

Characterization And Corrosion Behavior Of Manual Metal Arc P91 Weldment By Using Dilute H₂SO₄

Mr.E.Hariharan¹, Ms.E.Jamuna²

¹Assistant Professor Department of Mechanical Engineering, Annai Mathammal Sheela Engineering College, Tamilnadu,India.

²Assistant Professor Department of Mechanical Engineering, The Kavery Engineering College, Tamilnadu,India.

Abstract- Strength of modified 9Cr–1Mo steel, which is used in the normalized and tempered condition, increases with increase in solutionising temperature with a corresponding reduction in percentage elongation. Initially P91 steel (9Cr–1Mo) plates were normalized and tempered, then microstructures determined by image analyzer and metallurgical microscope. Welding of P91 steel is done by using Shielded Metal Arc Welding (SMAW). Immediately after the completion of the welding post heating was carried out at 730⁰C for duration of 2hours. The microstructure performance in the welding zone of P91 steel, base metal and heat affected zone were examined by means of image analyzer and inverted metallurgical microscope. Thereafter hardness of throughout specimen determined using micro hardness tester. Then electro chemical polarization and behaviour of P91 steel has been investigated in acid and alkaline environment. Corrosion studies of P91 steel in concentrated acid as well as basic scarcely reported. Therefore corrosion behaviour of P91 steel of different concentrated of solution of dilute hydro chloric acid and dilute sulphuric acid used as corrosion environment. Finally, determination of corrosion rate and tafel plots drawn by electrochemical analyzer.

1. Aim and Scope

The 9%Cr steels developed for advanced power stations, P91 have been investigated. Quantitative microstructural investigations (sub-grain width, dislocation density, particle size distribution and their chemical compositions) have been carried out using analytical transmission electron microscopy. The microstructural parameters of 9%Cr steel and correlation with different creep rupture behavior are presented. The results show that in the first 3000 h of creep exposure at 600 and 650°C, there were a rapid reduction in the dislocation density and an increase in a tempered martensite sub-grain width. During long-term creep deformation, the M₂₃C₆ carbides coarsened, while the MX precipitates exhibited insignificant change in size. Large particles of Laves phase, Fe₂(Mo,W) were also precipitated. The increase in the thermal efficiency of fossil fuel fired steam power plant that can be achieved by increasing the steam temperature and pressure has provided the incentive for the development of the 9% chromium steels towards improved creep rupture strength.[1]

During the last twenty years, P91 steel has been developed to commercial Production. P91 was originally developed by the Oak Ridge National Laboratory for application in the fast breeder reactor and has now become well-established steel for power station components To meet the demands of the power generating industry with its aim of increasing steam temperatures and pressures, Ferritic steels were preferred to austenitic steels because of their lower coefficient of thermal expansion and their higher resistance to thermal shock. Of these steels, the modified 9%Cr 1%Mo steel known as P91/T91. Typical issues include chemistry effects, fabricability, weldability, fireside corrosion, streamside corrosion, aging, long-time creep, and damage. [2]

This article describes corrosion behavior on P91 steel that was initially normalized and tempered at desired temperature and time. The welding of P91 steel was carried by using manual metal arc welding with heat input of 73.46J/mm with post weld heat treatment at 730° temperatures. The microstructure of the welding zone in P91 steel, base metal and heat affected zone were determined by means of image analyzer and inverted metallurgical microscope. Micro

hardness of P91 steel was determined by hardness tester. corrosion rate and drawn the tafel plot by means electro chemical analyzer with 0.5%,1% and 1.5% of H₂SO₄ solution environment were determined.

2. Experimental Work

2.1. Weld pad Fabrication

The base material was 12mm thick plates of modified 9Cr-1Mo(ASTM A213) steel received in the normalized (960^oC/1hour and air cooled) and tempered (780^oC/1hour and air cooled) condition, of dimensions 120 x 50 x 12mm. Base metals were cleaned using grinding wheel to remove oxide layer from the surfaces. The electrodes used were low hydrogen basic coated 9Cr-1Mo of non synthetic. Electrodes were of size diameter 3.20mm &450mm long, conformed to AWS classification E9018 –B9. The electrodes were baked at temperature of 250^oC for 2 hours prior to welding, in order to remove the moisture content in the electrodes and to aid good welding characteristics.

Table 1 Typical chemical composition of base metal in wt %

C	C	M	M	N	Si	P	S	V	A	Ti	F
r o n i l e											
0.	9.	1.	0.	0.	0.	.0	.0	.2	0.	0.	9
12	0	0	3	1	3	2	8	5	0	0	0.
5			9	2	3				1	3	1

Table 2 Typical chemical composition of Electrode in wt %

C	Si	Cr	S	Mo	Mn	Ni	P
0.07	0.28	9.0	0.0189	0.99	0.68	0.20	0.018

2.2. Edge Preparation & Joint Fit-Up

Edge preparation was done on the base metals as single “V” groove, butt joint type with an included angle of 120^o having land height of 3mm. The two base metals were kept close together in the flat position

(1G) with a root gap of 1.5mm and tack welded at the junction of two end points. The schematic diagram of weld joint fit-up shown in Fig 1

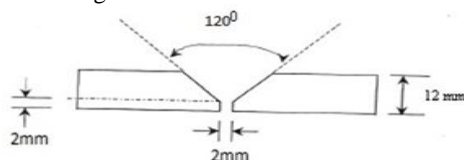


Fig 1 Edge preparation of the base metal

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization,

Volume 3, Special Issue 2, April 2014

Second National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2014)

On 21st & 22nd March, Organized by

Sri Krishna College of Engineering & Technology, Kuniathur, Coimbatore-641008, Tamilnadu, India

Starter and run-off tabs were provided at the both ends of the weld pad to avoid the interruption of arc starting and finishing of arc. No backing plates were used during welding. In order to reduce the cooling rate of weldmetal after welding, preheating was done at a temperature of 250^oC on the base plates before deposition of weld metal with muffle furnace as the preheating source.

2.3. Welding

After ensuring the joint fit-up of the base plates to be joined, welding was carried out with DCEN in the flat position (1G). Multi-pass welding was made with preheat and an interpass temperature of 250^oC. During deposition the detachability of slag was visually inspected & after each pass, de-slagging was carried out on the weldment. The weld metal in the root pass was ground back & re-welded from the opposite side to remove the root defects, if present. Done the welding of P91 steel with current 125A, voltage 30V, welding speed 49mm/sec and desired Heat Input is 1.875KJ/mm.

2.4. Post Welded Treatment

Immediately after the completion of the welding post heating was carried out at 730^oC for duration of 2hours. In actual welding, post weld heat treatment (PWHT) is used to produce a uniform tempered martensite structure across the weldments, making it difficult to distinguish the HAZ sub-zones and the boundary with the unaffected base plate.

3. Testing

3.1Metallographic Examination

A transverse section was taken from each of the weldpads. The surface on which metallographic examination has to be done was made flat using various grades of silicon carbide sheets ranging from 1/0 to 4/0.before emery polishing grinding is done to remove the coarse of specimen

Then the surface was polished with wet alumina. Final polishing was done on smooth cloth impregnated with alumina granules of size 6 microns and mirror like finish was obtained with alumina polishing of size 1 microns. Metallographic examination of the fusion zones, heat affected zone was performed using Villels's reagent nital as etchant. After etching the microstructures of the weldmetal, HAZ and base metal were studied with Image analyzer.

3.2Hardness Test

Hardness survey was carried out on a MATSUZAWA Model-MMT X-3 micro hardness unit using a 300gf load (Loading time-15 sec). Surveys were conducted both across the weld metal and HAZ into base metal. Generally the distance between the indents was made 1000 microns in regions.

3.3. Tafel Plotting And Corrosion Rate

By using tafel plotting system, the various regions of base metal, weldmetal and HAZ were analyzed. For that the solution of 0.25, 0.5, 0.75 and 1% of dill H₂SO₄ solution is prepared. All parts are to be cleaned only by using distilled water. The specimen is kept to fill the gap of 1cm², and solution is filled to chamber and all connections of working electrode, calomel electrode and graphite electrode are made. Finally the tafel plotting was made by using the software for each specimen, and then the Corrosion Rate was calculated.

4. RESULTS & DISCUSSION

4.1. Microstructural Analysis

In the as received normalized and tempered condition, the microstructure of P91 base metal consists of fully tempered martensite with small precipitate particles on the prior austenite grain boundaries and some within grains, which could be observed in light microscope at 100x magnification.

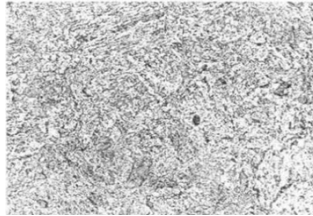


Fig 2 Microstructure of P91 base metal

In welded condition P91 electrodes produce a predominantly martensite structure in which solidification substructure characteristic of weld fusion zones are not seen. These weld metal metals solidify as ferrite in which the rapid diffusion considerable compositional homogenization. Other transformations also take place (from ferrite to austenite and austenite to martensite) in the solid state. The microstructure in the weld metal is composed of austenite and a little amount of delta ferrite. The principle reaction occurring during post weld tempering is the precipitation of carbides and other phases.

4.2. Micro Hardness Test

Hardness of the specimen determined by MATSUZAWA Model-MMT X-3 micro hardness tester. Hardness increase from centre of fusion zone to both sides of the test specimen. The dislocation density decreases with increase in the tempering temperature and time of holding. Dislocation density decreases due to the annihilation of dislocations and by the formation of low angle grain boundaries. The effect of solid solution strengthening is also affected due to precipitation reactions occurring during tempering. A decrease in hardness can be seen after PWHT. It was understood from literature that the decrease in dislocation density is more when tempering is done at high temperature. And also the coarsening of precipitates is a main factor for reduced hardness at higher temperatures.

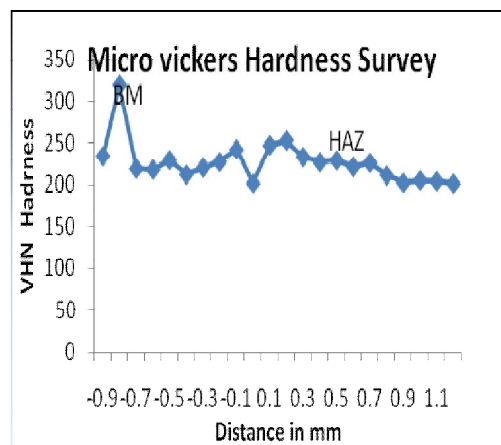


Fig 3 Representation of microhardness curve

Corrosion Rate Measurement

Corrosion rate of base metal, heat affected zone and welded zone were determined by tafel plots with help of electro chemical analyzer. Corrosion rate of different region of sample determined with different concentration of H₂SO₄. For the same tafel plots as follows

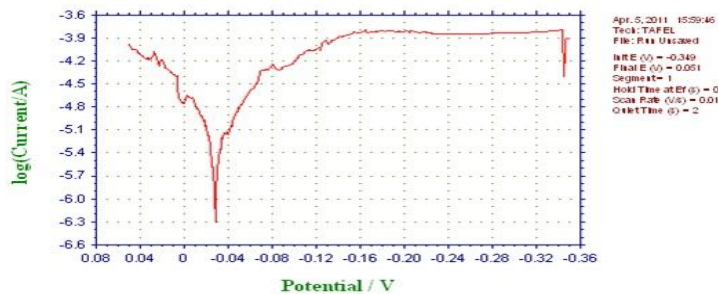


Fig 4 Tafel plot for weldment in 0.5% H₂SO₄ Solution with Corrosion Rate 4.59 mils/year.

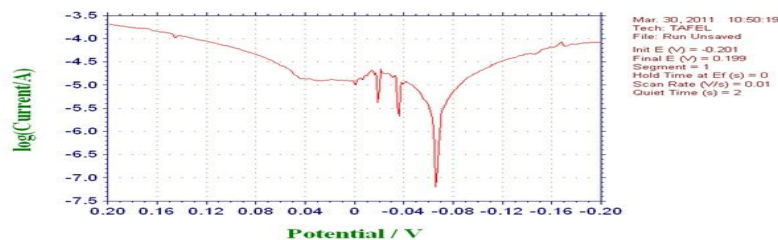


Fig 5 Tafel plot for weldment in 1% H₂SO₄ Solution with Corrosion Rate 8.17mils/year

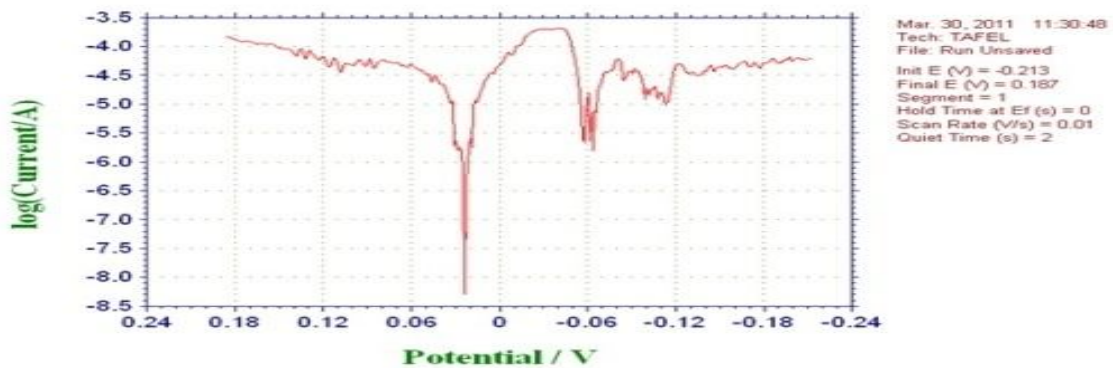


Fig 6 Tafel plot for weldment in 1.5 % H₂SO₄ Solution with Corrosion Rate 5.82 mils/year

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization,

Volume 3, Special Issue 2, April 2014

Second National Conference on Trends in Automotive Parts Systems and Applications (TAPSA-2014)

On 21st & 22nd March, Organized by

Sri Krishna College of Engineering & Technology, Kuniyamthur, Coimbatore-641008, Tamilnadu, India

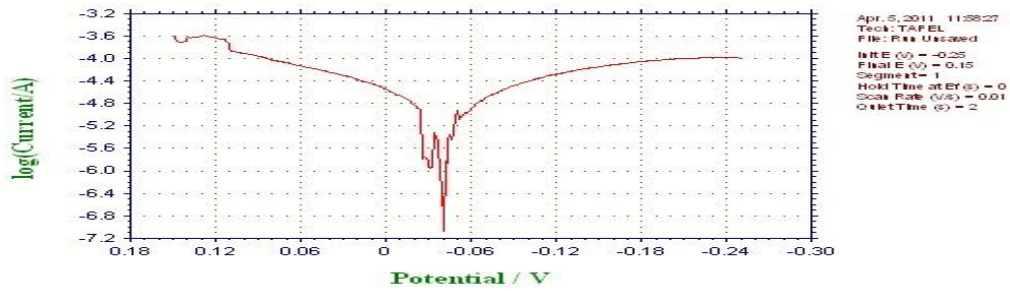


Fig 8 Tafel plot for HAZ in 1% H₂SO₄ Solution with Corrosion Rate 8.676 mils/year

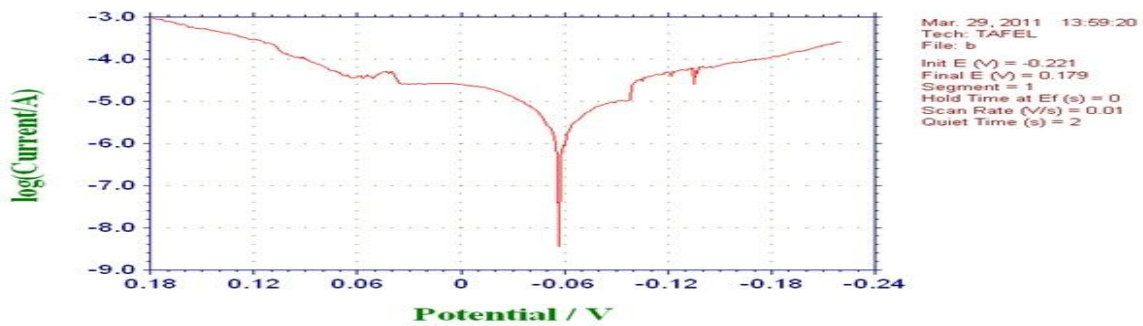


Fig 9 Tafel plot for HAZ in 1.5% H₂SO₄ Solution with Corrosion 9.3 mils/year

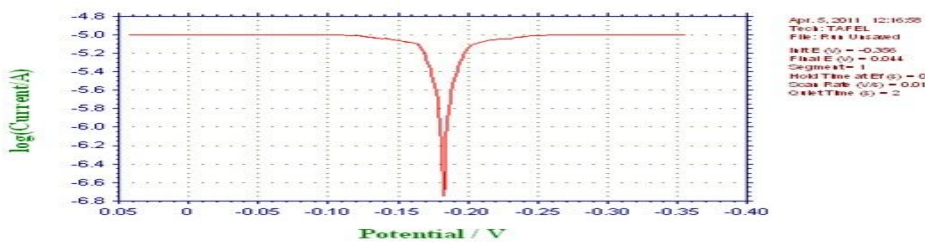


Fig 10 Tafel plot for Base Metal in 0.5% H₂SO₄ Solution with Corrosion 7.52 mils/year

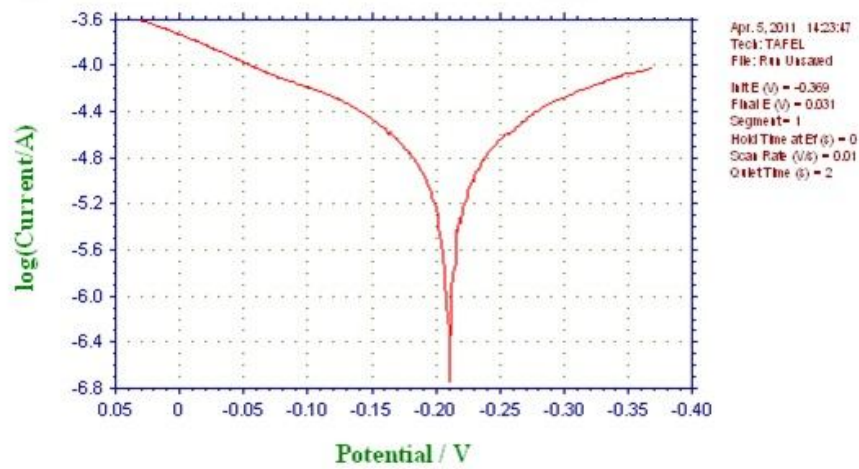


Fig 11 Tafel plot for Base Metal in 1% H₂SO₄ Solution with Corrosion 8.17 mils/year

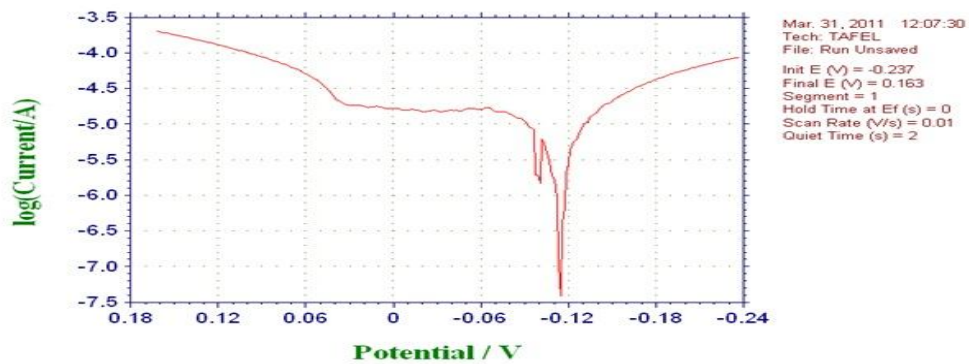


Fig 12 Tafel plot for Base Metal in 1.5 % H₂SO₄ Solution with Corrosion 8.63 mils/year

Table 4 final corrosion rate [mils per year] results:

Amount H ₂ SO ₄ solution	0.5%	1.0%	1.5%
Base Metal	7.52	8.21	8.63
Weldmetal	4.08	4.59	5.82
HAZ	8.5	8.676	9.3

Summary of the corrosion rate of base metal, weldment and HAZ of 0.5, 1.0 and 1.5% of H₂SO₄ solution environment drawn in graph as follows



Fig 13 Representation of Corrosion Rate for various concentration of H₂SO₄ solution

5.1. Conclusion

Welding of P91 steel is done by using Shielded Metal Arc Welding (SMAW). Immediately after the completion of the welding post heating was carried out at 730⁰C for duration of 2 hours. Many properties of welded P91 steel were carried out. It can be concluded that:

1. Base metal of P91 steel in normalized and tempered condition has Tempered Martensite structure.
2. Microstructure in the welding zone of P91 steel and heat affected zone are patches of ferrite with fine carbide observed by means of image analyzer and metallurgical microscope.
3. Micro Hardness Test reveals that the hardness has been gradually increasing from Weld Centre Line to HAZ and base metal.
4. Passivation behaviour of P91 steel is almost same for weldmetal and HAZ, but base metal has low value in 0.5, 1 and 1.5% H₂SO₄ solution environment.

REFERENCES

- [1] S.V.Nadkarni, 2005, "Modern arc welding technology", Oxford & IBH publishing company pvt ltd, vol 10, pp 429-431.
- [2] M. Vijayalakshmi, S.Saroja, V.Thomas Paul, R.Mythil & V.S.Raghunathan, 1999, "Microstructural zones in the primary solidification structure of weldments of 9Cr-1Mo steel", Metallurgical and materials transactions A, vol 30A, pp 161-174.
- [3] B.Arivazhagan, S.Sundaresan, M.Kamaraj, 2009, "A study on influence of shielding gas composition on toughness of flux cored arc weld of modified 9Cr-1Mo(p91) steel", journals of material processing technology, vol 209, pp 5245-5253.
- [4] C.R. Das a, S.K. Alberta, A.K. Bhaduria, G. Srinivasan, B.S. Murty, 2008, "Effect of prior microstructure on microstructure and mechanical properties of modified 9Cr-1Mo steel weld joints", Material science and Engineering A, vol 477, pp 185-192.
- [5] G. Hilson, S. Simandjuntak, P.E.J. Flewitta, K.R. Hallama, M.J. Pavierb, D.J. Smith, 2009, "Spatial variation of residual stresses in a welded pipe for high temperature applications", international journals of pressure vessels and piping, vol 86, pp 748-756.
- [6] M. Sireesha, Shaju K. Albert, and S. Sundaresan, 2005, "Influence of High-Temperature Exposure on the Microstructure and Mechanical Properties of Dissimilar Metal Welds between Modified 9Cr-1Mo Steel and Alloy 800" Metallurgical and materials transactions A, vol 36A, pp 1495-1506.
- [7] B. Huneau, J. Mendez, 2003, "Fatigue behavior of a high strength steel in vacuum, in air and in 3.5% NaCl solution under cathodic protection", Material science and Engineering A, vol 345, pp 14-22.