Stress-relief Cracking Susceptibility and Microstructural Characteristics of Modified T23 Steel

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1. Introduction

Stress relief cracking is a common cause of weld failures in many creep resistant precipitation strengthened alloys. The general definition of SRC is intergranular cracking in a welded assembly that occurs during exposure to elevated temperatures produced by post-weld heat treatments (PWHT) or high temperature service [1]. The coarse-grained heat-affected zone (CGHAZ) is the most susceptible region of a weldment.SRC occurs mainly in ferritic alloy steels [2-7].

A ferritic alloy steel, designated as T23, has been widely applied in sub-critical, supercritical and even ultra supercritical thermal power generating units whose wall temperature does not exceed 580℃ from the late 1990s in Europe and Japan[8,9]. The chemical composition has been modified to achieve the specified mechanical properties. In this article, the SRC susceptibility of modified T23 steel has been studied by Y-groove cracking test.

2. Experimental

Testing of T23 steel stress-relief cracking susceptibility is conducted according to GB4675.1-84 "Weldability testing-Method of Y-groove cracking test" as shown in Fig.1. Constraint and test weld are welded by

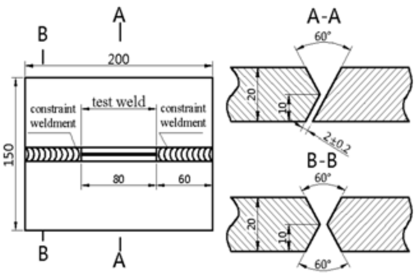


Fig. 1 Schematic graph of specimen for Y-groove cracking test.

SMAW with CHROMET 23L electrodes of Φ3.2mm, which are preheated for 1h at 350℃. Material composition of Test plates in Table 1 supplied by Baosteel meets the requirements of ASME Code Case 2199-4. In order to prevent cold cracks, preheating is carried out before welding. This experiment only focuses on the impact of PWHT temperature upon SRC. Test conditions and numbers are shown in Table 2 and 3.

3. Results and Discussion

3.1 Crack Rate

Surface and cross-section crack rate are calculated individually by crack detection and anatomy after 48h post-weld placement. The former is 0 and the later at

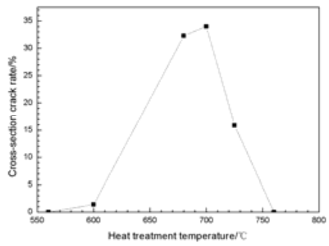


Fig.2 Cross-section crack rate as a function of PWHT temperature.

Table 2 Experimental conditions in Y-groove cracking Test

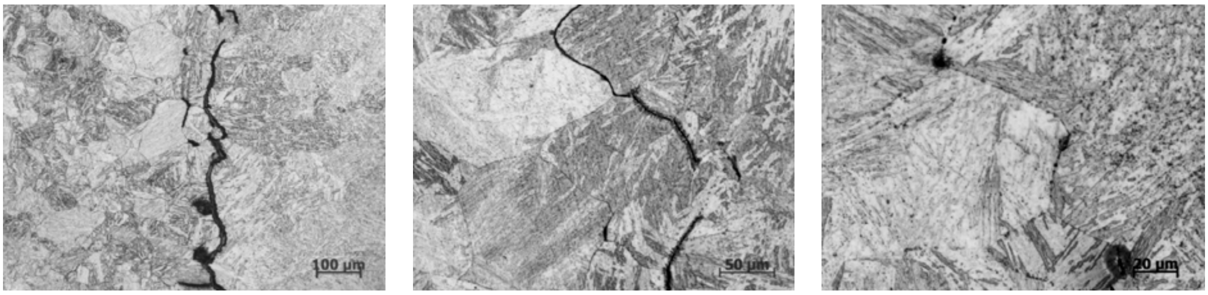
Preheat temperature /℃	PWHT time /h	Welding current /A	Arc voltage /V	Welding speed /mm •min-1
100	2	110	22-24	100

Table 3 Test number in the experiment

PWHT temperature /℃	560	600	680	700	725	760
Test No	Z1	Z2	Z8	Z3	Z4	Z5

Table 1 Composition Used in this Research of T23

C	Si	Mn	P	S	Cr	W	Mo	V	Nb	N	B	Al	Ti	Ti/N
0.06	0.28	0.37	0.012	0.002	2.32	1.56	0.08	0.22	0.044	0.0035	0.0026	＜0.015	0.009	3.9



a) Main cracks b) Micro cracks c) Crack propagation path

Fig. 3 SRC in modified T23 steel.

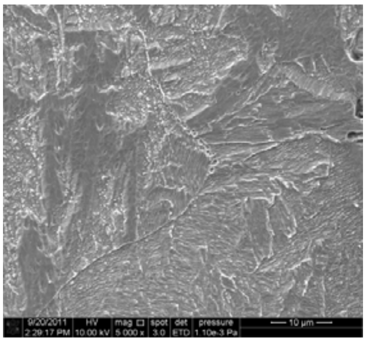


Fig. 4 Distribution of precipitates and cavities around the main crack.

different PWHT temperature is shown in Fig.2, which indicates the most susceptibility temperature of SRC.

3.2 Microstructural Characteristics

3.2.1 Characteristics of SRC

SRC is intergranular fracture and appears in the CGHAZ. Cracks propagate along or parallel to the fusion line of austenitic CGHAZ. Sometimes cracks are not continuous, as shown in Fig.3 (a). And Fig.3(b) shows that it usually occurs near to the grain boundary with a small angle to the propagation direction during propagating.

The appearance of SRC has a relation to residual stress and stress concentration. Also PWHT temperature plays an important role.Fig.3（c）shows the micro cracks of the sample Z5, whose CGHAZ has SRC and cavities in some grain boundaries while the root of weldment in stress concentration doesn't have SRC.

3.2.2 Distribution of Precipitates and Cavities

Fig.4 gives the distribution of precipitates and cavities around the main crack of the sample Z4. It figures out both intergranular and intragranular carbide precipitates. And the later mainly distribute along the bainitic laths while little on the ferrite matrix. Precipitates and cavities may appear simultaneously at the grain boundaries, the upper half is covered with precipitates while the lower with cavities.

3.3 Discussion

The general reason for the formation and propagation of SRC is the micro-crack（nucleation）generated by grain boundary sliding. But numerous theories exist on the causes of SRC ,such as elemental segregation , carbide precipitation strengthening of grain interiors and creep fracture. The last theory includes "wedge mode" and "cavitation mode" which are caused by stress concentration and cavities congregation respectively. The results in this experiment reveal that when suffered from stress and temperature, the lattice vacancies move and gather at the grain boundaries to which stress perpendicular. When achieving a sufficient number of cavities, the interfaces of grain boundaries will be destroyed and expand into cracks under the stress. So the SRC mechanism of the modified T23 steel is "cavitation mode".

4. Conclusion

Y-groove cracking test can fit the conditions, which is residual stress and stress concentration have existed before PWHT, for the formation of SRC. It has verified the modified T23 steel has SRC susceptibility at the most sensitive temperature of 700℃.And the SRC mechanism of modified T23 steel is the "cavitation mode" induced by accumulation of vacancies.

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