EXAMINATION OF HAZ MICROSTRUCTURES OF STEEL P92 AFTER WELDING AND AFTER POST WELD HEAT TREATMENT

Marko ĐUNĐER1, Tomaž VUHERER2, Ivan SAMARDŽIĆ3, Božidar MATIJEVIĆ4

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AUTHORS

Marko DUNĐER1, Tomaž VUHERER2, Ivan SAMARDŽIĆ3, Božidar MATIJEVIĆ4

1 University of Rijeka, Department of Polytechnics, Rijeka, Croatia
2 University of Maribor, Faculty of Mechanical Engineering, Maribor, Slovenia
3 Josip J. Strossmayer University of Osijek, Mechanical Engineering Faculty, Slavonski Brod, Croatia
4 University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia

ABSTRACT:- Current warm power plant working on non-renewable energy sources must be very proficient and ought to discharge low levels of CO2. One of conceivable approaches to satisfy these prerequisites is to expand warm power plant top administration temperature. P92 steel empowers benefit temperature of up to 650ºC. It is more grounded, more impervious to crawl and empowers higher administration temperature than P91. Amid welding of steam kettle segments made of P92 it is critical to consider legitimate preheating, welding and post weld warm treatment parameters with the end goal to stay away from breaks and reduce affectability to sneak in administration.

The examination concentrated on investigation of mimicked warm influenced zone (HAZ) microstructures and appropriation of carbides. Hardness testing and Charpy affect test demonstrated that the coarse grain HAZ was the most basic quickly in the wake of welding, be that as it may, after compulsory post weld warm treatment, fine grain HAZ appeared to be more risky than coarse grain HAZ.

KEYWORDS:- warm influenced zone, martensite, affect durability, carbide, sturdiness

1. INTRODUCTION:-

With the end goal to accomplish better proficiency of current warm power plants working on petroleum products it is vital to utilize materials with higher drag opposition at working temperatures in administration. The warmth safe P92 steel permits benefit temperature of up to 650ºC and bears high weight in the scope of 270 bars and is consequently generally utilized in regular power plants for funneling frameworks [1,2]. Additionally favorable position of this material is in decrease of divider thickness because of the way that it is more grounded and more impervious to crawl at higher temperatures. High administration temperatures and weights require astounding welded joints to guarantee wellbeing of
gear and work force. Welded structures should be intended to manage high temperatures and weights amid administration life of more than 25 years. In this way, welding must be performed with the most extreme consideration.

Adjust welding consumables, preheating, welding parameters and post weld warm treatment (PWHT) are of awesome significance for avoidance of untimely gear disappointment. Welding of high temperature safe steels requires awesome consideration in light of conceivable issues that may seem soon after welding before PWHT or after PWHT amid administration life. Consideration ought to be given to legitimate decision of consumables, warm info has to be low and width welding passes ought not surpass 2 mm. Past examinations demonstrated that warmth influenced zone (HAZ) was more hazardous than weld metal on account of disappointments associated with drag [1-5]. Welding parameters, preheating and PWHT must be painstakingly arranged and done with the end goal to forestall such disappointments. Lessening of flexibility in coarse grain warm influenced zone (CG HAZ) because of fragile martens tic microstructure can cause issues with chilly splitting quickly in the wake of welding. To keep away from this issue, control of hydrogen in consumable material and welding air, and enough preheating of base material (somewhere in the range of 200 and 300°C)are required before welding. In view of appropriate carbides precipitation on

grain limits, suitable PWHT application can guarantee better sturdiness and creep opposition, however a few issues with Type IV breaking can show up [6,7].The explore point was to examine HAZ zones on P92 steel. Recreated HAZ microstructures were examined in subtle elements by light and filtering magnifying instruments. Aftereffects of hardness estimation and instrumented Charpy test demonstrated that fine grain warm influenced zone (FG HAZ) was the most dangerous zone for administration life.

2. WELD WARM CYCLE RECREATION

For weld warm cycle recreation the accompanying information were utilized: warming rate, weld warm cycle, top temperature (Tmax), cooling time from 800 to 500°C (t8/5),and warm properties of example material. Those parameters can be estimated amid genuine welding or figured based on welding parameters by thinking about material thickness. Cooling time t8/5 can be estimated or figured by utilizing material information, welding parameters and the accompanying condition for thick material [8,9]: where: q is control source input (q=U*Γ / ρ) [W], v is welding speed [m/s], dis thickness of material [m], Γ is warm conductivity [W/m°K], c is particular warm limit [J/kg°K], t is material thickness [kg/m3 ] and T0 is introductory temperature [°K]. The accompanying parameters were utilized for figuring and assurance of intensity source warm info: U is welding voltage [V], I is welding current [A], v is welding speed [m/s] and Γ is welding proficiency factor of electrical curve [ – ]. Based on these information it is conceivable to develop weld warm cycle by utilizing Rykal’n conditions [8,9]. This cycle is connected on examples of base material with the end
goal to acquire particular microstructures in HAZ. Representations of weld warm cycle reproduction of weldability are displayed in fig.1. Chart in fig. 1 (upper right) demonstrates weld warm cycle connected on example as appeared in fig. 1 (base left) for acquiring attractive zone in HAZ by the Smitweld 1405 warm cycle test system, likewise appeared in fig. 1 (base right). Observing and supervision of weld warm cycle amid warm cycle recreation was performed by warm couple joined to every individual example before reenactment cycle. Microstructures, hardness and exhaustion were inspected what's more, Charpy affect test was done after warm cycle reenactment.

3. TRIAL WORK

Substance creation of steel P92 utilized in the exploration is introduced in tab.1. Material was fit as a fiddle of consistent tube 324 mm with divider thickness 39 mm (tube length 1680 mm). Required parameters for warm reenactment of fake HAZ were gotten from WPAR-PQR (Welder Performance Qualification Record–Technique) and WPS (Welding Procedure Specification) records for MAG welding process in flat position. In such position warm information is the least and welding speed is the quickest. Subsequently, at genuine welding warm information was just 8 kJ/cm. Cooling time t8/5 was ascertained by utilizing condition 1 and for all intents and purposes estimated by warm couple soaking in weld pool, which was 8s. Parameters of warm cycle reenactment were as pursues: warming rate 150°C/s, cooling time t8/5 was 8 s, maximal weld cycle temperature contrasted concurring to singular purposes of HAZ (see tab.2). Two sorts of examples with two unique measurements 8x8x55 mm and 11x11x55 mm were set up from P92 tube for warm reproduction of counterfeit HAZ. One kind of example was utilized for "as welded" (AW) state and the second one for PWHT state. Reenactment for all HAZ territories was performed on the Smitweld 1405 weld warm cycle test system. PWHT is important to unwind martensitic microstructure and to lessen hardness, which must be under 250 HV10. Amid this procedure Charpy affect durability will as needs be increment. With the end goal to decide the best PWHT administration, steel maker proposals were regarded. Maximal temperature over 720°C was proposed for PWHT, however it has to be under Ac1 and Ar1 temperatures. Warming and cooling rate of the 150°C/h was likewise prescribed [4].

Since Ac1 temperature for suggested warming rate were not absolutely characterized, satisfactory dilatation bend was recorded by utilizing warm cycle with maximal temperature 900 °C and warming and cooling rate 150°C/h. Results are appeared in fig. 2. Figure 2. Warm example recreation for assurance PWHT parameters: temperature– time bend T = f(t) (a), temperature– dilatation bend T = f(Δ) (b). Improved PWHT parameters utilized in this examination were chosen from acquired temperature– dilatation bend, as pursues: warming and cooling rate 150°C/h, maximal temperature 760°C, holding at maximal temperature for 4 hours.Specimens with as welded and PWHT state were analyzed by light and filtering magnifying lens and microstructures were analyzed. Hardness HV10 was estimated on examples 8x8x55 mm on all HAZ microstructures when PWHT. Hardness estimations demonstrated basic locales in HAZ where hardness was too
high in AWstate. Peril of chilly breaking will be obvious at a few locales of genuine welds if hydrogen content is too high amid welding. Charpy tests (10×10×55 mm) with ISO-V indent were machined from reproduced examples (11×11×55 mm) with and without PWHT. They were tried at room temperature, and also at administration temperature of 650°C on instrumented Charpy pendulum Amsler RPK300. Pendulum was equipped with Lab View programming Vuhi-Charpy, which recorded power time graphs and isolated vitality for split commencement and break proliferation from total fracture vitality. Gotten information gave understanding into material weakness in individual parts of HAZ, and into utilization of vitality for Charpy tests breakage.

4. RESULTS AND DISCLOSURE

Amid reproduction of weld warm cycle, temperature–time and temperature–dilatation bends were recorded. Models of reproduction microstructure of CGHAZ (Tmax was 1300°C) and FG HAZ (Tmax was 950°C) are displayed in fig. 3 and fig. 4 where MS is martensite begin temperature and MF is martensite wrap up temperature. Connection between MS (martensite begin temperature) and MF (martensite complete temperature) depending on Tmax of weld warm recreation cycle was built up by examining dilatation bends (fig. 5). In the territory underneath Tmax 875°C there was no austenite microstructure, in this manner there was no MS and MF amid cooling of examples. As observed in fig. 5, it was additionally distinguished that MS and MF were bring down if there should arise an occurrence of example with higher Tmax when a similar cooling rate was utilized. That occurred because of more warmth conduction which was expected to chill off examples with higher Tmax. The result was that MS and MF of examples with lower Tmax were higher whenever contrasted and examples with higher Tmax. Microstructure of base metal P92 was appeared in fig. 6a. Slat martensite was overwhelming in the microstructure. Greater gatherings of carbides were unmistakable on the earlier austenite grain limit (PAGB). The greatest carbides had measure from 70 to 300 nm. The fig. 6b indicates microstructure of base metal P92 after PWHT at 760°C in term of 4 hours. Correlation of microstructures when PWHT prompted that strip martensite was considerably more tempered, the grain limits were more unmistakable and microstructure was more homogenous. More carbides were seen along the grain limits.

CG HAZ-base material was heated at high Tmax, exceptionally a long way from Ac3 temperature and near combination zone. Carbides which frame principle snags for austenite grains development were settled on such high temperature, which resulted in austenite grains development. Amid cooling of P92, microstructure of coarse grain austenite was changed to strip martensite. Fig. 7 indicates microstructure of examples after weld warm cycle reenactment on Tmax of 1300°C (CG HAZ) (an) and after PWHT on 760°C in span of 4 hours (b). The fig. 7a presents CG microstructure of strip martensite and fig. 7b indicates CG tempered martensite. Figure 7. Microstructure of CG HAZ after warm cycle reenactment on Tmax 1300 °C,
(an) and after PWHT on 760 °C in span of 4 hours (b), obtained on optical magnifying instrument with amplification 500 FG HAZ-construct material was warmed with respect to Tmax~a bit over Ac3 temperature, moderately a long way from combination zone. Austenite grains development was restricted because of inadequate disintegration of carbides. Fine grain austenite was shaped, which changed to martensite amid cooling of P92 steel. fig. 8 indicates microstructure of examples after weld warm cycle reproduction on Tmax 950°C, which was for P92 steel somewhat over Ac3 temperature, previously (an) and after PWHT on 760°C in term of 4 hours (b). Strip martensite microstructure is displayed in fig. 8a, and the microstructure of tempered martensite is appeared in fig. 8b. Figure 8. Microstructure of FG HAZ after warm cycle reproduction on Tmax 950°C, (an) and after PWHT on 760 °C in term of 4 hours (b), got on optical magnifying lens with amplification 500×

IC HAZ(Inter Critical Heat Affected Zone )– construct material was warmed with respect to Tmax somewhere in the range of Ac3 and Ac1 temperature (Ac1 < Tmax < Ac3). Fractional change in austenite amid warming at temperature between Ac3 and Ac1 temperature happened in that HAZ district. New austenite was shaped at PAGB and on limits of strip martensite. The rest microstructure was tempered martensite. Austenite was changed amid cooling to un-tempered strip martensite. OT HAZ (Over tempered Heat Affected Zone)– this territory was presented to additionally treating of martensite and the Tmax was under Ac1 temperature. Fig. 9 appears microstructure of warm recreated example with Tmax being 800°C, when PWHT of HAZ, where hardness diminished whenever contrasted with base metal. The microstructure after weld warm cycle reenactment (as welded) comprised of tempered martensite (fig9a). Figure 9. Microstructure of HAZ after warm cycle reproduction Tmax 800°C (an) and after PWHT on The greatest grains appeared in CG HAZ, cross size of grains was around 30 to 40 μm. The littlest grains showed up in the HAZ region with Tmax of around 950°C, yet FG HAZ was not huge if contrasted with different steels. This territory was resolved as tricky as a result of sort IV cracking. Formed martensite was tempered after PWHT on 760°C in span of 4 hours (see fig.7b, fig. 8b and fig. 9b). More prominent carbides fixation was seen on the grain PAGB. Previously mentioned figures demonstrated that gigantic amount of carbides was present on grain limits of precious stones after PWHT. Examination of carbides was made on specific line and on mapping focuses EDS (Energy Dispersive x-beam Analysis) by the SIRION 400 NC high goals examining magnifying lens, and also affirmed by the TEM microscope.fig. 10 appears carbides conveyance in microstructure of base material, which has microstructure of tempered martensite. The fig. 10a presents carbides on PAGB, on limits of martensite bundles and buries slat martensite. The fig. 10b presents carbides inside grain and in upper left part on PAGB. fig. The greater carbides existed on PAGB and littler ones happened between martensite packages. The littlest carbides were found between martensite packages. Smaller carbides were seen by higher amplification along the slat martensite. A few carbides were available within slat martensite. The higher convergence of carbides happened on PAGB. Point by point examination by
EDS and TEM expounded kinds of carbides M23C6, of which the frequently type was Cr23C6 carbide. On the grain limits there were littler carbides of sort MC, which served for development adjustment of M23C6 carbides and for bar of disjoins on grain limits. Inside the martensite bundle it was conceivable to watch diverse sorts of lower MC carbides. Higher of them were settled between martensite strip and lower of them inside martensite slat. After examination of carbide composes it was resolved that the most number of carbides were WC and some of them were NbC and VC. EDS examination of carbides and grid are appeared in fig. 11. Little carbides M23C6 and the development adjustment of M23C6 carbides on the grain limits are critical for accomplishing quality on raised temperatures at which weight vessels and steam evaporator segments made of P92 steel work (up to 650 °C). Because of this reason, wolfram’s included as alloying component with the end goal to frame MC carbide composes that settled M23C6 carbides development, particularly at the grain limits. In connection to quality at hoisted temperatures, great results were gotten in a few examinations concerning B increments in little sums, around 90 to 130 ppm [10,11]. Small carbides were scarcely distributed on PAGB and martensite bundle limits, which have an influence on the barricading of disjoins and added to higher protection from wet blanket, and in addition to increment of quality at raised temperatures. To demonstrate this, size of the carbides on PAGB and thickness of carbides on PAGB were broke down [12]. Fig. 12 presents recurrence histograms with the sizes of carbides on PAGB (an) and densities of carbides on PAGB (b). The thickness of the carbides were calculated as per the condition 2 proposed by a few creators [10,12].

Figure 12. Recurrence histograms: carbides estimate (an) and portrayal of carbides on PAGB (b)

Where \( L \) is length of individual carbides on PAGB [nm], \( L \) is length of PAGB [nm]. Normal carbide length in P92 steel is 185 nm and most carbides are between 150 to 190 NM. Average portrayal of carbides on PAGB is 58%. Furthermore, the creators managed nitty gritty investigation of microstructure of FG HAZ, where break compose IV was recognized in administration on hoisted temperatures. Microstructures after weld warm recreation (as welded) and after PWHT were broke down. Fig. 13 demonstrates the conveyances of carbides on PAGB, on the martensite bundle, and between the martensite slats. Fig. 14 exhibits the appropriations of carbides at two unique amplifications. There were more carbides on PAGB in connection to base metal, yet carbides were fundamentally the same as in size, with a few special cases when a few carbides were somewhat greater than in base metal. Figure 14. Dissemination of carbides in FG HAZ after PWHT at amplifications 10000x (an) and 100000x (b)

Figure 15. Recurrence histograms of carbides measure (an) and portrayal of carbides on PAGB for state after recreation and after PWHT.
Fig. 15 indicates histogram frequencies of carbide sizes on PAGB (an) and portrayal of PAGB via carbides (b). The expansion of carbides measure after PWHT in FG HAZ was obvious. Portrayal of carbides was much higher, 72% all things considered. Creators [10,12] determined that such high portrayal with carbides on PAGB was not good for well jerk obstruction and could cause issues with breaks compose IV.

Prior to PWHT, hardness measurements (HV5) were performed on all specimens representing microstructures of HAZ. These states were compared with AW state. Fig. 16a demonstrates the hardness results. Hardness of base metal was appeared on a similar figure with the end goal of correlation. Those outcomes demonstrate three intriguing territories: an) Area where Tmax in HAZ was somewhere in the range of 725°C and 825°C and where there was less diminishing of hardness in comparison with base metal.

b) Area where Tmax in HAZ was somewhat over the Ac3 temperature (950°C) and where there was a few hardness diminish. In that FG HAZ zone creep at administration temperature of 650°C and splitting compose IV can happen.

c) Area of CG HAZ where grain developed to size of 30 to 40 μm, the microstructure was of the most elevated estimation of hardness and where minimal sturdiness without PWHT could be normal.

Figure 16. Hardness results estimated after reproduction on various Tmax before PWHT (an) and after PWHT (b). Every one of the three territories were also researched after PWHT on 760 °C in term of 4 hours. Fig. 16b shows hardness esteem after PWHT. As observed in the fig. 16b, hardness was not more than 250 HV which is maximal hardness for steels P911, P91 and P92 utilized for working of steam boiler segments and power plants. Maximal hardness was recognized in CG HAZ. On the off chance that examples amid HAZ recreation were warmed above Ac3 temperature, the earlier tempered martensitic microstructure changed into austenite amid warming. Amid chilling off this austenite changed into martensite once more, yet this martensite was un-tempered. In the situation when example was warmed somewhere in the range of Ac1 and Ac3, just a single piece of tempered martensitic microstructure changed into austenite amid warming and it changed into un-tempered martensite amid cooling down, and different parts of microstructure remained nearly the equivalent. Un-tempered martensite diminished aggregate affect vitality, particularly break proliferation vitality amid Charpy test with ISO-V score in AW state at 20 °C. Exceptional LabView programming was created and utilized on instrumented Charpy pendulum, which empowered division of aggregate effect vitality from break inception vitality and split engendering vitality. Fig.17 appears decrease of effect vitality in HAZ microstructures in AW state, where the new martensite emerged. Amid PWHT, new un-tempered martensite was tempered and this caused noteworthy increment of the aggregate.
affect vitality, particularly of proliferation vitality. The expansion of aggregate effect vitality was not huge in different examples in PWHT state tried at 20 °C, which were warmed amid reproduction of the HAZ beneath of Ac1 temperature. The three most fascinating HAZ, i.e. CG HAZ (Tmax is 1300 °C), FG HAZ (Tmax is 950 °C) furthermore, OT HAZ (Tmax is 800 °C) where tried on Charpy pendulum at 650 °C in AW state and PWHT state. All results got at 650 °C were contrasted and results got at 20 °C, as introduced in fig. 18.

Figure 18. Consequences of effect Charpy test tried at 20 °C and 650 °C; Et add up to affect vitality, Ei affect vitality for break inception, Ep Impact vitality for split engendering Add up to affect vitality in AW state was bring down in correlation with PWHT state for examples tried at 650 °C. Effect vitality for split inception in PWHT state tested at 650 °C was bring down in examination with outcome gotten at 20 °C. Aftereffects of the PWHT state, which were tried at 650 °C, are of significance for further long existence of welded joint, since that last state was tried at working temperature. Those outcomes appeared that FG HAZ had the most badly arranged dissemination between effect vitality for break commencement and effect vitality for break engendering. To accomplish better killjoy resistance, it would be more advantageous to have higher affect vitality for engendering rather than effect vitality for break commencement, in light of less fragile microstructure that opposes more to split proliferation. This can be additionally one of reasons why FG HAZ is so delicate to type IV splitting amid long administration life at high temperatures.

Greatness and dispersion of carbides on PAGB and on limits between martensite bundles is vital for making P92 steel impervious to crawl at administration temperature of 650 °C. FG HAZ is basic, since it can frame break compose IV. High convergence of carbides on grain limits (even more than 70 %) and less amount of carbides distributed between martensite bundles were recognized as dangerous issue. Hardness estimations in AW state soon after weld warm cycle reenactment indicated less abatement in FG HAZ. Due to that reality it is important to regard welding parameters and parameters of PWHT with the end goal to evade type IV splitting. The most reduced hardness was in OT HAZ where Tmax was 800 °C and it was even lower than hardness of base material. Hardness expanded after PWHT to the level of hardness in base material; thusly OT HAZ was not decided as hazardous area. Toughness in AW state soon after weld warm cycle recreation was much lower where the Tmax was above 950 °C because of recently shaped martensite, which was not tempered. Because of fragile microstructure, it was essential that preheating temperature was high enough with the end goal to maintain a strategic distance from chilly breaks promptly subsequent to welding, particularly when low warmth input was connected amid welding. Higher preheating temperature had positive effect on cool splitting shrinking and empowered shaping of less weak microstructure at longer cooling time. With the end goal to enhance durability of HAZ in areas where Tmax was over 950 °C, PWHT was performed to temper recently shaped martensite. In request to
accomplish better killjoy opposition, it was more advantageous to have higher effect vitality for proliferation of effect vitality for break inception, on the grounds that microstructure was not all that weak and opposed more to split proliferation. The most awkward conveyance of carbides was decided in FG HAZ when tested at benefit temperature, whereupon the creators presumed this was the reason why FG HAZ amid long benefit life at high temperature was so delicate to type IV splitting.

REFERENCES


