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Research paper

Microstructure and mechanical properties of simulated unaltered coarse grained heat affected zones of 10CrNi3MoV steel by double-sided double arc welding

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ABSTRACT

This paper aims to reveal the influence of different welding conditions on unaltered coarse grained heat affected zones (UACGHAZs) of backing passes by double-sided double gas tungsten arc welding (DSGTAW) of 10CrNi3MoV steel. UACGHAZs were also compared with coarse grained heat affected zones (GGHAZs) of single gas tungsten arc welding (SGTAW). At lower heat input (21.7 kJ/cm for each run without preheating), CGHAZ mainly consisted of lath martensite (LM) while UACGHAZs composed of LM and small amount of lath bainite (LB). At higher heat input (33.2 kJ/cm for each run with 150 °C preheating), the microstructures of CGHAZ were LM and LB. In UACGHAZs, the microstructures would transform from LB + LM + granular bainite (GB) to LB + GB as arc distance (*d*) decreased. The toughness of UACGHAZs was related to martensite/bainite packet sizes instead of prior austenite grain sizes. At higher heat input, the formation of granular bainite deteriorated the toughness of UACGHAZs and negated the positive effect of LB on toughness. DSGTAW can significantly improve the toughness of coarse grained zones when lower heat input is adopted.

1. Introduction

Double-sided double arc welding (DSDAW) has been proposed by Zhang et al. (2007) for thick HSLA steel plates. Zhang et al. (2007) studied the effect of arc distance on the angle distortion and found that the residual angular distortion with increasing arc distance exhibits a non-linear relationship. At small arc distance, the bend-down angular distortion is induced to increase before decreasing, and when arc distance is large, bend-up angular distortion is induced to increase again and finally decrease. Zhang et al. (2009) found that the transverse stresses of DSDAW are lower than conventional single arc welding because of the thermal balance of two sides and the greater temperature gradient of single arc welding. Selecting proper arc distance and heat input can effectively reduce angular distortion and even achieve non-angular distortion according the work of Zhang et al. (2008). Yang et al. (2014a) investigated the effect of DSDAW on preheating temperature and found that the critical stress in DSDAW (528.31 MPa) without preheating is higher than that of conventional welding with 100°C preheating (393.44 MPa) which means DSDAW can effectively improve cold crack resistance and can realize welding thick HSLA steel plate with lower preheating temperature or even without preheating. Yang et al. (2014b) established a dual-robot DSDAW system and realized no backing chipping welding for thick plate, the welding properties were also good.

Most investigations to date have focused on joint microstructures, mechanical properties, temperature field, welding distortion and residual stress, but little work about the effect of arc distance on joint has been done except for that on angular distortion studied by Zhang et al. (2007). The object of this paper is to investigate the effect of arc distance on microstructure and impact toughness of UACGHAZs with different heat input and compare with CGHAZ of conventional single arc backing welding. The obtained results can provide guidance for engineering application of DSGTAW.

2. Experimental material and procedures

2.1. Materials

The material used in this work was 10CrNi3MoV quenched and tempered high strength low alloy steel. The steel plate was 35 mm in thickness.

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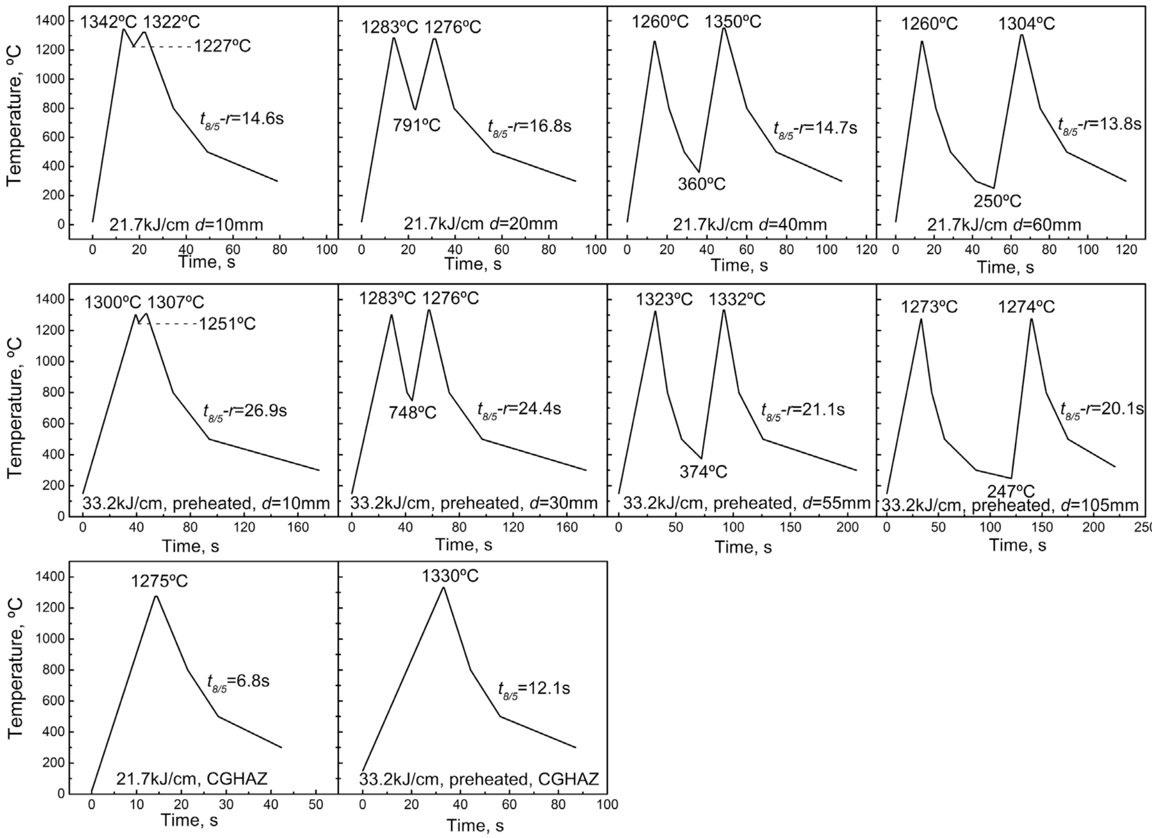

Fig. 1. Thermal cycles used for thermal simulation tests.

2.2. Welding simulation

Specimens with dimensions of 11mm × 11mm × 110 mm were prepared by sectioning perpendicular to the thickness direction of plate for thermal simulation test using Gleeble1500D. A type S thermocouple was spot-welded onto the middle of specimen for temperature record. The face that thermos-couple welded in was parallel to the thickness direction. Two welding heat inputs were simulated which were 21.7 kJ/cm for each run without preheating and 33.2 kJ/cm for each run with 150°C preheating. Different arc distances were also thermal simulated which were 10 mm, 20 mm, 40 mm, 60 mm at lower heat input and 10 mm, 30 mm, 55 mm, 105 mm at higher heat input. CGHAZs of SGTAW with the same heat input were also simulated. All thermal cycles imposed to the simulating specimens were present in Fig. 1, which were obtained from our previous work (Peng et al., 2017). 4 specimens were used for each thermal cycle among which 1 was for microstructural observation and the other 3 were for impact toughness test. In this study, specimens at lower heat input were cut from 1/2 in thickness and specimens at higher heat input were cut from 1/4 in thickness as Fig. 2 shows.

2.3. Metallography and microscopy

The oxide coatings on the surfaces of specimens which were for microstructural observation were firstly removed by coarse sandpapers, then ground and polished. To reveal prior austenite grains (PAG), the specimens were immersed and etched in a saturated picric acid solution containing a small amount of sodium dodecyl benzene sulfonate for about 60s. The solution was kept at 60 °C by thermostatic water bath. After etching, the specimens were slightly polished, then etched in the solution again. This process should repeat 3 or 4 times until the prior austenite grain boundaries were clear. After the observation of the prior austenite grains by optical microscope (OM), these specimens were then polished again and etched with 2 vol.% nital for 15s. The microstructures were examined by OM and Quanta 200FEG Scanning Electron Microscope (SEM). The average PAG sizes and martensite/bainite packet (M/BP) sizes measurements were calculated by using a linear intercept technique. To account adequate number of austenite grains and martensite/bainite packets, 8 metallographs were taken to measure the PAG sizes while 7 metallographs were taken to measure the M/BP sizes for each specimen. For electron backscatter diffraction (EBSD) analysis, specimens were mechanical polished with OP-S silica suspension for more than 20 min and characterized by Quanta 200FEG equipped with an EDAX-TSL EBSD system with 0.5 μm step. The

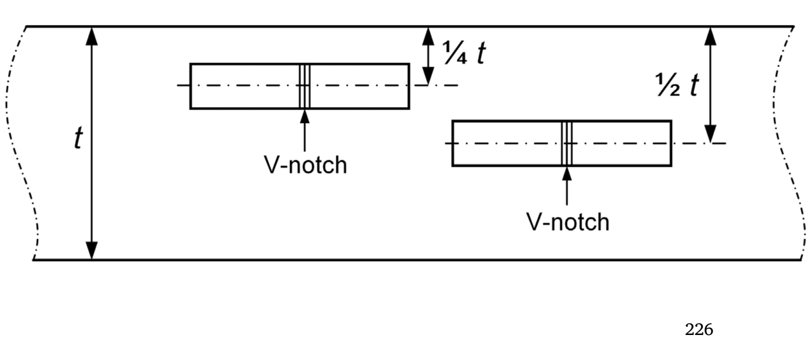

Fig. 2. Positions of thermal simulation specimens.