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Tensile properties and fracturing behavior of weld joints in the CLAM at high temperatures

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HIGHLIGHTS

- We use the stress triaxiality theory to explain the plastic deformation and facture behavior of the joints during the short term tensile tests at high temperature.
- The tensile strength of CLAM welded joint at high temperature is lower compared with that at room temperature.
- We explained the formation of crack and the reason of fracture.

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ABSTRACT

The tensile properties and fracturing behavior of weld joints in the Chinese low activation martensitic steel (CLAM) at high temperatures were studied. The result revealed that the cracks of weld joints in the base metal would appear in the heat-affected zone, after post-weld heat treatment for the high-temperature tensile test. The microstructure in the fractured frontier had different deformation and directions, and the fractured surface had different angles, a result associating with the normal faulting and shear fracturing. The tri-axial theory of stress can well explain the deformation and fracturing behavior of weld joints in the high-temperature tensile.

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1. Introduction

The fusion reactors recently gained traction because of their attractive properties before and after neutron irradiation. As one of the members sitting in the ITER international program, China has been the leading Country in the field of fusion reactors. The developing Chinese low activation martensitic (CLAM) steel, also known as one of the reduced activation ferritic/martensitic (RAFM) steel, has been selected as the primary candidate structural material for blanket components in fusion DEMO reactors [1,2]. It now becomes the major issues in the engineering technology of the component fabrication regarding the application of candidate materials. As such, welding is being adopted for the fabrication of complex components. Major methods such as electron beam welding (EBW) [3,4] and tungsten insert gas (TIG) welding [5–8] are being developed to explore suitable techniques for manufacturing of the first wall (FW), the cooling plates (CP) and the assembly of the components.

In the present study, two plates of CLAM steel (5 mm in thickness) were butt-welded with TIG, using the filler metal of the initial CLAM composition that were divided into two groups, i.e., group A and B. The high temperature tensile tests were carried out in the TIG welded joints where group A was achieved through post-weld heat treatment (PWHT) but group B was not. The temperature for tensile test are 500, 550, 600, and 650 °C, respectively. The objective of this study is to achieve the tensile properties and fracturing behavior of the CLAM welded joints.

2. Experimental

With the composition shown in Table 1, two plates of CLAM steel (with martensite microstructures) were prepared in a 5 mm of thickness. The plates with 60° V-groove were welded using TIG under the same conditions as the filler metal in the initial CLAM composition (cf. Table 2). For the operation, the welding voltage used was 12 V and the protecting gas was 12 L/min. The

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Table 1
Chemical composition of CLAM steel.

Elements	Cr	W	V	Ta	Mn	C	Al	Fe
Mass fraction	8.91	1.44	0.20	0.15	0.35	0.12	0.18	Balance

Table 2
Chemical composition of the filler metal.

Elements	Cr	W	V	Ta	Mn	C	Al	Fe
Mass fraction	8.90	1.54	0.23	0.16	0.34	0.13	0.17	Balance

welding speed in the first layer was 1.2 mm/s while that in the second layer was 1.8 mm/s. The interpassing temperature was controlled at 200 °C and the preheating temperature is 150 °C. The specimens in the group A have been normalized at 760 °C for 120 min (air cooling) [9]. The tensile properties were tested at 500, 550, 600, 650 °C using an electronic testing machine.

Once the above procedure was completed, the microstructure of the CLAM joints was polished, followed by chemical etching in a solution made of C_2H_5OH (95 mL), HCl (5 mL) $C_6H_3O_7N_3$ (1 g). The resulting products were determined and characterized using a LEICA DM 2500M optical microscope (OM), a scanning electron microscope (SEM; JEOL-JSM-7001F) and transmission electron microscope (TEM).

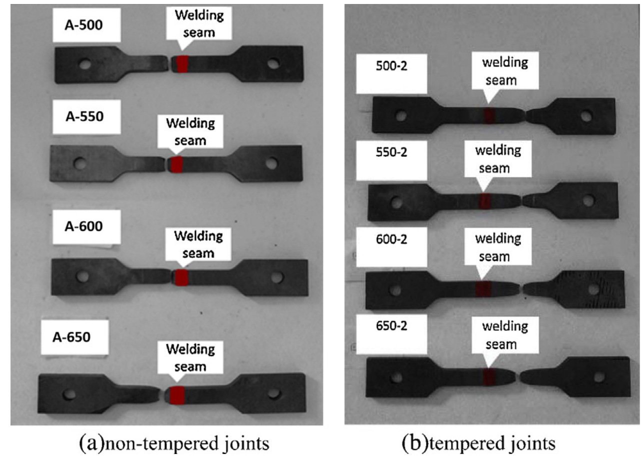

Fig. 1. Fracture positions of the samples after high-temperature tensile tests.

2.1. High temperature mechanical properties and fracture mode

The result for the tensile test at high temperature was presented in Table 3. The fracture of the welded joints, with post-weld heat treatment (PWHT) in base metal (BM) and without having PWHT

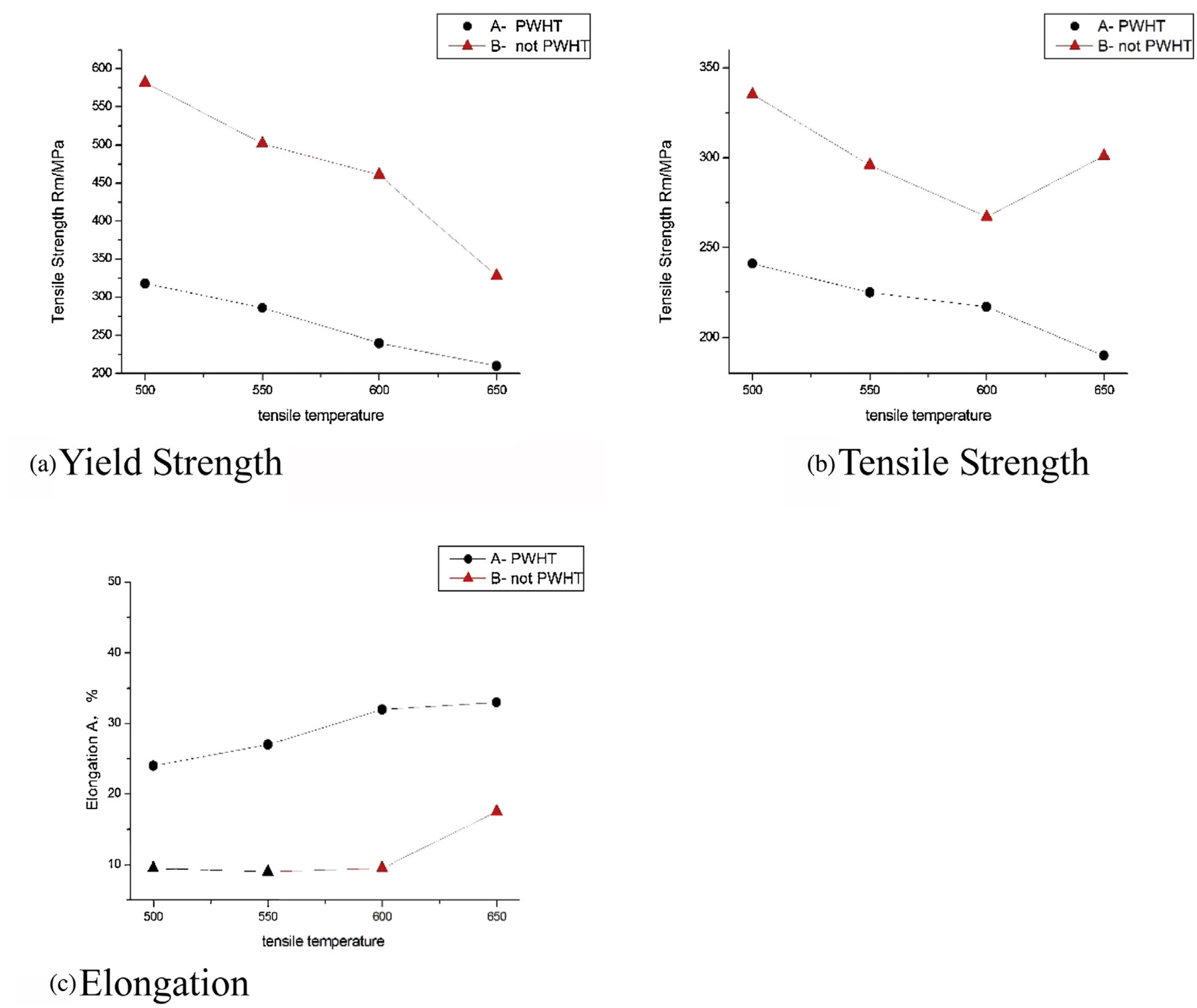

Fig. 2. High-temperature tensile properties of the CLAM joints.

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