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Indentation of creep testing on P92 Material

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similar welding,
Austenitic stainless steel,
High strength Low alloy steels,
HAZ,
Finite Element Analysis

Abstract

Generally Fusion welding is done in steel pipeline in construction of power plants. Steel pipes carrying steam with high temperature and pressure, under creep in service. The main aim is to safety of boiler and human life and also increasing efficiency by reducing cost of material. To satisfy to all factor high-grade martensitic P92 steel is introduced to power plant pipes. T92 is used as pipes linking super heaters and reheater. T92 steel was developed in the late 1990's by changes of chemical compositions from T91.These new material have high creep resistance material. P92 steel pipes usually joined with similar material and also joined with dissimilar material to austenitic steel by using nickel based welding consumables. During Welding, residual stresses are caused in welding material. This stresses are removed by post weld heat treatment (PWHT). In this paper, analyzing of indentation creep testing on P92 material. The welding is done by laser welding method. The advantages of laser welding is more penetration compare with spot welding. The penetration can be achieved by controlling speed of weld. Finite element analysis is used to simulate cone indentation creep in materials across a wide range of hardness, strain rate sensitivity, and work hardening exponent. The assumption of the hardness strain rate sensitivity (H *m)* equaling the flow stress strain rate sensitivity (σ *m*) and indent area increases in proportion to depth. A method is provided for estimating area from depth during creep.

I. Introduction

In worldwide the increasing of electric energy consumption, there is demand to improve the efficiency of current power plants. To improve efficiency of power plants, the temperature and pressure are to be increased of pressure parts. It is necessary to find the modern new materials, which are able to resist these high steam parameters. The new material to be withstand to higher creep resistant strength (CRS) and service temperature.

P92 material is developed from P91 material by adding tungsten. P92 material is best creep rupture strength compared to P91. From different experiment, it is found that higher creep resistant strength (CRS) takes its origin in the balanced contributions from precipitation strengthening, solid solution strengthening with high dislocation density. To achieve high values of creep rupture strength to P92 material nitrogen and boron is essential. Without boron in P92 material, creep rupture strength is very low when compare to P91.

P92 material has high thermal conductivity, low susceptibility to thermal fatigue, low in thermal expansion coefficient, good corrosion and oxidation, resistance and relatively good creep resistance. P92 could be used to manufacturing of parts of super critical boiler. Crack easily created in 9-12% Cr martensitic steels. Hence the post weld heat treatment is must to avoid crack formation.

Welding of similar metals P92 preheat necessary before welding to avoid crack formation. Weld pool solidification takes from base metal to Centre of the weld. In the centerline weld, pool is symmetric in shape.

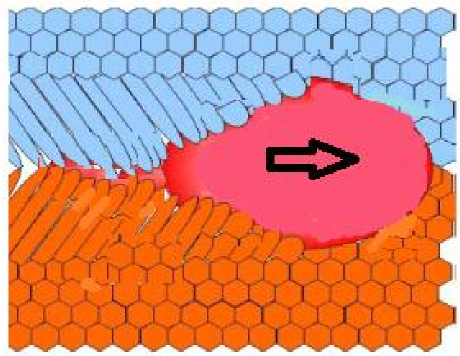

Fig. 1 view of similar joint

It is analyzed that high strength and less HAZ in similar joint. In this project, we analysis the laser welding by similar welding method.

I.1 Problem description

The main aim of the project is to analyse creep strength of P92 based on different parameter in laser welding. To establish physicals properties of P92 material in weldment and detailed finite element analysis through indentation creep testing method.

II. Literature study

P. Mohyla, Z. Kubon, R. Cep, I. Samardzic (01) this article evaluate creep properties of P92 base material (BM) and welded joints (WJ). The results of creep rupture test of base metal and welds are presented in this article. Initially Creep rupture strength (CRS) of welded joints is very close to base metal. At long time service welded joint of P92 material fracture and higher temperatures, creep strength are decreases.

Short-time CRS of welded joints lies close to base metal , but with increasing time to rupture at higher testing temperatures, creep strength of welded joint lied in between 20 % lower band of the mean CRS value and the - 40 % scattering band applicable for welds. The creep behavior of the welded joints is controlled performance of main steam pipelines at high temperature. Generally crack occurs in the low temperature HAZ, near to parent material, and then developed to additional axial or bending stress due to system loading.

David W.J. Tanner, Mohammed Saber, Wei Sun, Thomas H.Hyde [02] in this journal provides information that Creep Behavior of P92 and Welding at 675 _C. ,creep strength and resistance, Physical properties. Impression testing was performed to determine the relative creep behavior of the Heat affected zone (HAZ) and uniaxial tensile creep comparison between the P92 PM and similar P92 WM. The impression creep testing revealed that the minimum strain rates at low temperature HAZ were higher than corresponding values for the P92 PM and WM.

Y.Gu, G.D.West, R.C.Thomon [03] this paper discuss the Investigation about creep Damage in P92 material. The aim of the research is to analyzing characterize the microstructures of creep tested P92 samples. The Creep strength enhanced ferritic (CSEF) steels are used in headers, pipes, and tubes. The combination of properties of P92 material which are low susceptibility to thermal fatigue, good corrosion and oxidation resistance, high thermal conductivity, low thermal expansion coefficient, and creep resistance. It found that in the early stages of a creep test, the creep cavities in high Cr steels start to nucleate. Backscatter detector using an accelerating voltage. After exposure to creep test conditions revealed that majority of them were associated with hard ceramic particles. By using a combined in-lens SEM to analysis that born particles were present in regions of sample free from cavities.

A. Pfenniga, P. Zastrow, A. Kranzmann [04] In this journal provides information about strength of steels used for saline aquifer carbon capture and storage sites (CCS) is usually achieved by applying heat treatments. The properties of heat treatment are dependent on several parameters, such as time and temperature of material, cooling rate temperature to room temperature as well as time and temperature of annealing after the first cooling. From these, mechanical properties and corrosion behavior of materials have been studied. The long-term exposure tests in CCS environment, hardening and tempering at 600–670 ◦C offers the best corrosion resistance against uniform and pit corrosion at injection conditions of 60 ◦C and 100 bar.

A.H.Yaghi, D.W.J.Tanner, .T.H.Hyde, A.A.Becker, and W. Sun [05] in this article discussed about Finite element thermal analysis of the fusion welding of a P92 steel pipe. In this, detailed informed that construction of the pipes by applying fusion welding, involving thermal cycles, causing rapid heating and cooling of the welded metal. This induces residual stresses in the weld material and the heat affected zone (HAZ) of the pipes. In this study, the purpose of Post-weld heat treatment (PWHT) in P92 materials. The finite element (FE) numerical method, residual stress predictions throughout the welded component, sharp peaks of the stress field, depending on refinement of the generated finite element mesh. Due to unbalanced distribution of residual stresses, it was found that Peak of the stresses occur inside surface of Stainless steel part.

Jian Cao , Yi Gong , Zhen-Guo Yang , Xiao-Ming Luo, Fu-Ming Gu, Zheng -Fei Hu [06] this article discuss creep fracture behavior of dissimilar material between T92 and HR3C. The creep fracture is dependent on stress. Creep behavior and degradation of creep properties of components are designed for long life at high temperature. The material to be withstand at high-temperature at least twice the projected design life. The methods of creep property assessment is based on physical changes during service exposure rather than simple parametric extrapolation of the short-term data are necessary. In this article, reviewed that Physical models in prediction of microstructure–creep property relationship in creep-resistant steels

Josef kasl, Dagmar Jandova , Eva Chvostva , Petr Martinek [07] this chapter discuss about welding of P92 in GTAW & SMAW method. Creep testing conducted at temperatures from 575 to 650 °C and stresses from 70 to 240 MPa. Samples were analyzed with help of scanning and transmission electron after creep tests above the temperature 575 °C increase in size of secondary phases. Voids were concentrated in fine prior austenite grain heat affected zones. Grade P92 is ferritic 9Cr - 1.75W - 0.5Mo steel micro-alloyed with vanadium and niobium and with controlled boron and nitrogen contents. During tempering and creep exposure an intensive precipitation of Laves phase occurs, which leads to tungsten depletion of solid solution. However, it does not tend to more prominent decrease of creep strength. During welding, each weld pass effects the steel structure. Great attention need for selection of welding method and filler material .This paper deals with the study of microstructure evaluation in the similar weld joints of P92 steel fabricated in industrial conditions after creep tests.

T.H. Hyde, A.A. Becker1, W. Sun, A. Yaghi, J.A. Williams, and S.Concar [08] this article investigates creep properties for P91 weldment materials at 625C". Requirements in order to ensure satisfaction, safe and economic use of high temperature under creep conditions. From this article , the result was found that uniaxial and notched bar creep tests have shown that the creep rupture strengths of the parent material and weld metal are close to each other, and match with P91 mean data. And also weld metal show that the weld metal is slightly stronger than the parent material.

D. W. J. Tanner, M. Puliyaneth, W. Sun and T. H. Hyde [09] In this article detailed explain that Creep damage modelling of P92 pipe weld at 675 C. Creep data from ferritic steel P92 parent material, weld metal, cross-weld and heat affected zone specimens tested at 675uC are used to establish material behavior models necessary for describing the creep behavior of a P92 pipe with a circumferential weld. The method for determining the material properties for the heat affected zone of a P92 weld, in a single state variable creep damage constitutive model, using the data from cross-weld and impression creep tests, is described. The material properties for the parent material and weld metal regions have been already been published.

Creep continuum damage finite element analyses are subsequently performed for a P92 pipe internal pressure and end loading, in order to assess the high temperature integrity and failure behavior of a typical power plant component, from which the lifetime and potential failure modes can be predicted. Post-weld heat treatment was performed on the material from which the material properties were determined, and this stress relieving heat treatment was also assumed to have been performed on the pipe weld

Table 1 Phycial properties of P92 material

Sl.no	Elements	Units
1	Density	7850 kg/m3
2	Tensile strength	776Mpa
3	Solid temperature	1420^0 C
4	Liquid temperature	1500 ^{0}C
5	Latent heat	260 kj /kg
6	Creep failure	830^{0}C

Table 2 Chemical composition

Element	C	Mn	Si	S	P	Cr	Ni	Mo	Nb	V	B
Min	.07	.30	-	-	-	8.5	-	.30	.04	.15	.001
Max	.13	.50	.5	.01	.02	9.5	.40	.60	.09	.25	.006

III. Description of the experiment

The laser welding is done on P92 material with various parameters with nitrogen, helium and argon gases and its combination. The different welding speed and power gases are used to analysis character of P92 materials in laser welding.

Fig. 3 Preparation of sample piece

Table 3 Welding parameters

Power used	2500, 3000 and 3500 watts
Speed	1 M/min, 2M /min and 3M/min
Shied gas	Helium (He), Argon (Ar), Nitrogen (N2), and combination of Nitrogen and Argon.

Table 3

Sample no	Power	Speed M/Min	Shield gas
1	3500	2	Helium
2	3000	1	Helium
3	2500	1	Helium
4	2500	2	Argon
5	3000	2	Argon
6	2500	3	Argon
7	2500	1	Argon
8	3000	2	Argon+ Nitrogen
9	2500	1	Argon+ Nitrogen

The material preparation is involved by following steps such as milling, polishing and etching. Laser beam welding (LBW) is a welding technique used to join multiple pieces of metal through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. The minimum required size of the material for creep testing is 10 x 15 x 15 mm. The required size is done by milling machine. First the centre line of weld is marked and then 7.5 mm is marked on both ends. In marked place a small punch mark to be done for identification. Now the milling operation done to required minimum size. Etching is process of removing dust, oil and grease from surface of weld. This process is done by using chemicals which is called by Viellalas. Its combination of 1 gram picric acid, 5 ml hydrochloric acid, 100 ml ethanol or methanol.

The P92 samples and base materials were tested in Indentation creep testing machine at 600ºC using a punching stress of 100 MPa. The reading recorded such as time, depth on indentation, strain rate and creep rate.

III. Estimation of creep parameters

The steady-state creep rate of a metallic material can be correlated to the applied stress by the well-known power-law equation.

$$\varepsilon^{o} = A(\sigma\ imp)^{n} \exp \frac{-QP}{RT}$$

Where , T-Temperature, σ – shere modulus, A-Material constant , n- stress exponent, Q- Creep activation energy and R-universal gas constant.

Kutty et al.(2010) suggested that the impression rate (punch velocity) can be correlated with strain rate as:

$$\varepsilon^{o} = Vs/d \approx Vs/a$$

where ε^{o}- strain rate, Vs- impression rate, a-diameter of punch, d-depth of plastic zone.

Mahmudi et al. (2010) suggested that to correlate impression and tensile creep data, equivalent stress and strain rate can be evaluated from the impression velocity (Vimp = dh/dt), the impression stress under the punch.

$$\sigma = \frac{\sigma\ imp}{C1} \text{ and } \varepsilon^{o} = \frac{dh/dt}{\varnothing c2} = \frac{Vimp}{\varnothing c2}$$

Where c1 and c2 are constant, so rearranging the above two equations, we get,

$$Vimp = B(\sigma\ imp)^{n} \exp \frac{-QP}{RT}$$

Mahmudi et al. (2010) suggested that since B is a constant, it is possible to obtain the stress exponent n from a plot of In(_imp) at constant T. They said that, the activation energy Q can be obtained from a plot of In (Vimp) versus (1/T) at constant (σ imp).

Accroding to Akbari-Fakhrabadi (2012) the study-state impression velocity (Vimp) has been frequently correlated to the applied impression stress (σ imp) by the Dorn equation.

$$= \frac{V\ impT}{G} = A \left(\frac{\sigma\ imp}{G}\right)^{n} \exp\left(\frac{Q}{RT}\right)$$

IV. Result and discussion

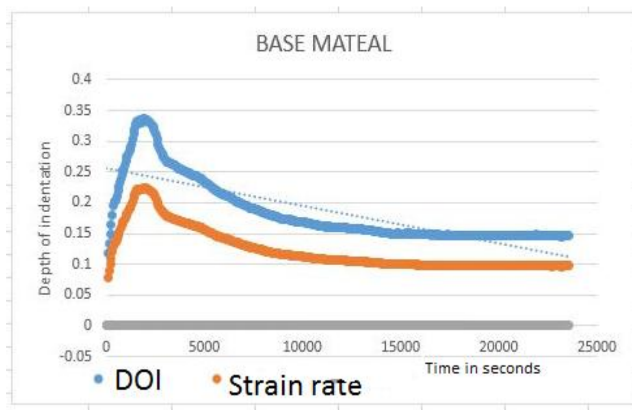

Fig. 3. Testing data of Base metal P92 in graph

The P92 base material is tested is indentation creep testing machine. This data are converted as graph for analysis result. This specimen is testing on at temperature of 600ºC and stress 100 Mpa. We get reading of Depth of indentation, strain rate and creep rate are noted. This reading is to be compare with sample which is welding material.

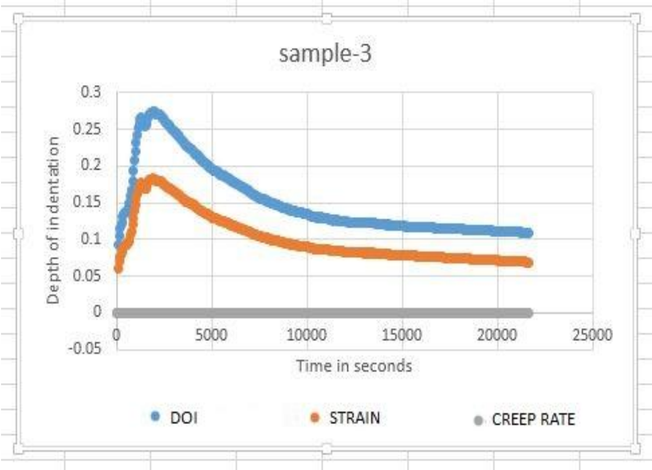

Fig. 4. Testing data of Sample-3 in graph

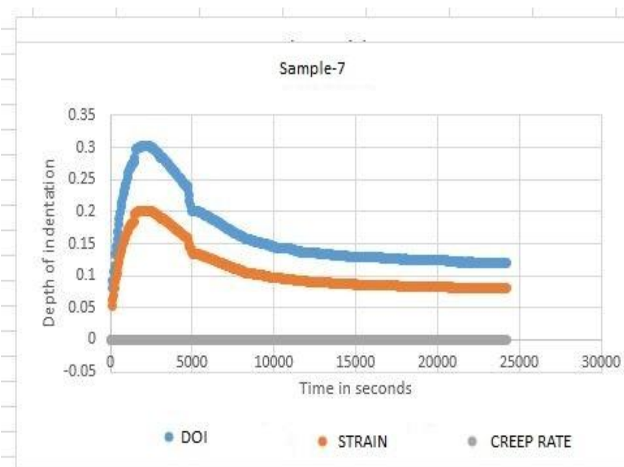

Fig. 5. Testing data of Sample-7 in graph

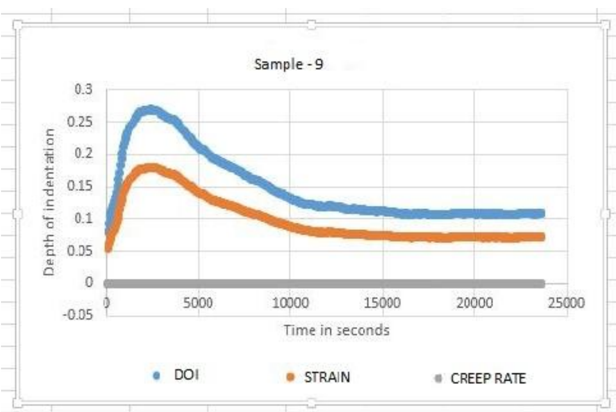

Fig. 6. Testing data of Sample-7 in graph

Conclusion

The thermal cycles due to welding metallurgical changes occur in the weld region and HAZ. This lead to joints to failure such as cracks. The final microstructure of the welded pipes, which is significant since it is desired that the pipe has good resistance to creep and fracture under abrasive conditions during service. The heat input can strongly influence the creep behavior of P92 welds. Heat input control is thus very critical for overcoming the problem of cracking in power plant steels. So that P92 base metal and samples pieces are tested in indentation creep testing machine for comparison to study the stress, strain, and creep rate.

An analysis of indentation creep at constant load has been performed to the characterization base material P92 of residual stress, Creep resistant strength studied with nine samples pieces with various parameters of welding. Comparing From testing data, residual stress, and Creep resistant strength of the following sample 3, 7, 9 are same with base material. From result, we conclude that by using the above three samples parameters of welding, joint to be withstand high temperature and pressure at long life without crack like base material. To improve the mechanical properties of welded joints the post weld heat treatment (PWHT) is carried out.

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