Experimental Study On Creep Strength Of The Weld Joints Of 9%Cr Heat Resistant Steels

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Abstract: **The aim of this study is optimizing the creep properties of T91 weld joints at high temperature and pressure. After welding, tube portions were subjected to different cycles of post welding heat treatment, than creep tests at 650°C and a range of pressure values. Crept specimens were exterminated in order to determine the weakest zones in the joint.**

It was found that the rupture occurs in the base metal at high pressures and in the heat affected zone at low ones.

The creep rupture time of weld joint is lower than those of the base metal.Microstructure after creep is compared to the original one, to better understand the impact of creep exposure on microstructure evolution and to evaluate the strength of weld joints.

Keywords: **Power plants, T91, Environment, Welding, pwht, creep, SEM investigations.**

I. INTRODUCTION

Increasing the efficiency of power plants and respecting the environment are the main defies in developing new generations of power plants. Reaching high temperature ranges (more than 600°C) has a significant impact on increasing power plant efficiency and reducing pollution emission. Such objectives are substantially related to the use of high

resistant steels. The 9-12 % Cr ferritic/martensitic steels are major candidates to work at high temperature and pressure values increasing power performances [7, 8, 9].

The ASTM A213 T91 (also known as the Modified 9Cr-1Mo-V steel) has been widely used in power plants since the eighties. The international experience with the steel has been qualified as successful. In fact, it has proved excellent performances at high temperature by the mean of a high conductivity and a very low dilatation coefficient. The T91 improved mechanical properties are potentially related to its heat stable microstructure based on tempered martensitic matrix with rich fine carbides and carbonitrudes embedded in. Two typologies of precipitates are distinguished : the $M_{23}C_6$ carbides along prior austenitic grain boundaries (PAGB), packets , blocs and laths boundaries, and MX carbonitrudes which are fiely dispersed within laths[9]. It has been shown by the aim of several works that these precipitates exhibit low coarsenig rate during service. Thus, microstructure remains stable and the steel exhibit a successful creep life experience mainly at moderate condition (when temperature is below 600°C). Nevertheless, several problems are related to the use of this heat resistant steel. On a one hand, two major limiting life factors has been reported and affected directly the bulk material of tubes; microstrcuture evolution[6,7,13] and oxidation. On the other hand,

the grade 91 weld joints have a lower life time comparing to the base metal. Indeed, type IV rupture occurs mainly at the heat affected zone (ZAT) and enhances the creep failure of the installation, which consist serious problems [2]. Several works have been conducted to improve the quality of the weld joints and to more homogenize weld assemblies[13,14,15] In order to increase the deficiency of the installations and respect universal environmental codes. The Tunisian Company of Electricity and Gas (STEG) is planning to stand up the barrier of 600°C increasing permanences. Such a trend should be accompanied with various kinds of technical preparations. Therefore, this paper represents a technical support to better evaluate the performance of T91 weld joints at high temperature. Indeed, the maximum temperature reaches 550°C in super heaters; Referring to the long experience of STEG with T91 tubes, no creep damages have been localized in weld joints, but a great precaution have to be given at higher ranges of temperature.

II. MATERIAL

Chemical analysis were performed by an optical emission spectrometer (OES) type Foundry Master. Optical and Scanning elctronic microscopy (SEM) were carried after mechanical polishing by the mean of a series of silion papers from 320 to 1200um and villela (1g of picric acid + 5mL of hydrochloric acid + 100mL in ethanol) etching . Therefore, optical microscope type Austria Micros equipped with a digital camera and a software was used, while SEM examination were elaborated using a Juol SEM. A manual Vickers machine was used to carry out microhardness measurements along weld joint samples. Smooth specimens were extracted from Weld tubes longitudinal axis to conduct creep test; Thus, an Adamel Lombarghy creep machine was used. Specimen elongation was measured using a 10 um sensitivity sensor. The temperature fluctuation was within 2°C.

III. EXPERIMENTAL

1. Caracterization of the as received tube

a) Chemical composition: To conduct this work, a portion of Tube T91 Tube was provided by the "Central Electricity Generation of Rades" belonging to STEG. The outer diameter and the thickness are respectively 45 mm and 9mm. The chemical analysis is shown in table 1.

TABLE I: chemical composition of the as received tube compared to ASTM standards[1]

Element	ASTM A213 T91	ASTM Standards	Element	ASTM A213 T91	ASTM Standards
Fe	88.6	———	**Al**	0.003	0,004 max
C	0.143	0.05- 0.15	**Co**	0.01	———
Cr	8,72	8-9.5	**Nb**	0,111	0,02-0,1
Mo	1,2	0 ,85-1,2	**Ti**	0 ,005	———-
V	0,178	0,18-0,25	**W**	0,02	———-
Ni	0.26	0,4 max	**Pb**	0,023	———

b) Metallography: Fig.1 illustrates a typical old austenitic grain which is divided into packets, and each packet is also divided into blocks. Thus, the microstructure of steels with 9% chromium seems complex. In fact, when changing the packet, the orientation of the laths and blocs change too.

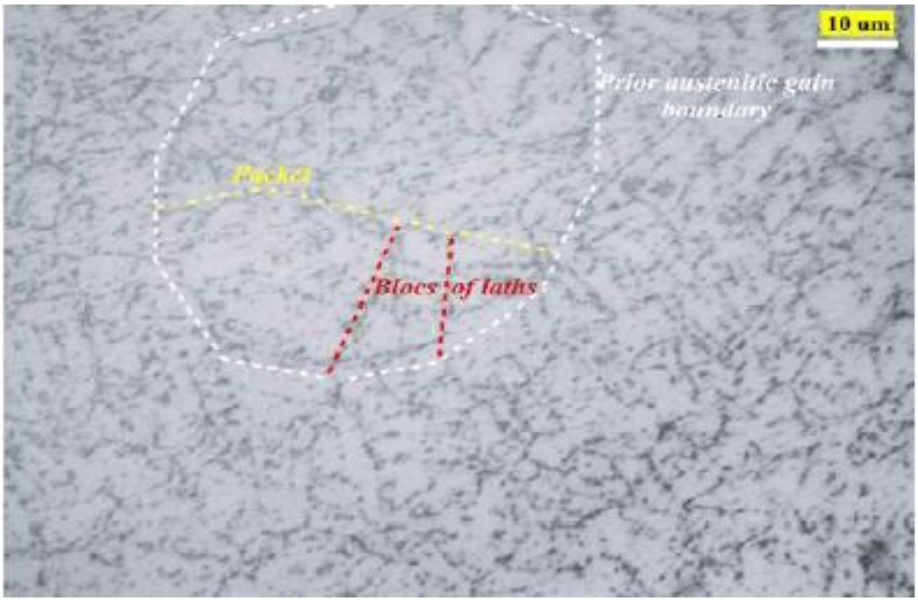

Figure I: Optical Metallography Of The As Received Material

2. Welding And Post Welding Heat Treatement (PWHT)

The welding process adapted in this study is the Shielded metal arc welding (SMAW). The properties of the filler metal are indicated in table II.

Table II: The properties of the filler metal

YS	UTS	Heat Treatment	Tempering	Hardness
363MPa at 500 C and	585 MPa	1060°C/30min	760°C/30min	220 H_v

The weld joint is obtained by the assembly of two tubes on X groove as shown in Fig.2.

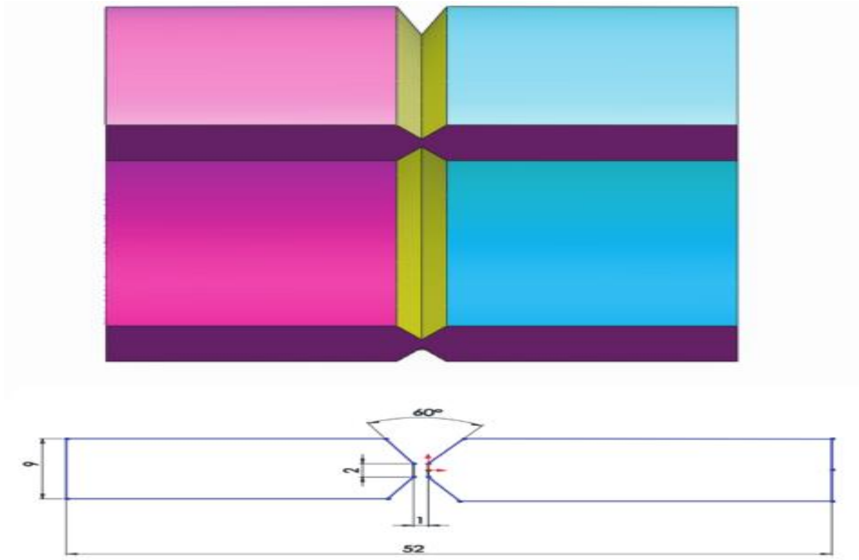

Figure II: Schematic illustration of the weld geometry

The welding parameters are shown in table III.

Table III: The welding parameters

Welding	SMAW
Preheating	200 C /30 min
Number of pass	1
Voltage	26V
Amperage	160A
Speed	12 cm /min

Before welding, a preheating was applied. Then, after welding, three post welding heat treatment were adopted. The aim is to better reduce residual stress generated by welding process and homogenize the microstructure of the weld joint and the heat affected zone (ZAT) [Fig.3].

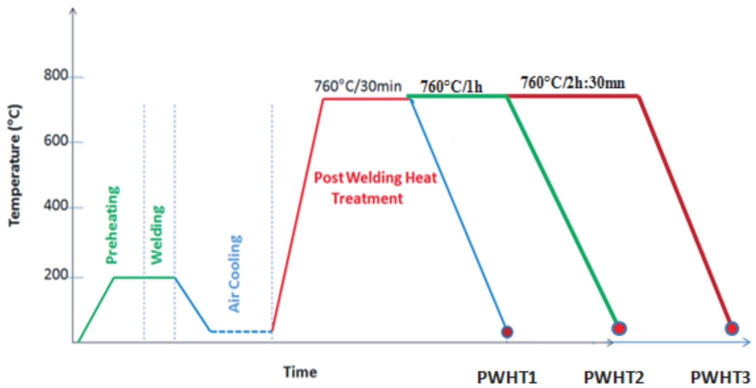

Figure III: Parameters of the different pwht applied in this study

3. Metallography Investigations on the Weld Joint

The aim of metallography investigations is to reveal the as-welded microstructure. Thus, it consists of different zones metallurgically heterogeneous. Indeed, the weld metal consists of fresh martensite. The ZAT, which is close to

It, is formed by three areas: The coarse grained heat affected zone (CGHAZ), the fine grained heat affected zone (FGHAZ)and the inter-critical heat affected zone(ICHAZ)[Fig.4].

Figure IV: Different zones presents in the weld assembly

SEM metallography of those areas is shown in Fig.V

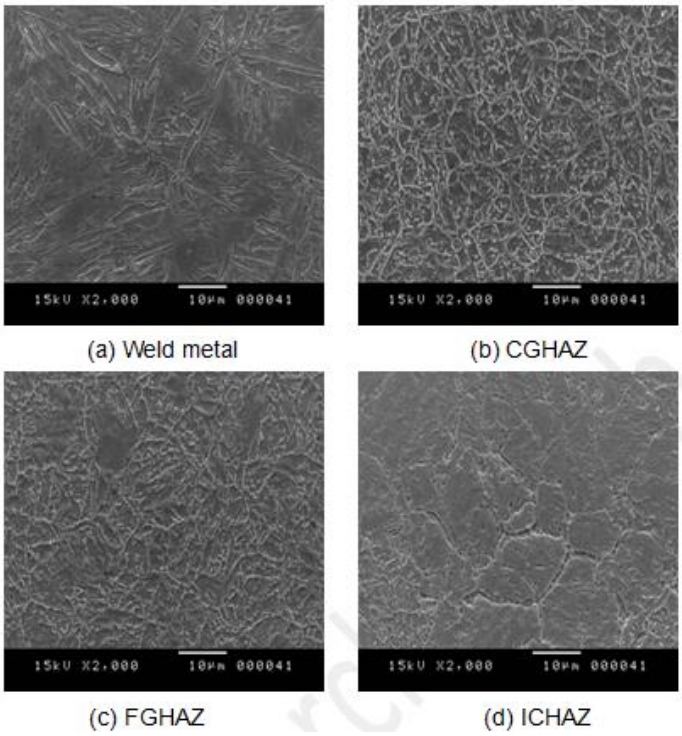

Figure V: Different area in the weld assembly

4. Microhardnes Measurements

Micohardness measurements traduce this microstructural heterogeneity[Fig.VI]. In fact, a high level hardness is found in the weld metal, and a gradually increasing is noticed when approaching to the base metal. Here, values reach the typical value of 224 Hv.

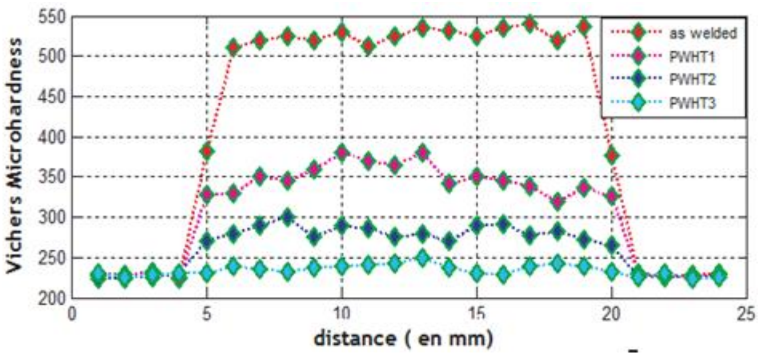

Figure VI: Microhardness measurements along the weld assembly

5. Creep Tests

The geometry of creep specimens is shown in Fig.VII.

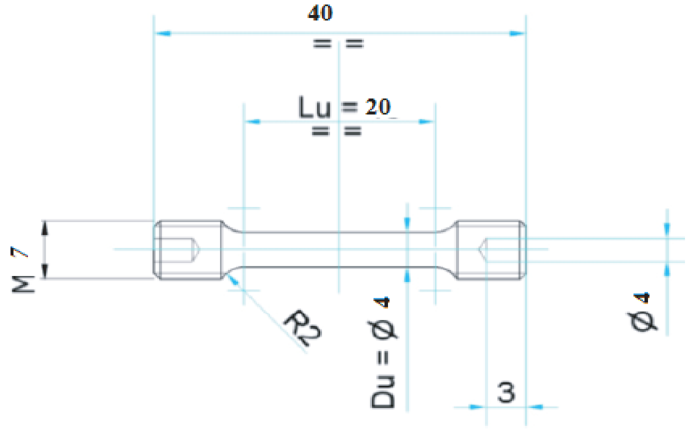

Figure VII: Geometry of the creep specimen

A program of creep tests is planned and tests are under running. The aim is to determine creep rupture time for different pressure values at 650◦C. At the present time, 4 tests are finished and results are carried out [Fig.VIII]. The time rupture of weld metal is clearly shorter than the base metal (three times shorter is found here). The longest creep test was interrupted and then continued, the stage I was not recorded.

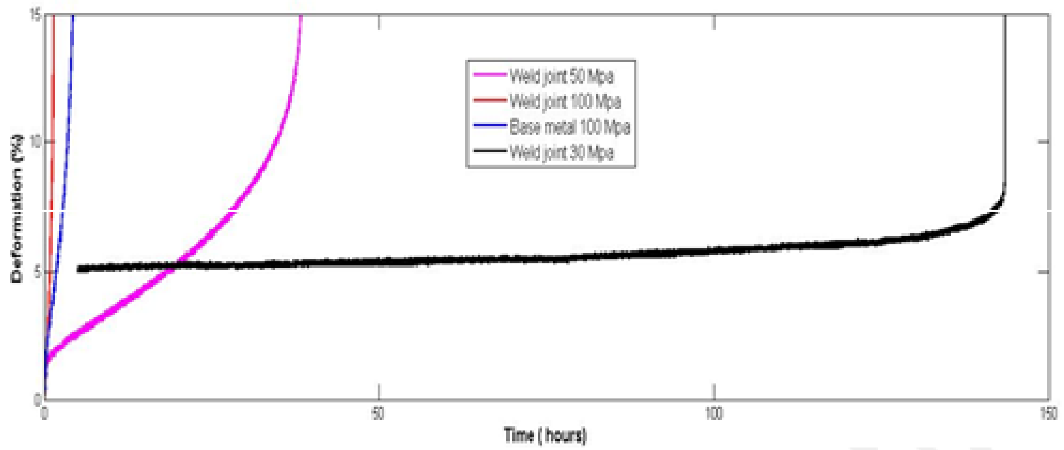

Figure VIII: Creep tests

IV. DISCUSSION

Creep curves are executed. Thus, the data provided here are :

- Weld joint life time is 3 times shorter than base metal. Such a result is in accord with a result found in literature[11]
- For high stress level, rupture occur in the base metal
- For low stress, it occurs in the weld metal
- Comparing these results to literature ones [16], the creep rupture seems to be controlled by viscoplastic deformation.

V. CONCLUSIONS

T91 are subjected to creep tests at 650◦C for different ranges of pressures. In order to raise up the quality of weld joints, welding process have to be done with high precaution. The parameters of post welding heat treatment affect

strictly joint life time. At the present time, four tests are conducted, but the program still under execution and the more results issued from creep tests and the examination of the crept specimen will be presented in the following work.

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