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Characterization of the Type IV crack in high Cr steel weldments

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Abstract: The weldments for several types of high Cr ferritic steels were investigated to understand the fracture mechanism of the Type IV crack. The creep testing shows that the Type IV cracking is more likely to occur at the lower stress level, whereas at the higher stress level the crack shifts towards parent metal. The microstructures observed in the HAZ for all the materials are mostly tempered lath martensites. There was no δ ferrites found in all creep specimens.

Key words: ferritic steel; weldment; HAZ; Type IV crack; modelling; fracture mechanism

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1 Introduction

High chromium ferritic heat resistant steels, usually referred to the Cr-Mo steels, are widely used in high temperature environment, combining high strength at both ambient and elevated temperatures with adequate toughness[1]. Based on basic crystal structure of materials, the heat resisting steels include perlitic, bainitic and martensitic types. These steels contain chromium contents up to 12% with usually about 1% Mo. They were used in oil and processing industry as early as 1930s[2,3].

The welding is one of the most essential fabrication processes for component manufacturing. The thick sections of these steels need to be welded. The welding related all types of crackings, in which Type IV crack is a crack occurs in the fine-grained heat-affect-zone, caused problems. The principal cracking mechanism affecting large CrMoV welds has still not clearly been identified.

2 Experimental

Creep rupture tests were performed at different stresses and temperatures. Four types of materials (P91, P92, E911 and P122) were tested in the PWHT condition. Thereby, all the creep specimens were taken parallel to the longitudinal direction of the pipe but perpendicular to the welding direction in such a manner that the HAZ was in the middle of the gauge section.

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Biography: SUN Ben-shuang(born in 1965), Male, Professor, Doctor.

3 Results

Fig. 1 showed the marcograph of Type IV crack in the HAZ zone compared with the weld metal and parent metal failures.

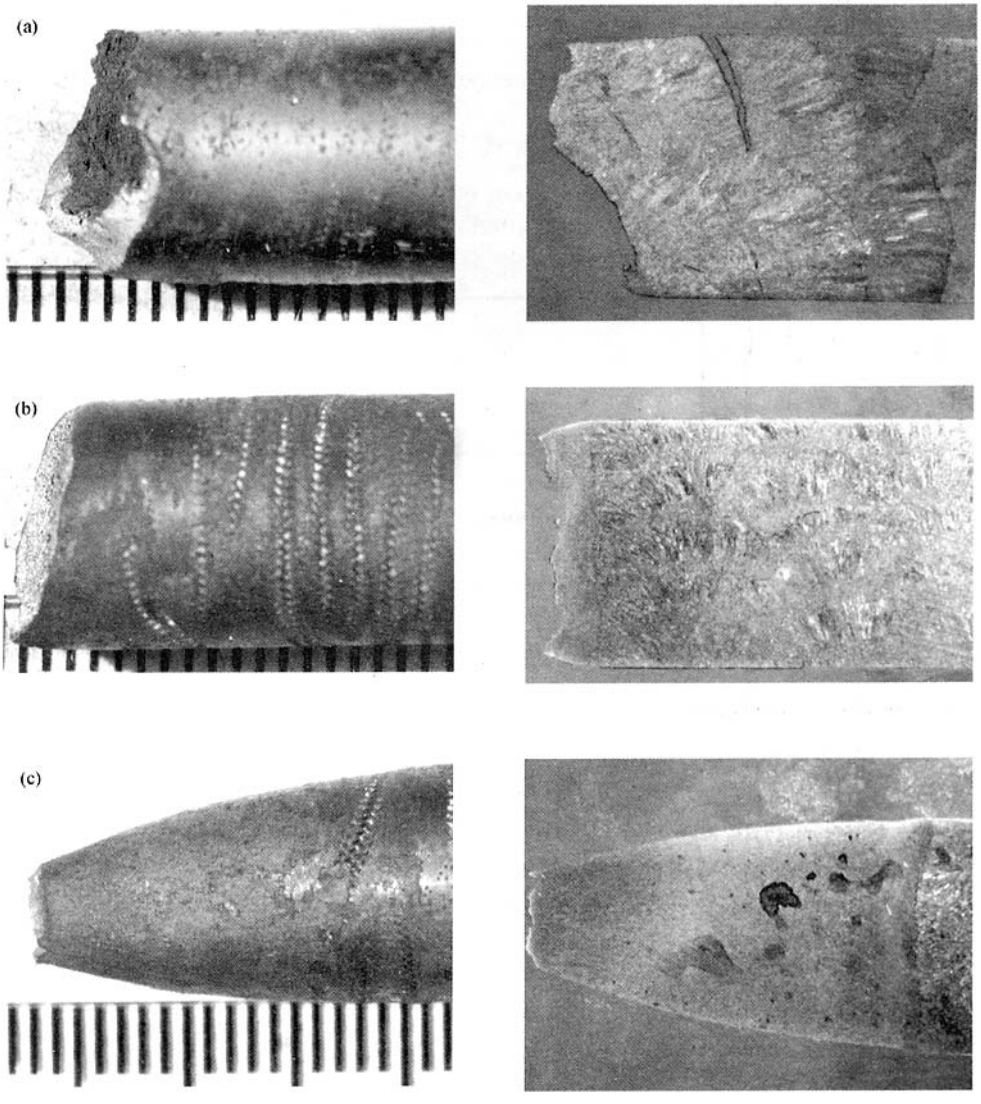

Fig. 1 Macrographs and sectioned of the fracture
(a)—Weld metal failure; (b)—Type IV crack; (c)—Parent metal failure

4 Discussion

4.1 The Type IV crack zone

The heat affected zone (HAZ) is shown in Fig. 2. The Type IV crack is the crack that occurs in the fine grained zone but about one fourth region at the outer edge of HAZ which is close to the parent metal. So we can call this region the Type IV zone. This range is still within between A_{c1} to A_{c3}. For the compari-

son the Type III crack region is also shown in here, which is totally different with the Type IV cracking. Provided that fusion welding is employed, the Type IV zone will always be present. It is inevitable that there will always be a zone that is exposed to the critical temperature range. The width and the distance of this zone from the fusion boundary may vary, however not significant, in this case the HAZ zone is about 2.0 mm wide while the Type IV zone is in the range of 0.1 to 0.5mm from the edge of the PM. Therefore The Type IV crack region is relatively rather constant, the welding process can only have an indirect influence through the heat input and the cooling rate and not change the position of the Type IV cracking, a higher welding temperature will lead to a wider zone, which will be placed further away from the fusion line[4]. Therefore it can be concluded that the Type IV cracking is a kind of cracking which is strongly related to the parent metal, whereas the Type III crack region is a weld metal strongly related cracking region, on which the heat input would have a great effect.

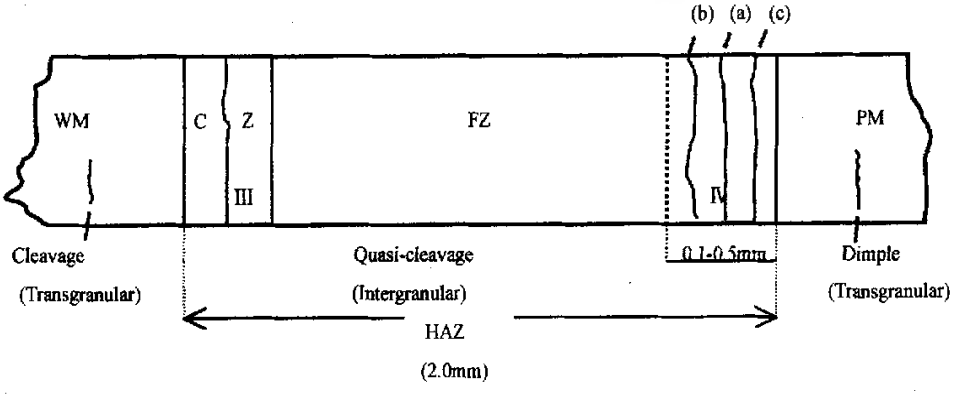

Fig. 2 The Type IV cracks location

4.2 Effect of process on the fracture

4.2.1 Effect of the stress

It can be seen in Fig. 3 that all the four types of materials have presented the Type IV cracks and the 9Cr steel (P91, P92 and E911) is more sensitive to the Type IV cracking compared with the 12Cr steel (P122) which is more tending to fail in the weld metal. From the Fig. 3 it is also clear that at the lower stress level there are more chances that the Type IV crack occurs. As the stress increases, the failure will shift to parent metal. From this point of view the Type IV cracking is more related to parent metal strength.

4.2.2 Effect of the temperature

Fig. 4 shows that the temperature has no significant influence on the Type IV cracking.

5 Conclusions

(1) The microstructures in the HAZ for all the materials are mostly tempered lath martensites. No δ ferrites were observed in all creep specimens.

(2) The Type IV crack will more likely happen at the lower stress, whereas at the higher stress levels, the crack will shift to the soft zone.

(3) There is no strong temperature effect on the Type IV crack.

(4) The cavitation initiation and rapid GB precipitate growth induced intergranular fracture is the mechanism of the Type IV cracking.

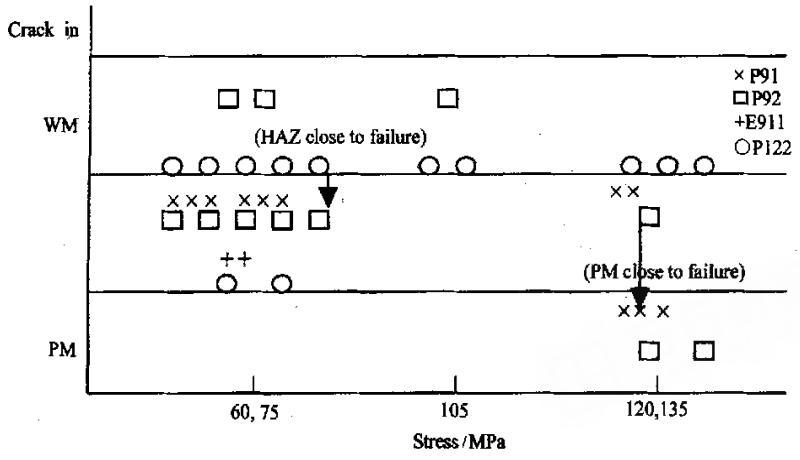

Fig. 3 The effect of the stress on the fracture

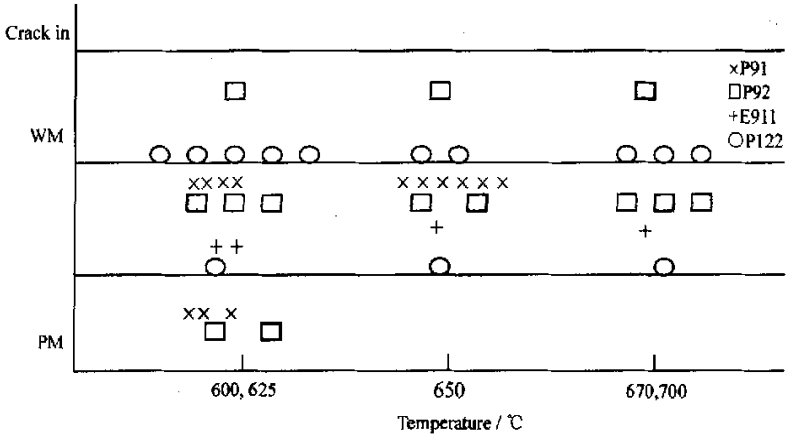

Fig. 4 The effect of the temperature on the fracture

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