Technical Note

Evaluation of Creep Behaviour in Different Zones of Similar & Dissimilar Weldments by Impression Test

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ABSTRACT

Preliminary investigation on impression creep behaviour of different zones (base metal,weld metal and Heat Affected Zone) of similar and dissimilar Cr-Mo steel welded joints in as welded and PWHT conditions has been attempted. It has been possible to evaluate the steady state creep rate of different zones and PWHT has shown a detrimental effect on the impression creep resistance of all weldments.

1.0 INTRODUCTION

Low-alloy ferrite steels have widespread applications at elevated temperature because of their suitable mechanical properties at high temperature and adequate resistance to corrosion [1]. These steels are used in steam power plants, chemical processing plants and petroleum processing plant. The current operating conditions of pressure and temperature of steam power plant have led to use of steels such as T91 [2,3]. However, T22 and T91 steels are both used in steam boilers, whereas the T91 tubes are used at higher temperature and pressure conditions, while the T22 tubes are installed at lower temperatures and pressure regions. The T22 tubes and T91 tubes are joined by fusion welding. The weldment according to the manufacturer's instructions [4] should be allowed by postweld heat treatments (PWHT). Performing the PWHT inside a boiler is technically very complex due to the limited access to the weldment region. However, the influence of PWHT on thermal and mechanical stability of the weldment between tubes of T91 steel and T22 steel and its necessity are not very clear. Also, the performance of a weldments depends on the performance of two additional zones created by fusion welding e.g. weld metal and HAZ and weakest zone between the two should be identified in order to rectify for further improvement of joint performance.

Normally, weldment mechanical properties are evaluated with the procedure and sample geometries which are originally designed for metals with homogeneous microstructures. For example, the tensile properties of weldment can be obtained from standard samples machined either perpendicular or parallel to the centreline of the weld. Such extracted sample may provide tensile properties of weld zone; but not for heat affected zone. However, a more complete understanding of the mechanical properties of welded joints can only be achieved if the specific contributions of the Zones in the weldments are considered [5].

The impression creep test method introduced by Li and co-workers [6,7], offers several advantages over the conventional creep tests, viz., small quantity of testing material, constant stress at constant load, absence of tertiary stage creep etc However, this technique has not been widely applied to the study of weldment, in particular Cr-Mo steel, although impression creep behaviour of other materials have been reported [8-10].

The aim of the present investigation is determine the effect of PWHT on the microstructure of similar and dissimilar weldments between tubes made of T91 and T22 steel and to elevated creep properties of both weld and HAZ of such weldments using impression creep.

EXPERIMENTAL PROCEDURE

The specimens for impression creep studies were from tubes made of T91 and T22 steels. The specimens were prepared by cutting segments of T91 and T22 tubes and welding with one to one and with one to another. The grove design of the tubes is shown in **Fig.1**. The welding of single V-groove joint is composed of three layers. The root pass was given by GTAW using ER905-B3 2-4mm filler wire and back filling was made by SMAW with a 2.5 mm E9018-B3L coated electrode. The welding parameters are given in **Table 1**. All completed welds were given PWHT as per specification. The welded joints were examined by radio-graphy and the specimens were prepared only from sound weldments.

Microstructures of the weldments were studied using optical microscope and Scanning electron microscopy (SEM). Microhardness survey across the weldment was performed for

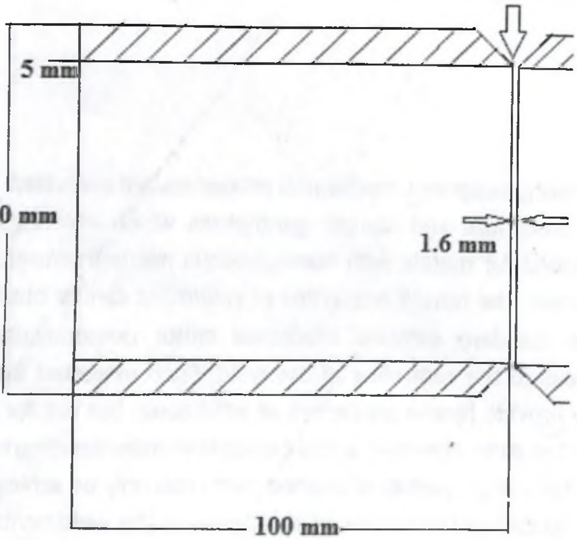


Fig 1 : Groove design of the tubes.

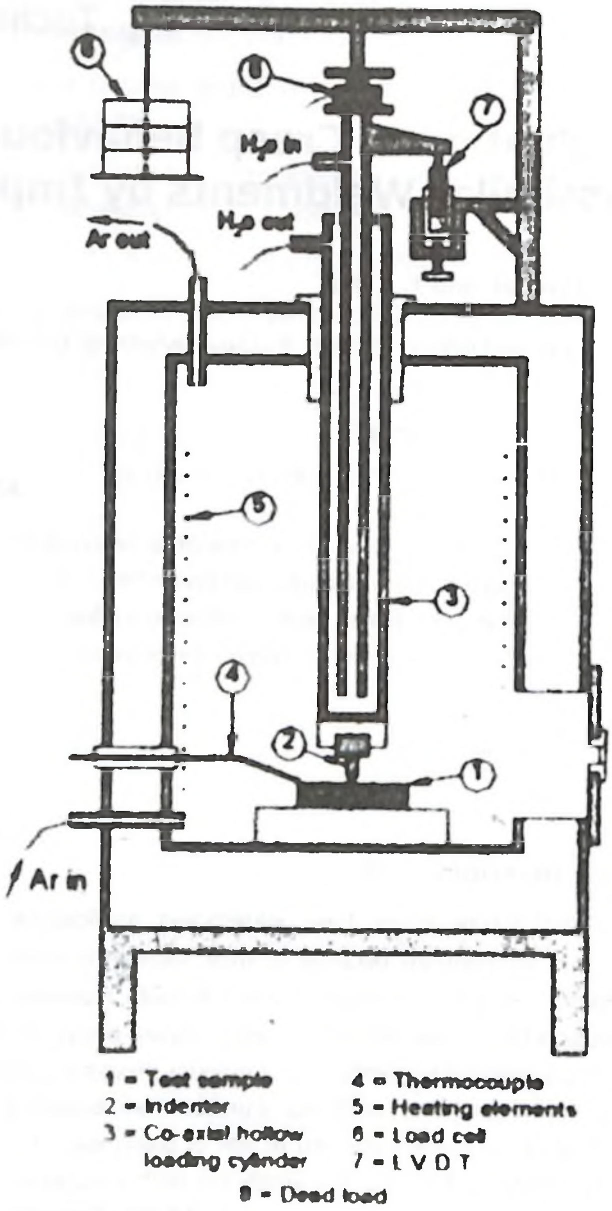


Fig 2 : Schematic diagram of impression creep testing set up.

Table 1 : Welding parameters used for similar and dissimilar welds.

Sample No.	Joint Type	Filler Metal	Pass Sequence	Voltage (Volts)	Current (Amps)	Preheat Temp (°C)
1	2.25 Cr-1Mo & 2.25 Cr-1Mo	2.25 Cr-1 Mo	Root Pass	25.3	77.5	175
			Back Filling	25.1	79.0	
2	2.25 Cr-1Mo & 9Cr-1Mo	2.25 Cr-1 Mo	Root Pass	25.7	79.0	200
			Back filling	25.5	78.5	
3	9 Cr-1Mo & 9 Cr-1Mo	9 Cr - 1 Mo	Root Pass	24.5	78.0	250
			Back filling	25.0	79.0	

different weld joints.

Prior to testing, all impression creep samples were ground flat, to approximately 3 mm thick slices, polished using standard procedure and finally light etched with 2% nital to reveal the sub zones. Samples were placed into the impression creep testing apparatus and the temperature was stabilized prior to the application of the creep load.

APPARATUS

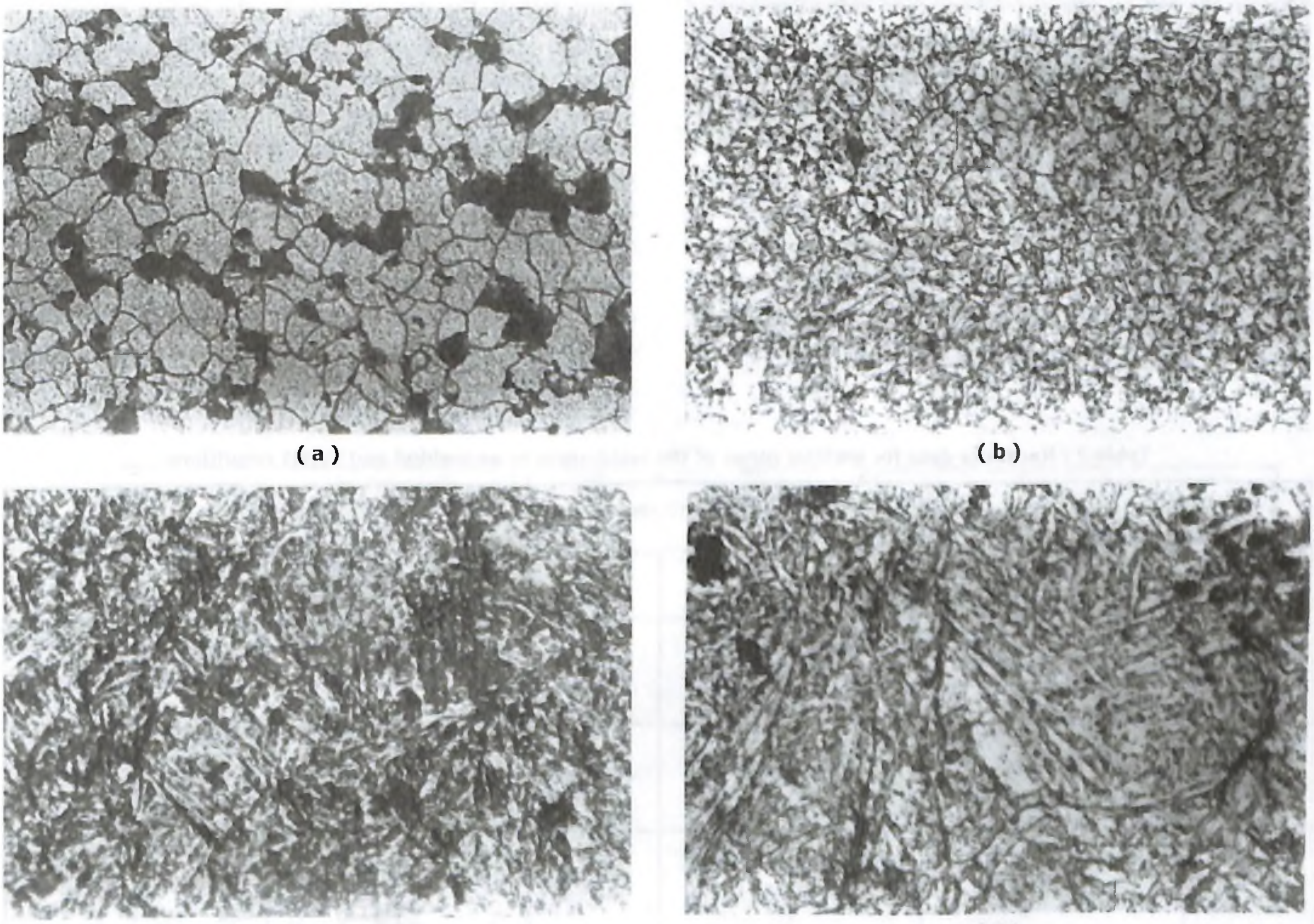
The testing arrangement for impression creep test is shown schematically in **Fig.2**. A flat end cylindrical punch with 1.1 mm diameter, machined from tungsten carbide rod, was used for the impression test. The test was performed at 545°C for 300 hours under a load of 27 kg. The displacement of the punch was monitored by a LVDT attached between load cell and the sample and was recorded as a function of time for each creep test.

RESULTS AND DISCUSSION

Microstructure

The microstructure of T22 steel consists of equiaxed grains matrix and of about 30 vol % pearlite (**Fig.3a**). The average grain size of the ferrite is about 14μm. The microstructure of T91 steel consists of tempered martensite matrix and precipitate (**Fig.3b**). The weldment between the T91 and the T22 steels can be divided into five subzones: The T22 fine grained HAZ, T91 coarse grained HAZ, the weld metal, the T22 coarse-grained HAZ and T22 fine grained HAZ. The microstructure of subzone 1 and subzone 2 (T91 HAZ) consist of martensite. The average size of primary austenite grain in the coarse- grained HAZ is about 32μm, while in the fine grained HAZ, it is only about 6μm.

Weld metal in as-welded condition consists mostly of martensite with some ferrite and bainite (**Fig.3c**). However, after PWHT the weld metal shows a mixture of ferrite, bainite and spherical precipitates (**Fig.3**).



(a) (b) (c) (d)

(e)

(f)

Fig.3 : Microstructure of base metal (a) T22, (b) T91, weld metal (as welded and PWHT) (c) T22, (d) T91, HAZ (as welded and PWHT) (e) T22, (f) T91.

The coarse grained and fine grained HAZ of T22 steel in as-welded condition are composed of ferrite and upper bainite. No microstrucal difference is observed between these two sub-zones except for average grain size, which is approximately 32μm in the coarse-grained HAZ and 6μm in the fine grained HAZ (**Fig.3e**). In the PWHT condition, the coarse grained HAZ shows ferrite and spherical precipitate with some upper bainite. However, no upper bainite is observed in the fine-grained HAZ of steel.

Hardness Test

The macro hardness of the different welded joints are shown in **Table.2**.

The microhardness profiles of the weldments in as-welded and PWHT conditions are shown in **Fig.4**.

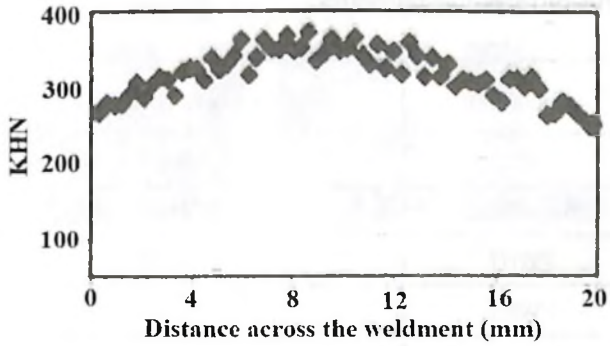
The microhardness profile across the weldment reflects the microstructural variation observed in different regions. A softer zone is observed adjacent to the fusion line in dissimilar Cr-Mo weldments. The soften zone arises due to carbon migration during PWHT. The driving force for the carbon migration is reported [11, 12] to be primarily a difference in chromium content of the base material versus that of the weldmetal. The carbon migration is towards the higher chromium material where carbon activity is the lower i.e. from 2.25 Cr-1 Mo to 9Cr-1Mo.

Impression Creep Studies

Typical impression creep curves, showing the variation in the depth of penetration of the indenter with time, are given in **Fig.5**. These curves corresponding to weld metal, HAZ, and

Table 2 : Hardness data for various zones of the weldments in as-welded and PWHT conditions

Sample No.	Type of Joint	As-welded Hardness (VPN)			PWHT Hardness (VPN)			PWHT (°C)
		Base Metal	Weld Metal	HAZ	Base Metal	Weld Metal	HAZ	
1	2.25 Cr-1 Mo & 2.25 Cr- 1 Mo	263	404	390	256	364	315	700
2	2.25 Cr-1 Mo & 9 Cr- 1 Mo	260 / 278	384	323 / 451	268 / 282	302	264 / 344	720
3	9 Cr-1 Mo & 9 Cr- 1 Mo	285	467	429	280	350	343	760



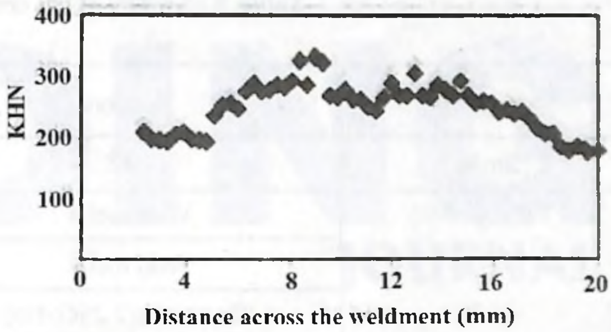
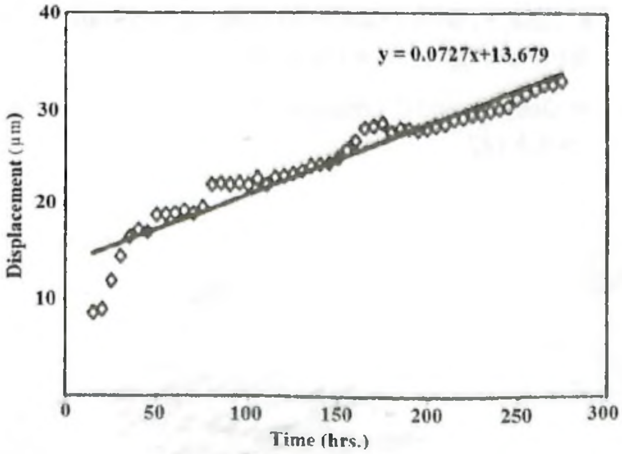


Fig. 4 : The microhardness profiles of the weldments in as-welded and PWHT conditions

base metal of similar and dissimilar weldments in PWHT conditions at a stress of 278.71 MPa and at 545°C. It can be observed that a steady state (linear region) is reached after an initial short transient period, as in conventional creep. Similar curves are obtained in other weldments and conditions. For creep deformation, a general correlation between activation area and stresses for all materials has been suggested by Balasubramanian [13] based on assumptions that the creep is single rate process and the dislocation structure remains essentially constant during a change of temperature, pressure or stress.

The usefulness of the impression creep technique lies in its ability to yield information on the creep behaviour of individual zone in weldments. The creep properties of the different zones in the present weldments are correlated with variation in the microstructure. Steady state creep rate is taken as the basis for evaluating the creep properties. It is to be noted that the curves show ups and downs and it becomes difficult to determine from the slope of the straight-line fitted in the second part of the curve. **Table 3** gives the steady state creep rates of different zones in different weldments found in impression creep test.

The weld zone in case of sample 2 in as-welded condition exhibits minimum creep rate. After PWHT the creep rate of weld metal increases. In fact, PWHT produces a detrimental effect on the impression creep resistance for all the weldments. This has been attributed to coarsening of microstructure [14]. Furthermore, while studying steady state creep rate of 2.25Cr-1Mo steel weldments, the authors reported that base metal undergoes creep at faster rate than weld metal tested at 773K, 827K and 873K and stress above 175MPa [14]. HAZ is the weakest link in sample 2. It is to be noted that the presence of δ-ferrite in the HAZ of 9Cr-1Mo steel reduces its grain growth tendency [15,16]. Courser carbide as well as equiaxed dislocation cells structure in sample 1 compared with fine carbide and lath martensite with high dislocation density in sample 3 is probable cause of such creep behaviour.



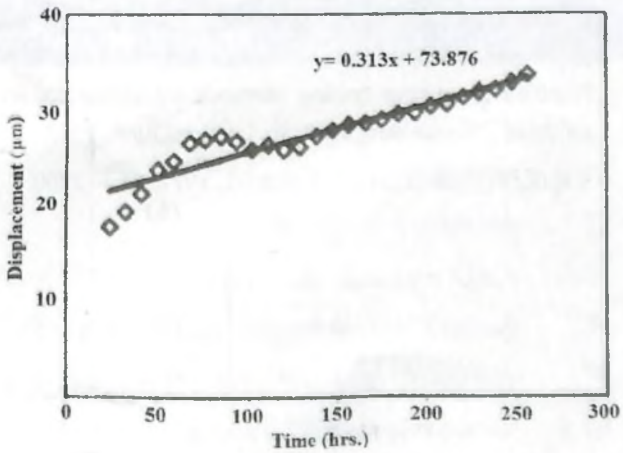


Fig.5 : Typical impression creep curve in HAZ of T22 (a) After PWHT and (b) As-welded condition

Table 3 : Steady state creep rate for different weldments

Sample No	Position	Condition	Creep rate (x10-8/sec)
1 (Similar)	HAZ	PWHT	5.1465
2 (Dissimilar)	Weld metal	As-welded	0.34595
	Weld metal	PWHT	1.8005
	Base metal(2.25Cr-Mo)	PWHT	1.75
	HAZ (2.25Cr-1Mo)	PWHT	7.861
	HAZ (2.25Cr-1Mo)	As-welded	1.8358
3 (Similar)	HAZ	PWHT	4.2045

CONCLUSION:

Preliminary investigation on impression creep behaviour of Cr-Mo steel weldments indicates that the impression creep test method could be used for determining the creep behaviour of different zones in weldments. PWHT produces a detrimental effect on the impression creep resistance for all the weldments.

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