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Research Article

Repair welding of p-91 material by using Half layer method

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half layer technique.
heat treatment process

Abstract

Repair welds, are frequently used in material structure either to remedy initial fabrication defects or to rectify in service degradation of component. some previous investigations indicates that repair welding by techniques Such as temper bead welding technique is likely to push adverse effect in the long term integrity of the structure exposed to high pressure and temperature actions. It believed that high residual stress are associated with the said repair process and must probably play an important role in many of subsequent failure. Repair welding using temper bead welding technique might aggravate the size magnitude and distribution of tensile residual stresses in the weld mend. To over come such problems and to eradicate those short coming in repair welding processes this paper deals with repair welding using half layer technique. The material involved in p91 the most common material used thermal power plants. By using half layer repair welding technique the problem such as creep was rectified and result analysis shows better results when compared with temper bead welding technique and also this eliminate the need for post weld heat treatment process.

1.Introduction

Components operating at high temperature or harsh working conditions are subjected to different failure regimes which require special consideration. In scheduled shutdowns, critical components are inspected and if necessary either replaced or repaired. Generally, the cost effective choice is to extend the life of aged components by repair rather than replacement.

Repair can be the only alternative particularly if the required material for repair is not available within outage time constraints. Repair welding maybe carried out using a range of welding techniques depending on the nature of the repair. Commonly, most weld repairs require post weld heat treatment (PWHT) to restore the deteriorated metallurgical and mechanical properties. However, critical issues in the course of PWHT such as time, component geometry and unsupported loading during the time the component is hot, mean that it is not always possible to carry out the full procedure. Duration of hold time during the PWHT cycle can be very long especially for thick walled components which result in the extension of the unit downtime. Complex geometry may cause difficulties in reaching the exact region of repair therefore a larger area has to be heated instead. This can lead to distortion particularly when mechanical loads are attached to the structure since deformation may occur at the elevated temperatures of the heat cycle. Due to the difficulties and limitations encountered with PWHT, alternative techniques have been developed. The role of this paper is to develop alternative techniques to PWHT. Welding processes, parameters and techniques and the key aspects of successful weld repair are also considered.

2. Techniques for avoiding PWHT

One of the alternative echniques for PWHT is bead tempering during the welding process, where this technique is usually called temper bead welding (TBW). In actual effect, the HAZ created by the former of two successive beads is tempered by controlling the heat input ratio between the two beads (which may also form two weld layers). The final passes of the weld bead may be in an un tempered state but these can be removed by grinding. The idea is to manipulate a standard welding process in such a way that the heat of one pass of the weld pool can be used to temper the metallurgical structure of previous beads, thereby during the welding stage itself achieving the metallurgical structure that is obtained after PWHT. The task involves controlling metallurgical transformations by modifying the welding technology, such as by using different sizes of electrodes. The amount of damage and the depth of material that requires to be tempered is reduced by using small weld beads, which means small diameter consumables and lower amperages and heat inputs. Several techniques for bead tempering have been developed to modify the microstructure of both weld metal and HAZ in order to improve the as-welded fracture toughness. These include:

• The half bead technique, where the beads are ground back before welding the next layer.
• The back step technique, where the laying of the weld bead is repeatedly moved opposite to the direction of welding progress.
• The half layer technique, where the repair weld layer is removed for the earlier passes and again weld is done above it.

Among those techniques the half-layer technique has been included as an accepted alternative to the half-layer technique described in Section XI of the ASME Code

An extensive research project , jointly conducted by both TWI in the UK and EWI in the USA, concentrated on the assessment of half layer technique for its applications for various carbon and low alloy steels, commonly used in the power industry. The Welding Research Council's critical review and publications have discussed the practical aspects of the temper bead technique processes. However, systematic understandings of the micro structural changes as a result of the varying in welding sequences and the resulting properties have not been established.

2.1 Grade 91 Material

Half layer technique welding has become a popular repair choice for many carbon and lower alloy steel materials but, it has not been attempted on Grade 91. This is primarily because the chemistry of Grade 91 results in a martenstic structure during most heating and forming operations. Unlike 2 1/4 Cr -1 Mo, 1 1/4 Cr – 1/2 Mo, and carbon steels; welding of Grade 91 can result in a very hard brittle microstructure. Hardness values after welding are commonly above 450 Hv (45 Rc) in the weld metal and HAZ. Welds completed with matching filler metal prior to PWHT often demonstrate less than 10 ft-bls (13.5 Joules) toughness and after heat treatment may be below 20 ft/lbs depending on welding process used.

Many successful repairs have been completed on carbon steel, Grade 11, and Grade 22 materials in power plants using the SMAW welding process. Repair cavities generally do not lend themselves to automated GTAW repair methods. For half layer technique to be valuable for Grade 91 components, it would have to be developed using the SMAW process. The half layer technique welding development in this chapter was performed on 1 ½” (38 mm) thick Grade 91 plate and included toughness, hardness, tensile, and rupture testing.

3. Experimental work

3.1 Materials and preparation

The chemical compositions of grade 91 are given in Table 1.

Table.1.Chemical Composition of base metals

BASE MATERIAL	ELEMENTS(%)												
	C	Mn	P	S	Cu	Si	Ni	Cr	Mo	V	AL	Cb	N
ASME/ASTM	0.08-0.12	0.30-0.60	0.020	0.010	NS	0.20-0.50	0.40	8.00-9.50	0.85-1.05	0.18-0.25	NS	0.06-0.10	0.03-0.07
PLATE	0.11	0.48	0.11	0.003	0.13	0.27	0.28	8.36	0.98	0.217	0.016	0.078	0.046

Table.2.Chemical Composition of filler metals

C	Mn	Si	S	Ni	Cr	Mo	V	Al	Cu	Nb	N
.09	.59	.20	.002	.63	8.93	.87	.21	.006	.05	.07	.045

3.2 Design of Experiments

Grade 91 is the most common material used in power plants, which are subjected to high temperature and stresses is generally repair welded using temper bead technique here half layer repair welding technique is designed to meet out the defect occurs during such condition. The half layer technique welding development in this chapter was performed on 1 ½” (38 mm) thick Grade 91 plate and included toughness, hardness, tensile, and ruptures testing. Initially welding is done by TIG/MIG welding method and then half of the weld bead is removed, and again welding is done on HAZ and the process is repeated. Finally Testing and their results are tabulated

Table 2 TIG Welding parameters

SNO	WELDING LAYER	NO OF BEADS	CURRENT Amps	VOLTAGE Volts	TRAVEL SPEED mm/min	HEAT INPUT KJ/min	TOTAL HEAT INPUT KJ/min	BEFORE WELD mm	AFTER WELD mm	AFTER GRINDING mm	FILLER METAL DEPOSITION mm	FILLER METAL REMOVAL mm
1	1	12	170	9	60.15	1.56	18.72	15.9	13.6	14.80	2.25	1.125
2	2	10	170	9	76.22	1.20	12.04	14.8	13.0	13.90	1.80	0.9
3	3	10	170	9	62.05	1.48	14.8	13.9	11.0	12.30	2.70	1.3
4	4	8	170	9	58.24	1.58	12.64	12.3	9.40	11.00	2.90	1.3
5	5	7	170	9	53.15	1.72	12.08	11.0	7.90	9.30	3.10	1.4
6	6	7	170	9	54.05	1.69	11.83	9.30	6.40	7.60	2.90	1.2
7	7	9	170	9	50.52	1.81	16.29	7.6	4.80	5.40	2.90	1.1
8	8	9	170	9	52.77	1.73	15.65	5.9	2.80		3.10	

Table 3 Parameters used for half layer in MIG Welding

SNO	WELDING LAYER	NO OF BEADS	CURRENT Amps	VOLTAGE Volts	TRAVEL SPEED mm/min	HEAT INPUT KJ/min	TOTAL HEAT INPUT KJ/min	BEFORE WELD mm	AFTER WELD mm	AFTER GRINDING mm	FILLER METAL DEPOSITION mm	FILLER METAL REMOVAL mm
1	1	8	195	27	25	1.26	10.10	15.80	10.8	13.30	2.5	1
2	2	7	195	27	25	1.26	8.84	13.30	8.8	10.8	2	2
3	3	7	195	27	25	1.26	8.845	10.8	5.8	7.8	2	3
4	4	7	195	27	25	1.26	8.845	7.80	4.4	6.4	2	4
5	5	7	195	27	25	1.26	8.845	6.40	2.40	4.6	2	5
6	6	7	195	27	25	1.26	8.845	4.60	0.2	2.6	2	6
7	7	8	195	27	25	1.26	10.10	2.60			2	7
1	1	8	195	27	25	1.26	10.10	15.80	10.8	13.30	2.5	1

4. Results and discussion

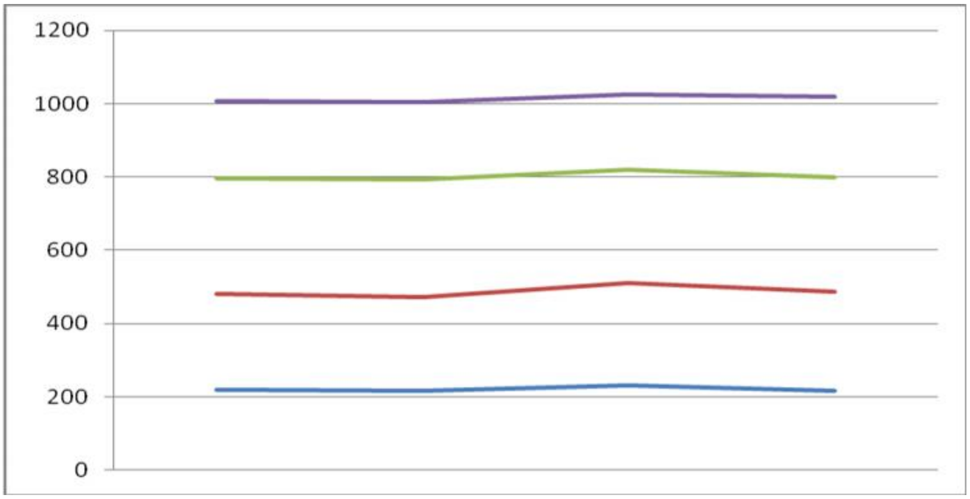
Thus half layer technique is successively developed on the grade 91 work pieces and on that work pieces hardness test is carried out using Vickers hardness testing machine and the corresponding results are tabulated. Then surface finishing test is done to check the surface, finally the microstructure is studied using metallurgical microscope and results are analysed.

Hardness test

Hardness test is carried out by Vickers hardness machine, the result indicated that half layer method is better over the temper bead technique and half bead technique, the hardness level is comparatively high.

Table 4 TIG welding hardness test result

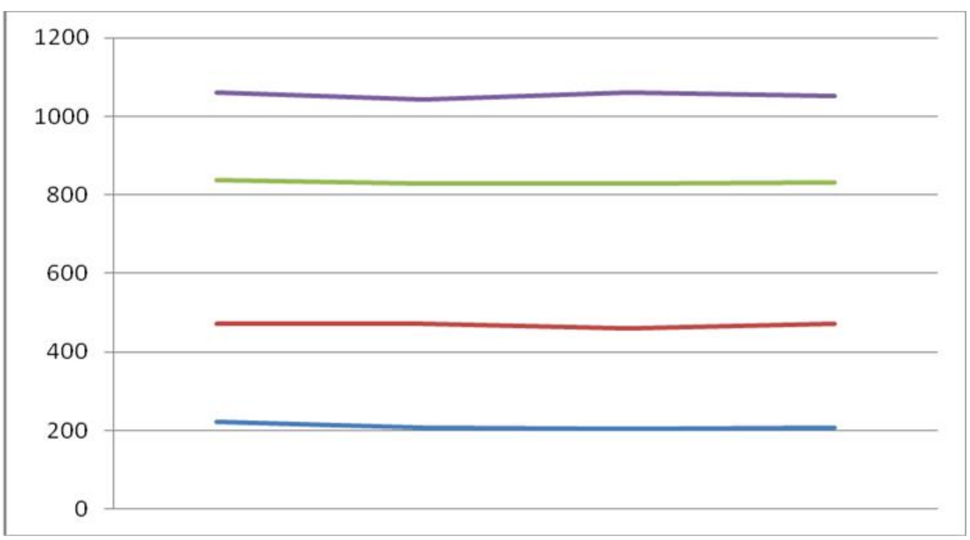
Weld metal	220	217	231	218
Fusion line	260	255	280	270
HAZ Zone	315	321	310	312
Base metal	211	210	205	219



Hardness vs Distance

Table 5 MIG welding hardness test result

Weld metal	223	210	206	208
Fusion line	249	261	253	264
HAZ Zone	367	359	370	361
Base metal	220	213	231	218



Hardness Vs Distance

4.1Microstucture

The recording observed under metallurgical microscope for in microstructure half layer technique can be the effective alternative to avoid PWH

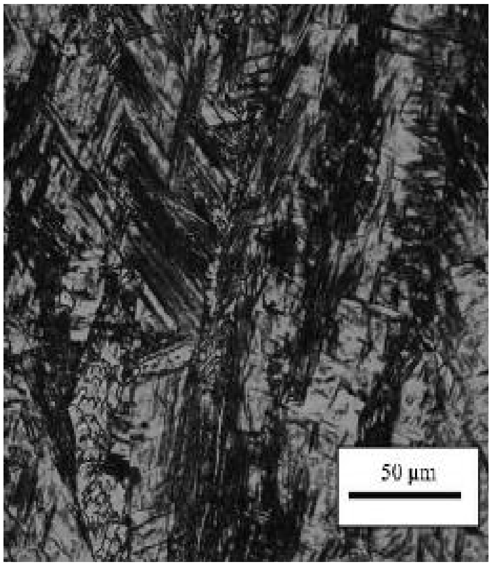


Figure 1 Microstructure of the weld metal, Microstructure of the HAZ

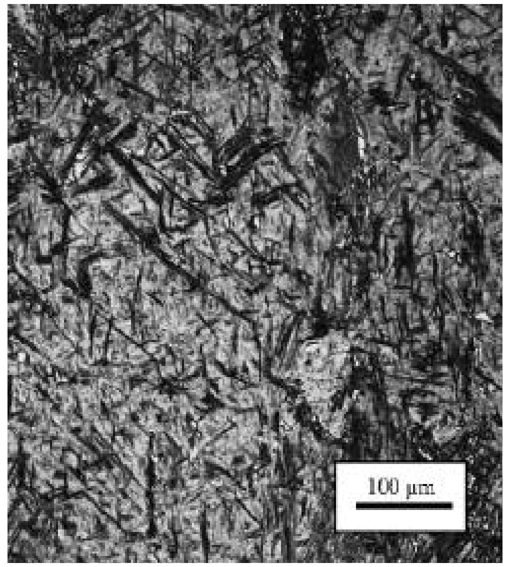


Figure 2 martensite and bainite phases

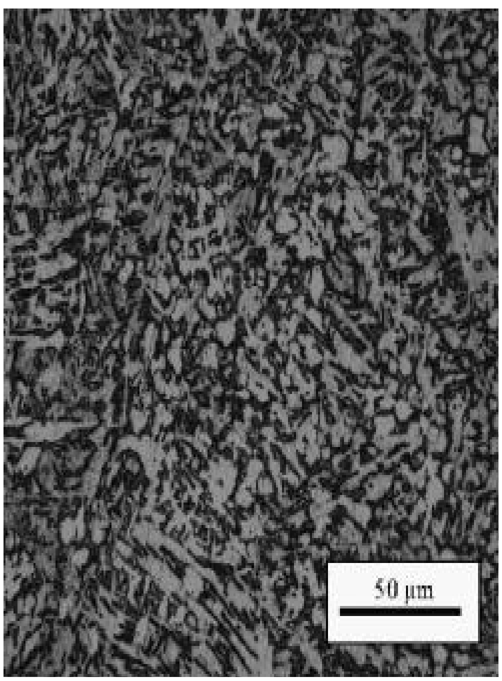


*Figure 3*Ferrite and bainite structures Predominantly bainitic structure

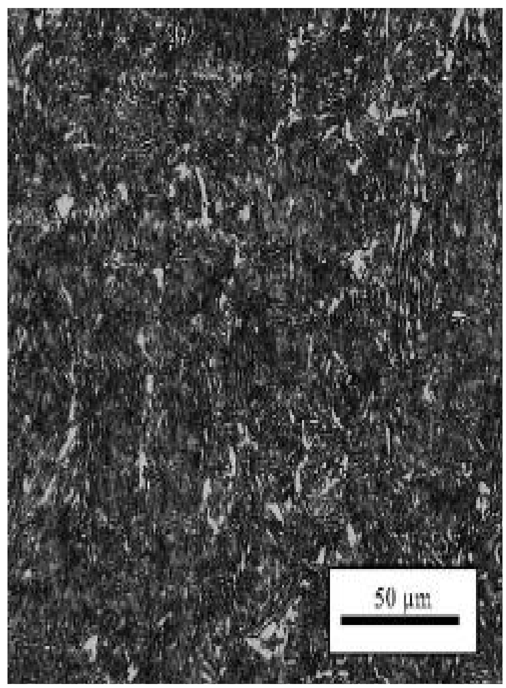


Figure 4 with tempered martensite

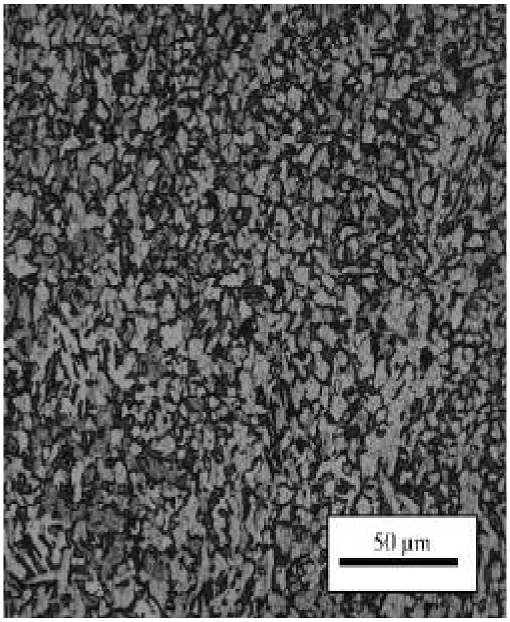


*Figure 5*Ferrite and pearlite microstructure

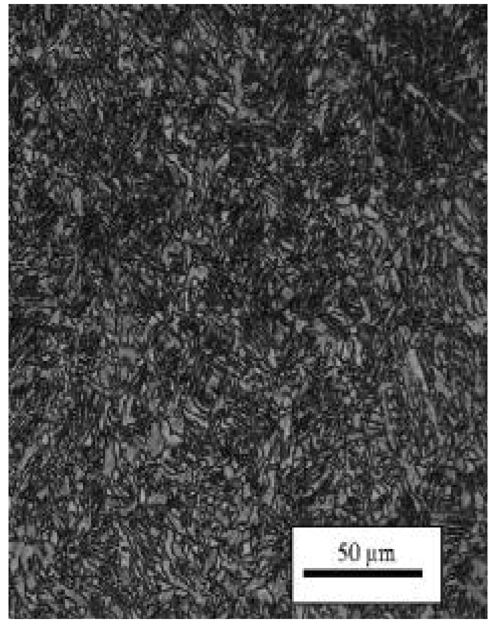


Figure 6 Bainitic microstructure

5. Conclusions

Based on the experiments and test results of the work, it is concluded that:

- The main alternative techniques to PWHT for large welds are half-bead, temper bead welding (TBW) and half layer technique. They are said in the literature to be effective in carrying out weld repairs but work continues to be developed which will refine that choice.
- Repairs without PWHT are not recommended to be used in highly stressed areas or in components which are susceptible to stress corrosion cracking.
- The half layer welding technique is recommended when compared to the other two techniques which do not requires heat treatment.
- The hardness test shows the VHN for the repair weld using half layer technique range from 320-350 VHN in HAZ. It shows that there is no need for PWHT
- The microstructure review indicates better results when compared with temper bead welding technique.
- Hence it can be concluded The half layer technique can be the one of the best alternative technique for repair welding and avoid PWHT as well as for effective repair welding.

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