

Micro Structural and Micro Hardness Evaluation of Dissimilar Header Welding of Grade 22 to Grade 91 under Different Conditions of Post Weld Heat Treatment

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ABSTRACT: This paper studies the micro structural evolution and micro hardness variation of a dissimilar welded header fillet welding between Grade 22 and Grade 91. The pipe material had been taken as SA 335 P91 whereas the tube material had been taken as SA 213 T22. The micro structural changes and micro hardness was examined by variation of post weld heat treatment temperatures at nil post weld heat treatment (PWHT), 690 °C, 730 °C & 770 °C. Electrodes were was 9018 B9. Preheat was done at 220 °C and soaking duration was one hour. The micro structural characteristic of the dissimilar header weld was found to be varying as we move from one base metal to the other. Also, different conditions of preheat, post heat and electrodes have significant impact on the micro structural characteristic and micro hardness.

KEYWORDS: header, Grade 22, Grade 91, post heat, welding

I. INTRODUCTION

The energy demand in India is on a continuous rise and the Working Group from the Ministry of Power has estimated 76,000 MW capacity additions in the twelfth five year plan (2012-17). The increased demand will lead to a push in better know how of the materials used in the power plants and optimizing the used of it [1].

Modified grade 91 steels are enhanced creep resistant steels that are extensively used in power plants for almost two decades now [2]. These steels are intensively used for high temperature applications in the super heater and reheater circuits of a thermal power plant where the design temperatures are in excess of 500° C. Grade 91 joints are susceptible to hydrogen induced cracking and intense care has to be taken while welding these materials. Much work has been done in this area to understand the factors influencing the property of the weld. Tavares SSM et al studied the grade 91 steel pipe butt joint for cracks and found out that presence of certain levels of residual elements can have an impact on the mechanical properties of the material [3]. Parker JD described the repair of Grade 91 component and described the metallography of the welds produced. They demonstrated that there are numerous options available for the repair of grade 91 materials [4].

Headers are extensively used in power plant boilers and are used as a junction of mixing media and from where further distribution of fluids takes place. It can be of varied shapes and sizes according to the function to be performed. Dissimilar header welding of Grade 22 and Grade 91 is increasingly being employed in supercritical boilers as it enables to save material and Grade 91 has better creep properties at elevated temperatures [5]. Although much work has been done in the field of dissimilar welding but in the literature it is seen that little work has been done in the area of dissimilar header welding. Dinesh WR et al studied the effect of dissimilar weld metal joint between austenitic and ferritic stainless steel using Inconel 82/182 consumables. They focused on slag inclusions, bead deposition and technique and NDT techniques [6]. Mehtap et al studied the effect of molybdenum on microstructure and hardness of

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intercritical HAZ of a low Cr-Mo steel [7]. Bettahar et al studied the microstructure and mechanical behavior of 13 Cr/2205 stainless steel welded pipes [8]. Rui Wu et al studied the effect of extra coarse grain on the creep properties by measuring the rupture time [9].

The dissimilar weld joints have a disadvantage that they are prone to hydro test failures which can be attributed to certain micro structural factors which can originate at the time of manufacturing or during the service. These dissimilar welds have heterogeneous mechanical and metallurgical properties and hence the welding microstructure should be carefully evaluated and studied.

II. DESIGN OF EXPERIMENT

Guideline and information regarding the approach of fixing the welding parameters will be discussed in the following section

A. Base materials viz. pipes and tubes and welding electrodes used

The base materials selected are SA 335 P91 for pipe material and SA 213 T22 for tube material. The pipe size used was $\Phi 273 \times 30$ mm. The tube size used was $\Phi 50.8 \times 6.1$ mm. SMAW (Shielded Metal Arc Welding) process was employed for the header fillet welding with 9018 B9 electrodes.

B. Hole design, joint fit up and welding sequence

Pipes and tubes of the above sizes were marked in a sequential manner and the hole sizes to be drilled were mentioned. Drilling was then carried out to ensure the stepped contour as per design requirement for a pipe to stub weld with the help of a CNC drilling machine. Deburring was then carried out to ensure a chip and burr free surface. Figure 1 show the pipe drilled with profiled holes to enable the welding of tubes onto it. Figure 2 shows the design of header welding comprising of pipe and tube and the selection of test piece for study of this paper.



Figure 1-Pipe with profiled hole drilled for fillet welding of tube

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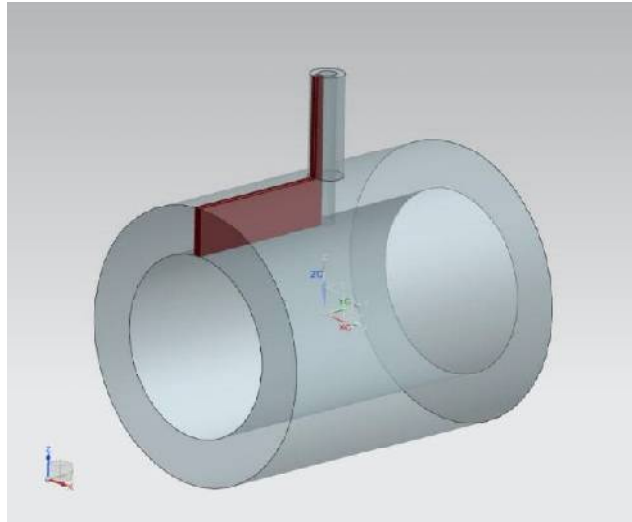


Figure 2 –Header design &selection of test piece

C. Welding process and Post Weld Heat Treatment

The welding process that was used for the header fillet welding is SMAW (Shielded metal arc welding). Three passes were used to complete the welding. For root pass $\text{Ø}2.5$ electrodes were used and for the subsequent passes $\text{Ø}4.0$ electrodes were used. The post weld heat treatment temperatures (PWHT) that were considered for study were nil PWHT, $690\text{ }^\circ\text{C}$, $730\text{ }^\circ\text{C}$ and $770\text{ }^\circ\text{C}$. Electrode used is 9018 B9. All the welds were made by ASME and IBR (Indian Boiler Regulations) qualified welders in accordance with Sec IX of ASME [5].

III. RESULTS AND DISCUSSIONS

A. Microstructure evaluation:

The carbon migration has a marked effect when different PWHT temperatures are used as shown in Figure 6. At nil PWHT, the SA 213 T22 to 9018 B9 weldment transition is a transition of bainitic to martensitic structure and the effect of carbon migration is negligible as shown in Figure 6(a). As the PWHT is increased, the effect of carbon migration becomes visible as shown in Figure 6(b). Moreover it is seen that carbon gets migrated from SA 213 T22 to 9018 B9 weldment which means that the grade 22 HAZ has lesser than required carbon available which can be detrimental when exposed to long cycles of stress and can ultimately fail in these HAZ regions. Further in Figure 6(c) and 6(d) we can see that the width of carbon migrated zone keeps increasing and thus higher temperature of PWHT are not desirable as they can have greater width of carbon denuded zones.

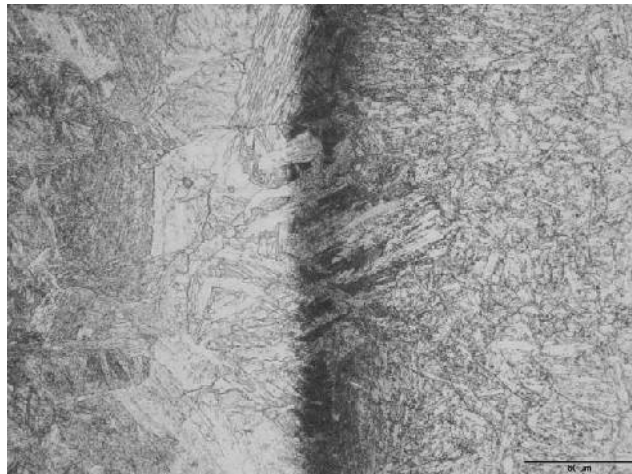


(a)

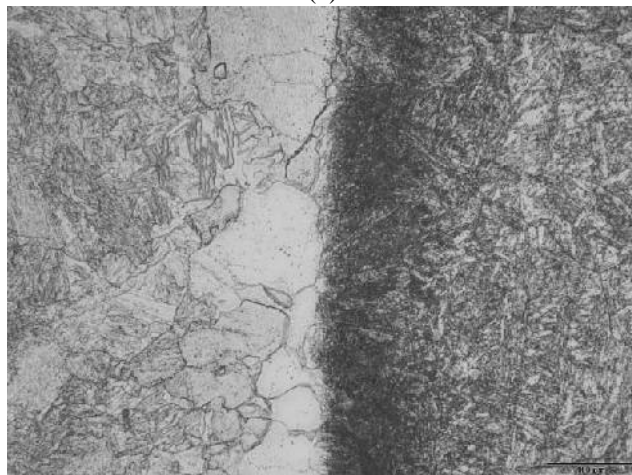
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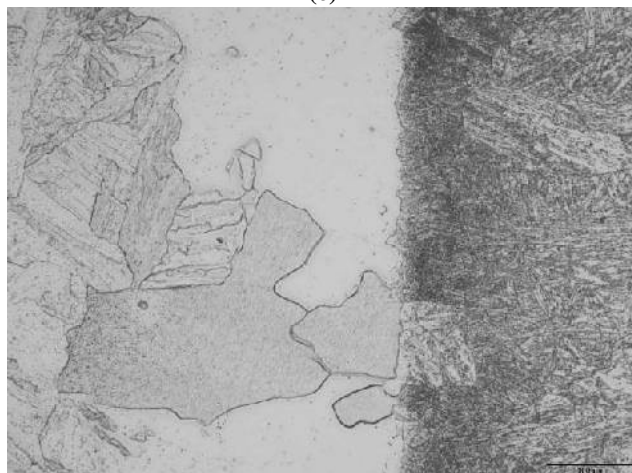
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(b)



(c)



(d)

Figure 3 – Grade 22 base material to 91 weld fusion line at 220 °C preheat and PWHT at (a) Nil (b) 690 °C (c) 730 °C (d) 770 °C when welded with 9018 B9 electrode

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B. Micro hardness evaluation:

The micro hardness has been taken along the header weldment for the 9018 B9 electrode used and its variation for the different PWHT temperatures employed has been plotted in Figure 4. As observed from Figure 4, the hardness values observed when no PWHT was done is very high and it is therefore concluded that the PWHT is an essential step in the welding cycle and usage without PWHT in cases involving grade 91 can have a detrimental effect on the system where it is used. PWHT temperatures of 690 °C and 730 °C shows a drastic decrease in the hardness values due to the tempering process but still the hardness values remain above permissible values.

This indicates that these tempering temperatures are not enough to have a proper tempering effect. At 770 °C, hardness values are in allowable range of below 280 HV and hence indicate that the weldments along with the base material are tempered to withstand the loading for the working life of the boiler.

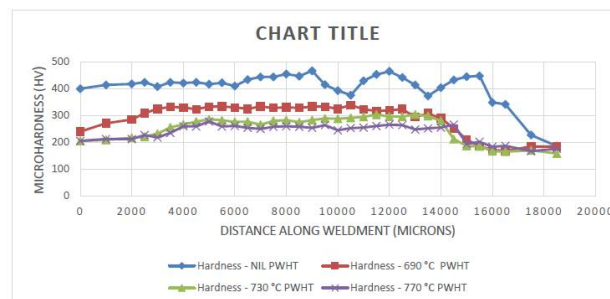


Figure 4 – Variation of microhardness along the header weldment for 9018 B9 electrode with 220 °C preheat

Based on the variation in microhardness along the header, it is evident that microhardness values are very much in range when post weld heat treated either at 730 °C or 770 °C. At these temperatures the hardness values are within the 300 HV range and are therefore less susceptible to creep cracks at a later stage during the cycle of operation. Due to the excessive increase in the carbon denuded zone, it is therefore better to employ 770°C temperatures as PWHT to ensure sufficient tempering of the weldment.

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