250 grade 18Ni maraging steel has been considered as a candidate for first stage motor case of a Polar Satellite Launch Vehicle. The objective of this work was to carry out fracture toughness analysis through 'R' curve method to establish the consistency of the welding as a part of welder's qualification.

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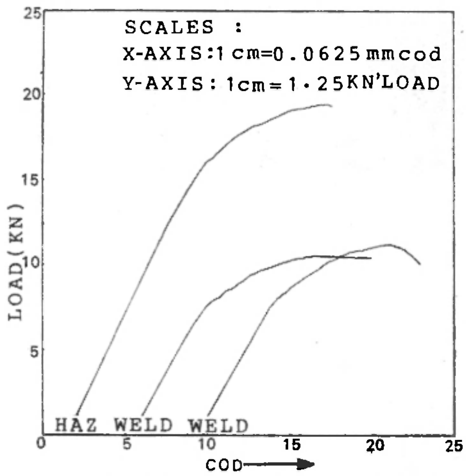
Materials & Experimental Procedure

Twenty sample plates of 18Ni M250 grade maraging steel were TIG welded manually using a filler wire of similar composition. The radiographed welded specimen blocks were surface machined and etched to locate notches in weld-metal and HAZ regions. From each plate three CTS samples as per ASTM standard 561 were obtained, namely two representing weld-metal and other one representing HAZ regions. Similarly three tensile samples were also made from each plate. The specimens were aged at 480°C for 3 hrs before testing.

The fracture toughness test through R curve method was carried out as per ASTM E561 standard[1]. 'R' curve characterises the resistance to fracture of materials during incremental slow-stable crack extension and result from growth of the plastic zone as the crack extends from a notch. The test procedure involves precracking to a crack-depth ratio of 0.45, followed by loading to failure. Simultaneously record of load versus COD curve was obtained in an X-Y recorder. A typical load versus COD curve is shown in Fig. 1. Secants are drawn to the test curve from the origin to arbitrarily selected points on the test record from which 2Vo/p, hence EB_2 Vo/p has been calculated. The effective crack length a_e, for each point was determined from Mc Cabe and Shaw equation[2], as given below :



LOAD-COD PLOTS FOR TEST ON MARAGING STEEL WELDMENTS

Fig. 1

$$\frac{EB2\ Vo}{P} = Ao + A_1(ae/w) + A_2(ae/w)^2 + A_3(ae/w)^3 + A_4(ae/w)^4 \quad (1)$$

The respective K_R is then calculated using the expression :

$$K_R = \frac{P}{B\sqrt{w}} f(a/w) \quad (2)$$

where

E = Young's Modulas
B = Thickness
2Vo = Crack Opening Displacement
P = Load
W = Width
a_e = Effective crack length
K_R = Stress intensity factor
f(a/w) = Compliance function of a/w

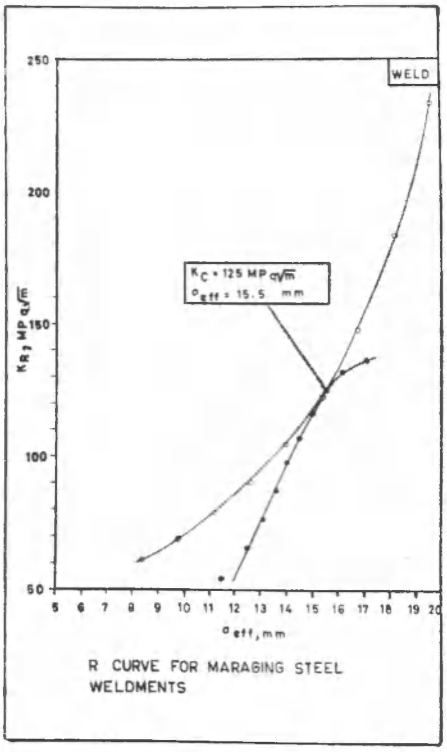


Fig. 2

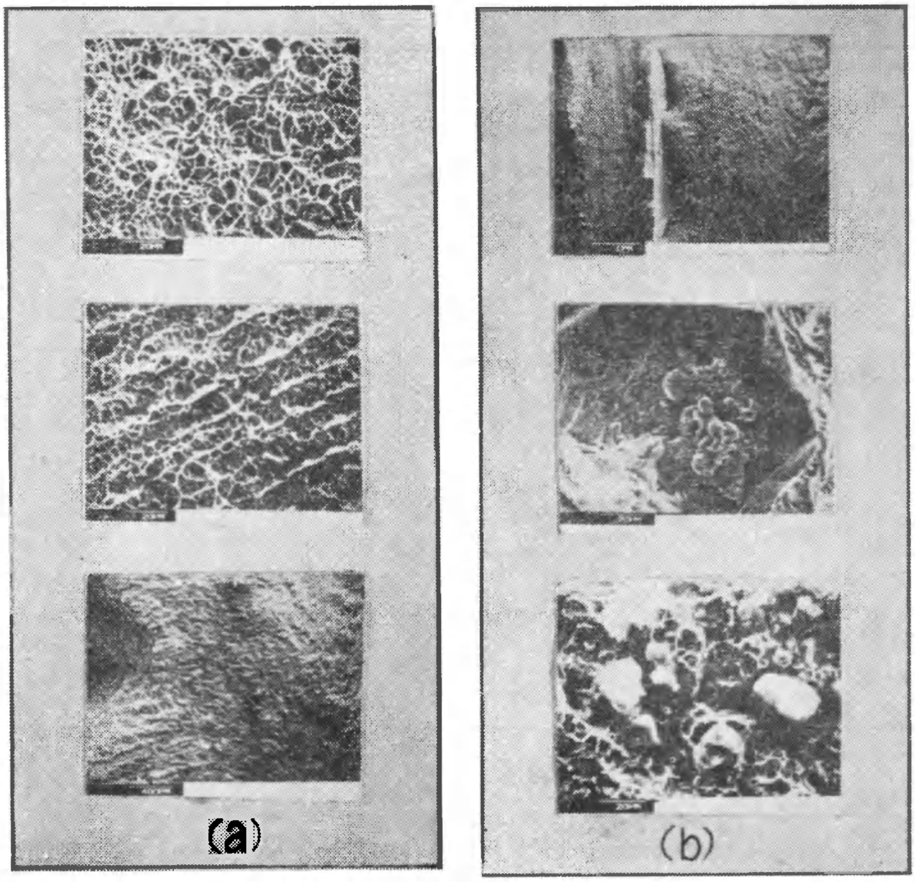


Fig. 3 (a) Electron Practographs showing transition from Weldmetal to HAZ.
(b) Electron fractographs showing weld defects.

A plot of K_R versus a_{eff} for each selected data point has been drawn to generate 'R' curve (Fig. 2). Further crack driving curve was obtained using equation (2), for a particular load by varying a/w values. A number of such crack driving curves were obtained for different load levels. The unique curve which develops tangency with the 'R' curve defines a critical load or stress that will cause onset of unstable fracturing. The K_R corresponding to the point of tangency gives rise to Kc. The Kc is valid if it satisfies the following criteria :

(1) Crack deviation from plan should not be more than 10%.

(2) The remaining ligament length (w-a) should be greater than $4\pi X (Kc/\sigma y)^2$

Results & Discussion

Kc values for weldments and HAZ were tabulated in Table Ia & Ib respectively. SEM fractographs showing mixed zone occurrence and defects were shown in Fig. 3a & 3b.

From the Tables 1 & 2, Kc value for HAZ were found to be higher than weldmetals in all the cases and was in accordance with reported literature ($_{3,4}$.) Hence only weldmetal toughness was considered for data analysis.

The weldmetal toughness was found to vary between 84 MPa$\sqrt{m}$ to 174 MPa$\sqrt{m}$. SEM analysis of the fracture surface of samples giving higher fracture toughness revealed the crack transit from weldmetal to HAZ thereby indicating that the crack started in weldmetal and entered into HAZ as the crack approached unstability. This was further confirmed by macro-etching. This might be due to improper location of notch with reference to weldmetal. Proper care had been taken to avoid the recurrence of this problem. The lower Kc values from the minimum specified value of 90 MPa$\sqrt{m}$ were attributed to the presence of defects, as evidenced from SEM fractographs, Fig. 3b.

From each plate average of weldmetal Kc values and average of all the three UTS values were considered in Fig. 4, while plotting fracture toughness and strength versus plate number. It was evident that most of the weldments passed the minimum specified strength and toughness values.

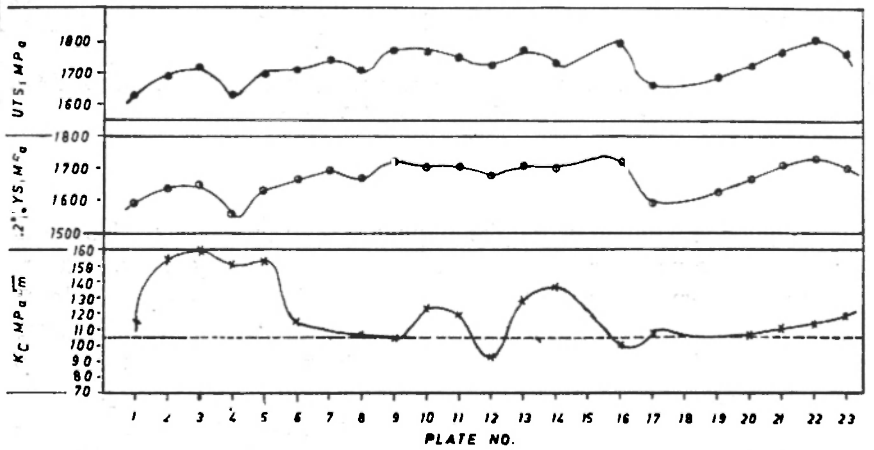
Table 1: Variation of Kc within a plate

PLATE NO.	Kc WELD 1 MPa√m	Kc WELD 2 MPa√m	AVERAGE MPa√m	% VARIATION
1	130	100	115	13
*2	174	134	—	—
*3	160	150	—	—
*4	145	156	—	—
*5	166	138	—	—
6	127	100	113.5	11.9
7	103	107	105.0	1.9
8	103	109	106.0	2.8
9	93	112	102.5	9.3
10	120	125	122.5	2.04
11	115	123	119.0	3.36
12	92	—	92.0	—
13	118	138	128.0	7.8
14	133	136	134.5	1.1
16	84	116	100.0	16.0
17	125	89	107.0	16.8
20	104	106	105.0	0.09
21	116	104	110.0	5.45
22	123	98	110.5	11.3
23	*145	115	115.0	—

*Indicates Mixed Zone

Table 2: Typical Kc values of HAZ

PLATE NO.	Kc, MPa√m
2	203
3	210
4	194
11	228
13	184
16	185



VARIATION OF STRENGTH AND FRACTURE TOUGHNESS OF MSW WITH PLATE NUMBER

Fig. 4

Conclusions

1. Fracture toughness of HAZ was found to be higher than weld-metal.

2. Most of the weldments passed the minimum specified value of strength and toughness.

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References :

1. ASTM Standard Part 10, E561-81.

2. D. E. McCabe and G. T. Shaw ASTM STP 632, 1977 p. 82-96.

3. Coleman M. C., Jordan M. F. Fracture toughness and microstructure of HAZ of a welded maraging steel. Metals Technology, Jan. 1974. 1, (1), 24-30.

4. N. Bailey, Weldabil'ty and toughness of maraging steel, the Welding Institute, 1971.

Attention :

Renewal of Membership

Members are reminded that the remittance for renewal of membership of the Indian Institute of Welding for 1986-87 to be made before

31st of July, 1986