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WELDING, CONTROL AND REPAIR OF MEMBRANE WELDS

ZAVARIVANJE, KONTROLA I POPRAVKA MEMBRANSKIH VAROVA

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Abstract

The paper describes design, production and inspection of membrane welds according to EN 12952-5 [1]. Stated procedures and technologies are based on water tube boiler manufacturing in the company ĐĐ Termoenergetska postrojenja d.o.o. Paper gives the overview of the standard manufacturing process: welding technology, marking and identification of welds, quality inspection and testing, macro and micro structure and hardness of welds. Presented testing results are used to show direct correlation between proper implementation of specified manufacturing process and achieved quality of welding.

1. Introduction

Parts of waste incineration plants are exposed to aggressive media that result from waste combustion. Waste incineration boilers operate at a pressure of 40 bars and steam temperature of 400°C, due to which they are at risk of corrosion caused by high-temperature. Development of corrosion and decay of material measured in millimeters per each year of exploitation increase along with increasing of operating conditions [1-2]. The most commonly used steels in boiler construction are 0.5CrMoV, 2.25Cr1Mo, 1CrMoV, X12, 304, 316, P91, P92, 304 H, P22, 13CrMo4-5 and 16Mo3. Therefore, samples were prepared by cutting segments from the membrane wall made from two pipe and strip positions as shown in Figure 1, and the tube and strip were made from

Rezime

U radu je opisan dizajn, izrada i ispitivanje membranskih zavarenih spojeva prema standardu EN 12952-5 [1]. Navedeni postupci i tehnologije temelje se na proizvodnji kotlova u kompaniji ĐĐ Termoenergetska postrojenja d.o.o. U radu se daje pregled standardnog proizvodnog procesa: tehnologija zavarivanja, označavanje i identifikacija zavarenih spojeva, pregled i ispitivanje kvaliteta, makro i mikro struktura, kao i tvrdoća zavarenih spojeva. Prikazani rezultati ispitivanja imaju za cilj prikazivanje izravne korelacije između pravilno izvedenog određenog proizvodnog procesa i postignutog kvaliteta zavarivanja.

1. Uvod

Delovi postrojenja za spaljivanje otpada izloženi su agresivnim medijima koji nastaju sagorevanjem otpada. Kotlovi za spaljivanje otpada rade na pritisku od 40 bara i temperaturi pare od 400°C, zbog čega su izloženi riziku od korozije izazvane visokim temperaturama. Razvoj korozije i propadanje materijala mereno u milimetrima po svakoj godini eksploatacije raste sa povećanjem uslova rada [1-2]. U konstrukciji kotlova najčešće se koriste čelici 0,5CrMoV, 2,25Cr1Mo, 1CrMoV, X12, 304, 316, P91, P92, 304 H, P22, 13CrMo4-5 i 16Mo3. Zbog toga su uzorci za ispitivanja pripremljeni odsecanjem segmenata sa zida

membrane napravljenih od dve pozicije cevi i trake kao što je prikazano na slici 1, a cev i traka su napravljeni od osnovnog materijala, od čelika 16Mo3 steel base material (W. Nr. 1.5415). Welding by submerged arc welding (SA) is performed. Membrane walls are usually made of 16Mo3 low-carbon steel. [3-5].

The aim of this paper is to describe how membrane welds are welded and repaired, including:

- Mechanized submerged arc welding with wire electrode of membrane walls,
- Repairs of welds on membrane walls by manual arc welding,
- Control and review of welds according to the norm,
- Testing of welds according to the prescribed norm.

The most common standard used in membrane welding is EN 12952-5 [6].

2. Membrane welding proces

The welding technologist prescribes welding technology in WHTP (Welding, Heat Treatment and Testing Plan) and WPS (Welding Procedure Specification). The process manager in the field of membrane welding should provide the necessary documentation for the execution of the welding process and fill in the welding protocols. The head of membrane welding is the responsible person for monitoring the welding process. In case of deviation, the manager is obliged to stop the welding process and informs the welding technique service about it. [7]

Welding staff consists of: welders, welding operators on the machine and an auxiliary operator who must have valid certificates approved by the body in charge of the production of the certificate, and must comply with all technological measures prescribed by the welding technologist in the WPS.

2.1. Method of welding and control of membrane welds

Before starting welding membrane walls, it is necessary to weld a working test to check the welding parameters and the quality of the welded joint. The working test is performed per machine. The dimensions of the working test are a minimum of two tubes with a length of 1m, unless specified otherwise by the specification provided by the customer.

A working trial is done in case of:

- When we have a change in tube or fin material
- Change the dimension of a joint

16Mo3 (V. Nr. 1.5415). Zavarivanje se izvodi postupkom zavarivanja pod praškom (EPP). Membranski zidovi su obično napravljeni od čelika sa niskim sadržajem ugljenika 16Mo3. [3-5].

Cilj ovog rada je da opiše kako se membrane zavaruju i popravljaju, uključujući:

- Mehanizovano zavarivanje zidova membrane postupkom pod praškom (EPP),
- Popravke zavarenih spojeva na zidovima membrane ručnim elektrolučnim zavarivanjem,
- Kontrolu i pregled zavarenih spojeva prema standardima,
- Ispitivanje zavarenih spojeva prema propisanim standardima.

Najčešći standard koji se koristi u membranskom zavarivanju je EN 12952-5 [6].

2. Postupci membranskog zavarivanja

Tehnolog zavarivanja propisuje tehnologiju zavarivanja u WHTP (plan zavarivanja, termičku obradu i ispitivanja) i WPS (specifikacija postupka zavarivanja). Rukovodilac procesa u oblasti membranskog zavarivanja treba da obezbedi potrebnu dokumentaciju za izvođenje procesa zavarivanja i popuni protokole zavarivanja. Rukovodilac membranskog zavarivanja je odgovorno lice za praćenje procesa zavarivanja. U slučaju odstupanja, rukovodilac je dužan da prekine proces zavarivanja i o tome obavesti službu tehnike zavarivanja. [7]

Osoblje za zavarivanja čine: zavarivači, operateri zavarivanja i pomoćni rukovalac, koji moraju da imaju važeće sertifikate odobrene od strane sertifikacionog tela za sertifikaciju zavarivača, i moraju da poštuju sve tehnološke mere koje propisuje tehnolog zavarivanja u WPS-u.

2.1. Način zavarivanja i kontrola membranskih varova

Pre početka zavarivanja membranskih zidova potrebno je zavariti radnu probu kako bi se proverili parametri zavarivanja i kvalitet zavarenog spoja. Ispitivanje radne probe se vrši po mašini za zavarivanje. Dimenzije radne probe su najmanje dve cevi dužine 1m, osim ako nije drugačije određeno specifikacijom koju daje naručilac.

Radni test - proba se radi u slučaju:

- Kada je promenjen materijal cevi ili trake,
- Promene dimenziju spoja.

The method of control of the working rehearsal is a visual control that is carried out 100%, and the control of the macro cross section of the two tubes where the so-called "glasses" are made. After the work rehearsal control, the work rehearsal is certified by the controller and the manager of the membrane welding. In the case that the working trial does not meet the test criteria, it should be re-welded. The work rehearsal is checked by a qualified VT Level 2 person in front of the quality assurance service. The controller is obliged to inform QA/QC quality engineers and welding technologists about the results of the working rehearsal. If the results of the working rehearsal are acceptable welding of joints on the membrane walls can begin.

Welding of membrane welds is carried out in accordance with the WPS prescribed by the welding technologist. During welding, the welding operator monitors the process and welding parameters prescribed in WPS. The operator is obliged to check whether the geometry and quality of the weld is acceptable. If a welding error or deviations related to the geometry of the weld occur during the welding process, the operator is obliged to mark them with chalk. The operator controls the position of the tape with a depth meter or stencil, which must be moderate. With a moving scale, the operator checks the width of the default step.

In case of fatal defects such as contact conductor contamination and tube failure, the welding operator is obliged to mark them with a red felt tip pen and notify the welding manager. In case of such errors, the control engineer is obliged to open the NCR- Nonconformity report.

3. Membrane weld errors

All errors on membrane welds are repaired by manual TIG procedure in accordance with the prescribed WPS. Type of errors and method of repair:

- Cracks - not allowed. If they appear, they will be removed by grinding. Test with a surface method of 100%, and weld according to the prescribed WPS.
- Vertebrae of molten metal – will be removed in case of a larger number of droplets, and individual drops of pristine can be allowed.
- Errors caused by contact conduit contamination will be inspected by the controller who will open a notification of deviations for each such error.
- Tube failure - not allowed. In the case of a failed tube, a Nonconformity report is opened.

Način kontrole radne probe je vizuelna kontrola koja se vrši 100% i kontrola makro preseka dve cevi. Nakon kontrole radne probe, radnu probu overavaju kontrolor i rukovodilac membranskog zavarivanja. U slučaju da radna proba ne ispunjava kriterijume prihvatljivosti, treba ga ponovo zavariti. Radnu probu proverava kvalifikovana osoba VT nivoa 2, ispred službe za osiguranje kvaliteta. O rezultatima radne probe kontrolor je dužan da obavesti QA/QC inženjere kvaliteta i tehnologe zavarivanja. Ako su rezultati radne probe prihvatljivi, može se pristupiti zavarivanju spojeva na zidovima membrane.

Zavarivanje membranskih varova vrši se u skladu sa propisanim WPS koje propisuje tehnolog zavarivanja. Tokom zavarivanja, operater zavarivanja prati proces i parametre zavarivanja propisane u WPS. Operater je dužan da proveri da li su geometrija i kvalitet zavarenog spoja prihvatljivi. Ukoliko u toku procesa zavarivanja dođe do greške u zavarivanju ili odstupanja u vezi sa geometrijom šava, rukovalac je dužan da ih označi kredom. Operater kontroliše položaj trake pomoću dubinomera ili šablona, koji mora biti proveren. Sa pokretnom skalom, operater proverava širinu podrazumevanog koraka.

U slučaju fatalnih grešaka kao što su kontaminacija kontaktnog provodnika i lom cevi, operater zavarivanja je dužan da ih obeleži crvenim flomasterom i obavesti rukovodioca zavarivanja. U slučaju ovakvih grešaka, inženjer odgovoran za kontrolisanje je dužan da sačini NCR-Izveštaj o neusaglašenosti.

3. Greške membranskog zavarivanja

Sve greške na membranskim zavarenim spojevima popravljaju se ručnim TIG postupkom u skladu sa propisanim WPS-om. Tip greške i način popravke:

- Prsline - nije dozvoljeno. Ako se pojave, uklanjaju se brušenjem. Ispituju se površinskim metodama 100% i zavaruju se prema propisanom WPS.
- Nalepci od rastopljenog metala – uklanjaju se u slučaju većeg broja kapljica, a mogu se dozvoliti pojedinačne kapi.

- Greške uzrokovane kontaminacijom kontaktnih vodova pregleda kontrolor koji svaku takvu grešku prijavljuje obaveštenjem o odstupanjima.

- Graying out – the maximum allowed weld depth with a smooth transitional one is 0.5 mm. For higher depths, they are repaired by grinding or/and welding according to WPS.

- Surface porosities – dimensionally smaller pores (with a diameter of less than 3 mm) can be repaired without grinding. When the pores are larger in size or formed in the form of a nest it will be removed by grinding and welded according to WPS.

- Slag ports - not allowed and will be removed by grinding. When the overheating of the membrane weld is insufficient, the irregularity will be fixed by subsequent welding.

- Shear of the fin - linear and angular to the images below:

- Lom cevi - nije dozvoljeno. U slučaju neispravne cevi sačinjava se izveštaj o neusaglašenosti.

- Sivilo – maksimalna dozvoljena dubina zavara sa glatkim prelaznim je 0,5 mm. Veće dubine popravljaju se brušenjem i/ili zavarivanjem prema WPS.

- Poroznosti površine – dimenzionalno manje pore (prečnika manjeg od 3 mm) mogu se popraviti bez brušenja. Kada su pore veće ili formirane u obliku gnezda, one se uklanjaju brušenjem i zavaruju prema WPS.

- Uključci šljake - nisu dozvoljeni i ukljanjaju se brušenjem. Kada je predgrevanje membranskog zavarenog spoja nedovoljno, nepravilnost se popravlja naknadnim zavarivanjem.

- Smicanje traka - linearno i ugao prema slikama ispod:

Figure 1. *Shear fin*

Slika 1. *Smicanje traka*

When the linear or angular shear of the fin is larger than the permissible fin will be carefully cut off and removed. Cutting the fin is carried out with a grinder with a cutting plate. During cutting, the cutting plate should be directed to the fin so that it does not damage the tube. The prepared fin is inserted into the membrane wall and welded according to the specified WPS. The form of the welding joint is K. After welding, the joint is tested using the surface method.

Visual inspection is performed by welding staff on membrane welding, and is given by VT Level 2. Also, 10% of repaired welds will be tested using the surface method (PT or MT). Specific test requirements (e.g. endoscopic or surface methods) may be carried out as appropriate or if requested according to the customer's technical specification. If when grinding or eliminating an error, the thickness of the tube is less than 3 mm, then it is necessary to replace at the tube with a new inserted pipe with a length of at least 500 mm. [8]. Cutting by thermal methods (e.g. gas) to remove tubes or fin is not allowed.

Kada je linearno ili ugaono smicanje traka veća od dozvoljenog, pažljivo se odseca i uklanja. Rezanje traka se vrši brusilicom sa pločom za sečenje. Tokom sečenja, reznu ploču treba usmeriti ka traci kako se ne bi oštetila cev. Pripremljena traka se ubacuje u zid membrane i zavaruje prema navedenom WPS-u. Oblik zavarenog spoja je K. Nakon zavarivanja spoj se ispituje nekom površinskom metodom.

Vizuelnuo ispitivanje vrši zavarivačko osoblje na membranskom varu, koje poseduje sertifikat za vizuelno ispitivanje nivoa 2. Takođe, 10% popravljenih zavarenih spojeva se ispituje površinskim metodama (PT ili MT). Specifični zahtevi za ispitivanje (npr. endoskopske ili površinske metode) mogu da se sprovedu prema potrebi ili ako se to zahteva i mogu se izvršiti u skladu sa tehničkom specifikacijom kupca. Ako je prilikom brušenja ili otklanjanja greške debljina cevi manja od 3 mm, onda je potrebno zameniti cev sa ponovo umetnutom cevi dužine od najmanje 500

mm. [8]. Sečenje termičkim metodama (npr. gasom) za uklanjanje cevi ili traka nije dozvoljeno.

4. Marking weld

The operator is obliged to mark with a stamp welded joints by stamping the mark in the strip area on the points of view. A welder performing error repairs to welded joints stamps right next to the remediation site or at the beginning and end of separation in case of errors in a series (e.g. porosity).

5. Checking the quality of membrane welding

The methods (technologies) of quality testing and their extensive will depend on the basis of the product construction standards. In the case of membrane welding of water boiler panels according to EN, the necessary tests are determined by standard EN ISO 12952-6 [9], Table 9.1-3:

- All welds: VT 100%,

- Welds between tube and fin when making panels: limited to VT 100%,

- Additional welds between the tube and the fin and between the fin and din that do not include the primary panel construction: VT 100% and PT/MT 10%

- Additional requirements that are not based on the standard but may be a customer requirement: RT lane weld test - fin or fin/tube.

The VT test shall be carried out in accordance with standard EN ISO 17637 [10], and the eligibility criterion EN ISO 12952-6 [9], t9.3-1, EN ISO 12952-5 TC.1 annex C. In accordance with the standard, the test must also be carried out in accordance with the written test instruction. All welds regardless of additional testing methods must be tested VT 100%. In general, VT testing can be carried out before, during and after welding, with the standard practice being to conduct the test before and after the welding process.

In order to facilitate the implementation of the test, it is advisable to use the following aids: a measuring tape (meter) with a calibration of 1 mm, a magnifying glass with a scale (the possibility of increasing x5), and a manual lamp.

For surface indication detection, standard EN ISO 12952-6 [9] allows for a choice between penetrant (PT) and magnetic particle (MT) tests. It is recommended to use MT testing (Table 9.1-3) while penetration testing is not excluded if it is a group of materials 1 and does not have access to MT testing equipment. The standard practice in the facilities of ĐĐ Termoenergetska postrojenja d.o.o. is to conduct a PT test in accordance with HRN EN

4. Označavanje zavarenog spoja

Operater je dužan da pečatom označi zavarene spojeve utiskivanjem oznake u zoni trake na vidnom mestu. Zavarivač koji vrši popravke grešaka na zavarenim spojevima označava pečatom neposredno pored mesta sanacije ili na početku i na kraju popravke u slučaju grešaka u nizu (npr. poroznost).

5. Provera kvaliteta zavarivanja membrane

Metode (tehnologije) ispitivanja kvaliteta i njihov obim, zavise od standarda na osnovu kojeg je proizvod konstruisan. U slučaju membranskog zavarivanja panela kotlova za vodu prema EN, neophodna ispitivanja su određena standardom EN ISO 12952-6 [9], tabela 9.1-3:

- Svi zavareni spojevi: VT 100%,

- Zavareni spojevi između cevi i rebra pri izradi panela: ograničeno na VT 100%,

- Dodatni zavareni spojevi između cevi i rebra i između rebra koji ne obuhvataju primarnu konstrukciju panela: VT 100% i PT/MT 10%

- Dodatni zahtevi koji nisu zasnovani na standardu, ali mogu biti zahtevi kupca: RT ispitivanje zavarenih traka ili traka i cevi.

VT ispitivanja se sprovode u skladu sa standardom EN ISO 17637 [10], i kriterijumom prihvatljivosti EN ISO 12952-6 [9], t9.3-1, EN ISO 12952-5 TC.1 aneksom C. U skladu sa standardom, ispitivanje mora biti sprovedeno u skladu sa pisanim uputstvom za ispitivanje. Svi zavareni spojevi bez obzira na dodatne metode ispitivanja moraju biti ispitani VT 100%. Uopšteno govoreći, VT ispitivanje se može sprovesti pre, tokom i posle zavarivanja, sa standardnom praksom da se ispitivanje sprovede pre i posle procesa zavarivanja.

Da bi se olakšalo sprovođenje ispitivanja, preporučljivo je koristiti sledeća pomagala: mernu traku (metar) kalibracije 1 mm, lupu sa skalom (mogućnost povećanja x5) i ručnu lampu .

Za detekciju površinskih indikacija, standard EN ISO 12952-6 [9] omogućava izbor između ispitivanja penetrantima (PT) i ispitivanja magnetnim česticama (MT). Preporučuje se korišćenje MT ispitivanja (Tabela 9.1-3) dok ispitivanje penetrantima nije isključeno ako se radi

o grupi materijala 1 i ako nema opreme za MT ispitivanje. Standardna praksa u objektima ĐĐ Termoenergetska postrojenja d.o.o. je sprovođenje PT ispitivanje u skladu sa HRN EN ISO 3452-1 [11] ISO 3452-1 [11] and a written instruction for penetrant testing. The eligibility criterion is determined by HRN EN ISO 23277/AL2X standard [12].

The equipment used to conduct the test is:

- Colored fluorescent penetrant for double application (type III),

- Solvent-based cleaner (method E) for cleaning excess penetrants,

- Solvent-based developer (type d) to develop indications [7]

It is necessary to take care that only one test kit, i.e. one test kit, is used during the test. It is not allowed to combine penetrant, cleaner and developer of different manufacturers. The test temperature shall be controlled regularly and shall not exceed 20°C, while the illumination of the room at all times must be at least 500 Lx. The concept of test temperature refers to the workplace temperature and temperature of the test piece, since both elements have a significant impact on the results of the test carried out.

With VT testing, which always represents the first step when assessing the quality of membrane welding. The choice of testing method will depend on the quality (group) of the material being welded and on the possibility or not, of the possibility of using some test technology due to limited space.

The buyer of the boiler plant may in special cases require the testing of strips-tapes or strips/pipes of welded joints by radiographic method, but this represents a requirement outside the norm that is relatively difficult to implement. From all of the above, it can be concluded that it is necessary to ensure that the methods of non-destructive tests overlap are appropriately overlapping in order to achieve the desired results. The quality of preparation for the selected welding technology, dimensional accuracy and accuracy of the form will be checked by VT testing before and after welding. Possible surface indications that may arise as a result of high heat intake during welding, or during cooling of a welded joint, should be detected by VT or penetrant testing. In accordance with HRN EN ISO 12952-6 [9], the test may be carried out by a Grade 1 operator certified under HRN EN ISO 9712 [13], while in order to assess acceptable and unacceptable indications, this must be a level 2 tester in the appropriate method.

i pisanim uputstvom za ispitivanje penetrantima. Kriterijum prihvatljivosti određen je standardom HRN EN ISO 23277/AL2X [12].

Oprema koja se koristi za sprovođenje ispitivanja je:

- Obojeni fluorescentni penetrant za dvostruku primenu (tip III),

- Sredstvo za čišćenje na bazi rastvarača (metoda E) za čišćenje viška penetranta,

- Razvijač na bazi rastvarača (tip d) za razvoj indikacija [7]

Neophodno je voditi računa da se tokom ispitivanja koristi samo jedan test komplet, odnosno jedan komplet za testiranje. Nije dozvoljeno kombinovati penetrante, čistač i razvijač različitih proizvođača. Temperatura ispitivanja se redovno kontroliše i ne sme da prelazi 20°C, dok osvetljenost prostorije u svakom trenutku mora biti najmanje 500 Lx. Koncept temperature ispitivanja odnosi se na temperaturu radnog mesta i temperaturu ispitnog komada, pošto oba elementa imaju značajan uticaj na rezultate sprovedenog ispitivanja.

VT ispitivanje, uvek predstavlja prvi korak pri proceni kvaliteta membranskog zavarivanja. Izbor metode ispitivanja zavisi od kvaliteta (grupe) materijala koji se zavaruje i od mogućnosti/nemogućnosti korišćenja neke tehnologije ispitivanja zbog ograničenog prostora.

Kupac kotlovskog postrojenja može u posebnim slučajevima zahtevati ispitivanje zavarenih spojeva traka/traka ili traka/cev radiografskom metodom, ali to predstavlja zahtev van norme koji je relativno teško sprovesti. Iz svega navedenog može se zaključiti da je neophodno obezbediti da se metode ispitivanja bez razaranja preklapaju na odgovarajući način, kako bi se postigli željeni rezultati. Kvalitet pripreme za izabranu tehnologiju zavarivanja, tačnost dimenzija i tačnost forme proverava se VT ispitivanjem pre i posle zavarivanja. Moguće površinske indikacije koje mogu nastati kao rezultat velikog unosa toplote tokom zavarivanja, ili tokom hlađenja zavarenog spoja, treba da se otkriju VT ili penetrantskim ispitivanjem. U skladu sa HRN EN ISO 12952-6 [9], ispitivanje može da obavlja operater nivoa 1 sertifikovan prema HRN EN ISO 9712 [13], dok procenu prihvatljivih i neprihvatljivih indikacija mora obavljati ispitivač nivoa 2 za odgovarajuću metodu.

6. Sample testing

Sample testing was included: macrostructures, hardness, microstructures and dimension control. The category forms was 1223RP.

Base materials were:

- Tube: P265GH, ϕ 38 x 4 mm.
- Fin: 16Mo3, t=6mm.

Additional materials were:

- BÖHLER DMO-IG, ϕ 2,4 mm – welding wire for TIG
- Lincoln 780FG – welding flux
- Bavaria SchweissT.- BA-S2Mo ϕ 2 mm - wire for SA welding

Applied test standards were: EN 15614-1: 2004. + A2: 2012; EN 12952-5: 2011; EN 17659: 2004.

6.1. Test results

On the submitted samples 1223RP-1 i 1223RP-2, a macrostructure of the welded compound was tested. The samples are free of anomalies such as microcrucies, cracks and similarly. The HV 10 hardness was also measured on the sample marked 1223RP-1. On the same samples, a dimensional control of the weld was performed as given on the face of 2. The results are shown in Table 1.

6. Ispitivanje uzoraka

Ispitivanje uzoraka obuhvatalo je: makrostrukturu, tvrdoću, mikrostrukturu i kontrolu dimenzija. Uzorci su bili kategorije 1223RP.

Osnovni materijal bio je:

- Cev: P265GH, ϕ 38 x 4 mm.
- Traka: 16Mo3, t=6mm.

Dodatni materijal bio je:

- BOHLER DMO-IG, ϕ 2,4 mm – žica za zavarivanje za TIG
- Lincoln 780FG – fluks za zavarivanje
- Bavaria SchveissT.- BA-S2Mo ϕ 2 mm - žica za EPP zavarivanje

Primenjeni standardi za ispitivanja: EN 15614-1: 2004. + A2: 2012; EN 12952-5: 2011; EN 17659: 2004.

6.1. Rezultati ispitivanja

Na dostavljenim uzorcima 1223RP-1 i 1223RP-2 ispitana je makrostruktura. Uzorci su bez grešaka kao što su mikroprsline, prsline i slično. Tvrdoća HV 10 takođe je merena na uzorku sa oznakom 1223RP-1. Na istim uzorcima je izvršena kontrola dimenzija zavarenog spoja kao što je dato na strani 2. Rezultati su prikazani u Tabeli 1.

Table 1. *Dimensional control results*

Tabela 1. *Rezultati dimenzione kontrole*

Sample/ Uzorak	1223RP-1			1223RP-2		
	Dim. 13 / mm	Dim. 14 / mm	e_r / mm	Dim. 13 / mm	Dim. 14 / mm	e_r / mm
1223RP-1A	2,51	2,33	2,87	2,69	2,41	2,49
1223RP-1B	2,11	2,27	2,87	3,09	2,55	3,13
1223RP-2A	2,41	2,24	2,76	2,45	2,27	2,59
1223RP-2B	2,07	2,29	2,89	2,54	2,54	3,02

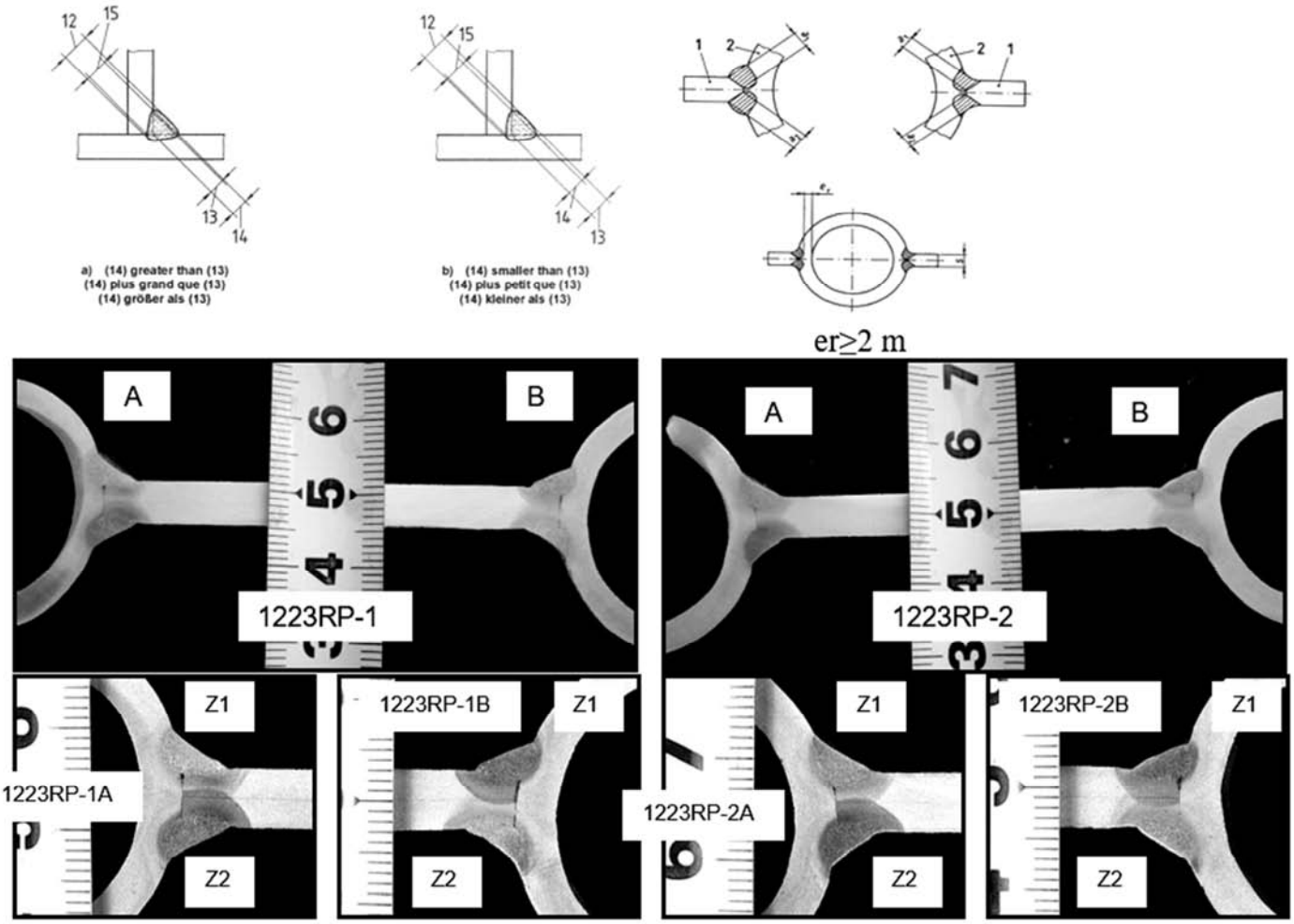

Figure 2. *Dimensional Control*

Slika 2. *Dimeziona kontrola*

Hardness was tested with HV10 and results are shown in Figure 3.

Tvrdoća je ispitivana sa HV10 i rezultati su prikazani na slici 3.

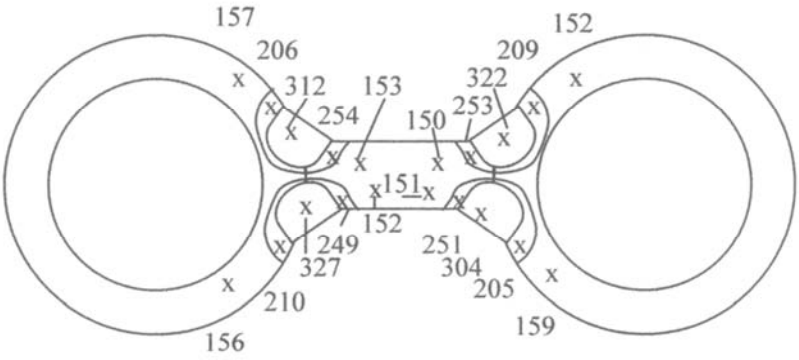

Figure 3. *Hardness test results*

Slika 3. *Rezultati ispitivanja tvrdoće*

Figure 4 to Figure 5 present the P265GH carbon steel microstructure characterized by an equiaxed structure of mid-sized grains of 4–11 and 10–20 μm for pearlite and ferrite.

Na slikama 4 do 5 prikazana je mikrostruktura ugljeničnog čelika P265GH koju karakteriše ravnoosna struktura sa zrnima srednje veličine od 4–11 i 10–20 μm za perlit i ferit.

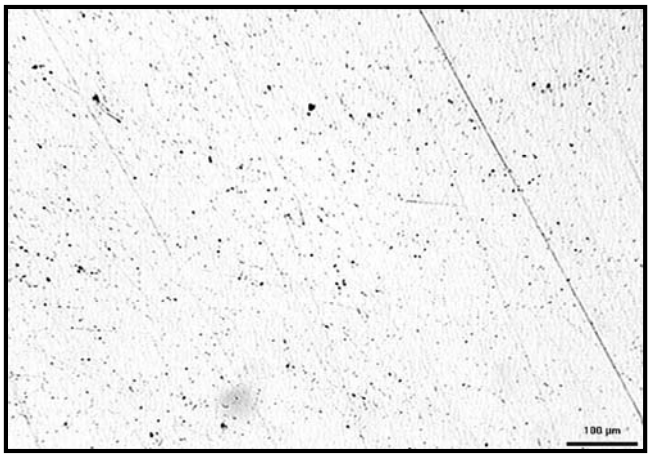

Figure 4. *Evaluation of metallurgical purity of base material P265GH: inclusions of type ED, oxides of globular - type - light series no. 5 according to EN 10247*

Slika 4. *Ocena metalurške čistoće osnovnog materijala P265GH: uključci tipa ED, globularni oksidi – tip- svetli serija br. 5 u skladu sa standardom EN 10247*

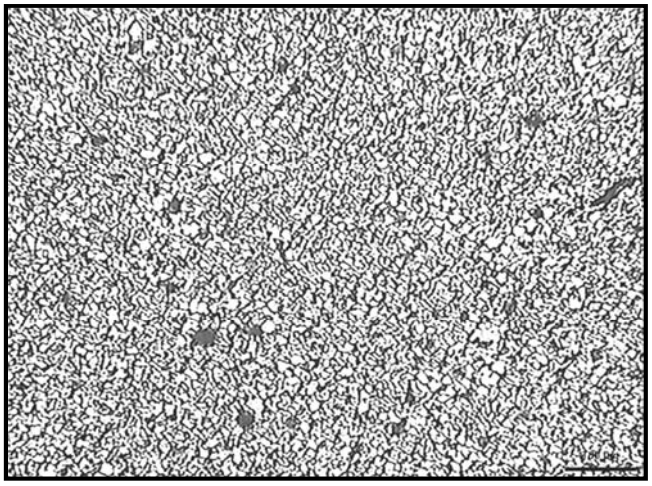

Figure 5. *Microstructure of base material P265GH. The structure is ferritic-perlite, average grain size 10 according to EN ISO 643. Etching in Nital 3%*

Slika 5. *Mikrostruktura osnovnog materijala P265GH. Sruktura je feritno – perlitna, srednja veličina zrna je 10 prema standardu EN ISO 643. Nagrizanje u Nitalu 3%.*

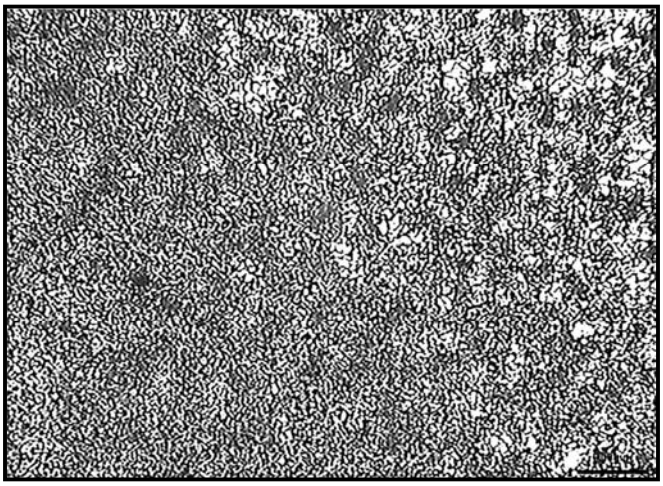

Figure 6. *Microstructure of the heat afected zone, fine-grained, ferritic-perlite, without anomalies. Etching in Nital 3%*

Slika 6. *Mikrostruktura zone uticaja toplote, fino zrnasta, ferit – perlit, bez grešaka. Nagrizanje u Nitalu 3%.*

7. Conclusion

In order to achieve the desired quality of membrane welding, and therefore to achieve the desired function of the boiler plant, it is necessary to define the production process in accordance with EN 12952-5 [6]. By the term production process means welding technology and technology of testing the quality of a welded joint. The technology of welding, except for the procedure itself, includes preparation for welding, marking of welds, definition of obligations and responsibilities of all participants in the procedure.

The technology of testing the quality of the welded joint includes all those procedures aimed at checking whether the welded joint meets the defined criteria. The boiler plant is exposed to the action of high pressures and temperatures, which places special requirements on welding technology. Likewise, the quality of the thermodynamic process of heat transfer from combustion gases to water will depend on the success of membrane welding. From all of the above, it is clear that the success of membrane welding will depend on the quality application of standard EN 12952-5 [6] and compliance with the prescribed parameters by welding technologists. Under quality application, planning, preparation, execution and supervision of production in accordance with the standard are considered. The production process defined and managed in this way is not easy, but it has no alternative in order to achieve a quality finishing product.

7. Zaključak

U cilju postizanja željenog kvaliteta membranskih zavara, a time i postizanje željenog funkcionisanja kotlovskih postrojenja, neophodno je definisati proizvodni proces u skladu sa standardom EN 12952-5 [6]. Pod pojmom proizvodni proces podrazumeva se tehnologija zavarivanja i tehnologija ispitivanja kvaliteta zavarenih spojeva. Tehnologija zavarivanja, osim samog postupka, obuhvata pripremu za zavarivanje, obeležavanje zavarenih spojeva, definisanje obaveza i odgovornosti svih učesnika u postupku.

Tehnologija ispitivanja kvaliteta zavarenog spoja obuhvata sve one postupke koji imaju za cilj proveru da li zavareni spoj ispunjava definisane kriterijume. Kotlovsko postrojenje je izloženo dejstvu visokih pritisaka i temperatura, što postavlja posebne zahteve za tehnologiju zavarivanja. Isto tako, od uspešnosti membranskog zavarivanja zavisiće i kvalitet termodinamičkog procesa prenosa toplote sagorevanja gasova. Iz svega navedenog jasno je da će uspeh membranskog zavarivanja zavisiti od kvalitetne primene standarda EN 12952-5 [6] i poštovanja propisanih parametara od strane tehnologa zavarivanja. Pod kvalitetnom primenom podrazumevaju se planiranje, priprema, izvođenje i nadzor proizvodnje u skladu sa standardima. Ovako definisan i vođen proizvodni proces nije lak, ali nema alternativu, da bi se postigao kvalitetan završni proizvod.

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