8. MEĐUNARODNO ZNANSTVENO-STRUČNO SAVJETOVANJE SBZ 2015
„PROJEKTIRANJE, IZRADA I ODRŽAVANJE ZAVARENIH KONSTRUKCIJA I PROIZVODA, SBZ 2015.“
Slavonski Brod, 21. - 23. 10. 2015.

8. INTERNATIONAL SCIENTIFIC-PROFESSIONAL CONFERENCE SBZ 2015
„DESIGN, PRODUCTION AND SERVICE OF WELDED CONSTRUCTIONS AND PRODUCTS, SBZ 2015“
Slavonski Brod, 21. - 23. 10. 2015.

ZBORNIK RADOVA
PROCEEDINGS OF FULL PAPER

Urednik/Editor:
Ivan Samardžić
Božo Despotović

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„Projektiranje, izrada i održavanje zavarenih konstrukcija i proizvoda, SBZ 2015“

„Design, production and service of welded constructions and products, SBZ 2015“

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PREDGOVOR
PREFACE

60-TI ROĐENDAN

Ove godine Društvo za tehniku zavarivanja Slavonski Brod, kao regionalno društvo za područje Slavonije i Baranje obilježava 60 godina postojanja. U samim začecima, tvornica Đuro Đaković je bila i područje rada i sjedište Društva. Većina aktivnih članova imala je radna mjesta u to vrijeme kolektivu koji je bio jedan od najvećih u širem okruženju. Prvi bljesci električnog luka, koji se miješali sa bukom od zakivanja dijelova mostova, lokomotiva ili spremnika dogodili su se u Đuri Đaković.
Prve korake pri uvođenju zavarivanja vodili su uglavnom majstori bravari, koji su uz rezanje plamenom započinjali i zavarivanje plamenom. Ručno elektrolučno zavarivanje obloženom elektrodom agregatom "Elin" primijenjeno je po prvi puta prilikom gradnje zagrebačkog željezničkog mosta preko rijeke Save davne 1938. godine.
Nakon toga, u krugu "Đure Đaković" brzo se radi na razvoju tehnologije zavarivanjem i osniva se poseban odjel naziva "Klinika za zavarivanje Đuro Đaković", gdje je započeto s kursevima za stjecanje vještina u zavarivanja.
Tako su stvoreni preduvjeti da su novo osposobljeni zavarivači "kursisti" iz "Klinike" počeli potiskivati dotad vodeće "nitere", "šraubere" i "šlajfere", pa tako iz proizvodnje "Đure Đaković" postupno nestaje zakivanje, kao i dobar dio vijčanih spojeva .
To su bile i godine pojave prvih domaćih obloženih elektroda iz Jesenica i Zagreba. Isto tako "Elka", "Iskra", "Rade Končar" pa i neki drugi proizvode prve domaće trafoe za zavarivanje, potom i ispravljače.

60th BIRTHDAY

This year, Welding Society in Slavonski Brod (later in text DTZ SB), as regional Society for area of Slavonia and Baranya is celebrating 60 years of existing. From the early begginings, ĐĐ Factory was area of the work, and also seat of Society. Most of the active members had workplace in one of the biggest collective in wider area during this period. First glimpses of electric arc, who were mixing with sound of bridge parts, engine or tank rivetting also happened in ĐĐ.
First steps in implementation of welding mostly were driven by the locksmiths, who cut with flame, they started to weld with flame. Shielded metal arc welding with coated electrode with "Elin" aggregate is applied for the very first time during the construction of railway – bridge in Zagreb on river Sava 1938.

After that, ĐĐ is continuously working on development of welding tehnics, and special section called "Welding Clinic ĐĐ" is formed, where courses for acquiring welding skills started.
Pre – conditions for newly trained welders, called the "trainees" from Clinic were created, and they started to slowly push away "rivetters", "bolters" and "grinders", who were leading then, thus rivetts and great part of screw joint are progressively dissapearing from ĐĐ productions.
Those were years when first inland covered electrodes from Jesenice and Zagreb appeared. Also, "Elka", "Iskra", "Rade Končar" and others started to produce first inland welding substations, later adapters.

Ipak, okosnicu su još dugo činili rotacioni agregati “Elin” i “Siemens”.
DTZ SB se, za potrebe proizvodnih radnih organizacija, aktivno uključivao u izbor opreme, preporuke za dodatne materijale, organizirao stručna predavanja iz područja zavarivanja ali i propagirao prekvalifikacije drugih profila u zavarivače. Tako je do 1960. god. obučeno već nekoliko desetaka elektro i plinskih zavarivača koji su prije bili drugih zanimanja: bravari, zidari, pa i zemljoradnici propalih seljačkih radnih zadruga. Zavarivači su uvijek bili spremni i zainteresirani za nove spoznaje u zavarivanju, nove postupke i provjere svojih znanja i vještina.
Natjecanja zavarivača bilo na nivou pogona, tvornica, republičkom ili državnom nivou imala su veliki interes i bile su posebne manifestacije za sve zavarivačke profile, posebno za mlade zavarivače. U pogonskim izlučnim natjecanjima u zavarivanju ĐĐ uvijek je bio dobro zastupljen u svim disciplinama (REL, MAG, TIG i PLIN), sa 150 pa i više zavarivača, te preko 70 organizatora, ocjenjivača i učesnika u pripremi.

Deseci zavarivača, uglavnom iz ĐĐ, osvajači su prvih mjesta na republičkim i saveznim natjecanjima u raznim postupcima zavarivanja, što je bio motivirajući faktor za učešća i “utakmicu“ zavarivača sa ostalim firmama. Zahvaljujući i DTZ-u SB novi tipovi vagona, lokomotiva, motornih vlakova, kotlova, kolona, mostova itd., sve u zavarenoj izvedbi, postaju osnovni vlastiti projekti izrađeni na novo nabavljenoj zavarivačkoj opremi poznatih svjetskih proizvođača opreme.
Odjel tehnologije u Institutu "Đuro Đaković", pod vodstvom dipl. ing. Zvonka Lukačevića, imao je snažan utjecaj na razvoj i definiranje zahtjeva u pogledu tehnologije zavarivanja

But, for the first time main things were rotation aggregates "Elin" and "Siemens".
DTZ SB, for the purpose of production work organisation has included actively in selection of equipment, recommendation of deposit material, organisation of professional training for the area of welding and encouraged pre – qualifications from other proffesions into welders. Till the beggining of 1960., few dozen of electric and gas welders were pre – qualified from other proffesions: locksmiths, masons, even agriculturists from failed agricultural cooperatives.
Welders were always ready and interested for new acquisitions in welding, new methods and testing of their knowledge and skills. Welding contests, no matter if they were on level of production plant, factory, republic or national level were very interested and special manifestation for all welding profiles, especially young ones.

In qualification contests in welding ĐĐ was always well represented in all disciplines (SMAW, MAG, GMAW, GAS), with more than 150 welders and 70 organisers, reviewers and contestants in preparation.
Dozens of welders, mostly from ĐĐ won first places in republic and federal contests in various welding methods, what was motive factor for partition and "clash" with other companies.
Thanks to DTZ SB, new types of wagons, engines, motor trains, boilers, columns, bridges and so, all in welded version became main own project made on newly purchased welding equipment of well - known gear manufacturer. Department of Technology in ĐĐ, led by dip.ing. Zvonimir Lukačević had strong influence on development and defining the requirements regarding to the welding technology

novih čelika odgovarajućim dodatnim materijalima, te uhodavanje novih uređaja u proizvodnim pogonima. Posebni napori su bili usmjereni na postupke predgrijavanja prije zavarivanja, dogrijavanja i odžarivanja zavarenih spojeva.

Jedna od prvih zapaženih aktivnosti DTZ SB u 70-tim godinama bila je organiziracija vrlo uspješnog savjetovanja na temu “Zavarivanje i tehnička obrada zavarenih spojeva” koja je izuzetno dobro prihvaćena u širem području bivše države. Organizacija znanstveno – stručnih skupova i savjetovanja jedno je od područja kojemu su sve generacije voditelja, uprava Društva i organizatora u ime Društva pridavale prioritetni značaj.

Prvi značajniji znanstveno – stručni skup održan je 1989. u Slav. Brodu na temu “Problemi primjene visokočvrstih čelika”, kada je prof. dr. Lukačević uspio okupiti najpoznatija stručna imena iz bivše države, među njima dr.sc. M.Gabrovšeka, prof. dr. sc. S. Sedmak, dr. sc. Inoslava Rak, mr .V. Glihu, A. Šimunovića, B. Sečkar, dr. sc. S. Jakšića, kada su zapravo postavljeni temelji za daljnju organizaciju sličnih skupova na raznim nivoima.

Za istaknuti je, danas već respektabilan niz održanih savjetovanja u Slav. Brodu u organizaciji DTZ-a SB uz pomoć suorganizatora poput: Strojarskog fakulteta u Slavonskom Brodu, Veleučilišta u Slavonskom Broda, Visoka tehnička škola u Bjelovaru, Fakulteta za strojništvo Maribor i ĐĐ Holding i mnogih drugih.

Savjetovanja su održana svake druge godine, kako slijedi (navedena po godinama održavanja i naslovima):

2001.- naslov savjetovanja "Ekonomski i kvalitativni aspekti visokoučinskih postupaka zavarivanja",

of new steels with suitable deposit material and running the new devices in production plants. Special efforts were directed on pree heating methods before welding, reheating and annealing of welded joints.

One of the first noticed activities of DTZ SB in 70s was organization of very successful counseling on theme "Welding and technical processing of welded joints", which was extremely well accepted in wider area of former Republic. Organisation of scientific – professional meetings and counselings is one of areas with priority meaning given by all generations of Directors, Bord of Directors and organisers in name of DTZ SB.

First more significant scientific – professional meeting was held in Slavonski Brod 1989. with theeme "Problems with application of high strenght steels", when proff. dr.sc. Zvonimir Lukačević managed to gather most – recognised names of experts from former Republic, such as: dr. M. Gabrovšek, proff. dr. sc. S. Sedmak, dr. sc. Inoslav Rak, mr. V. Gliha, A. Šimunović, B. Seškar, dr. sc. Jakšić, when grounds were setted up for further organisation of simmilar meetings on various levels.

It is important to notice that DTZ SB has organised respectable number of counselings in Slavonski Brod, with a help of co – organisers like: Mechanical Engineering Faculty in Slavonski Brod, Collage of Slavonski Brod, Technical Collage in Bjelovar, Faculty of Mechanical Engineering in Maribor, ĐĐ Holding and many others.

Counselings are holding every 2 years, as followed (listed by year and title of meenting):

2001. – title of counseling: "Economic and qualitative aspects of high efficiency welding technic"

2003.- naslov savjetovanja "Specijalni postupci i proizvodi u tehnici zavarivanja"
2005.- naslov savjetovanja: "50 godina zavarivačke tradicije za budućnost"
2007.- naslov savjetovanja: "Tehnologična primjena postupaka zavarivanja i zavarivanju srodnih tehnika u izradi zavarenih konstrukcija i proizvoda "
2009.- naslov savjetovanja: "Robotizacija i automatizacija u zavarivanju i ostalim tehnikama"
2011.- naslov savjetovanja: "Suvremene tehnologije i postupci pri izradi tlačne opreme , zavarenih metalnih proizvoda i konstrukcija"
2013.- naslov savjetovanja: "Suvremeni proizvodni postupci, oprema i materijali za zavarene konstrukcije i proizvode"

A pripremamo i ovogodišnje osmo, SBZ 2015, po redu međunarodno savjetovanja naslova :

“PROJEKTIRANJE, IZRADA I ODRŽAVANJE ZAVARENIH KONSTRUKCIJA I PROIZVODA, SBZ 2015.“

koje će se održati u Slav. Brodu, od 21. - 23. listopada 2015. god.

Zbornici sa svih dosadašnjih savjetovanja postali su poželjna stručna literatura. Svi Zbornici kao kolekcija nalaze se u knjižnici Strojarskog fakulteta u Slavonskom Brodu, i već su uvršteni u literaturu koju profesori preporučuju studentima u okviru redovite nastave.
Zbirka Zbornika sa zadnjim izdanjem sastoji se od 7 knjiga s preko 1900 stranica stručnog teksta. Više od 700 poznatih inozemnih i domaćih znanstvenika, inženjera i stručnjaka napisalo je, a DTZ SB publiciralo njihove radove na ovaj način, što smatramo vrlo važnim doprinosom općoj znanstveno - stručnoj zajednici.

2003. – title of counseling: "Special procedures and products in welding technic"
2005. – title of counseling: "50 years of welding tradition for future"
2007. – title of counseling: "Technological application of welding procedures and related tehnics in manufacturing of welded constructions and products"
2009. – title of counseling: "Robotisation and automatisation in welding and in other technics"
2011. – title of counseling: "Modern technologies and processes in pressure equipment, welded metal product and construction manufacturing"
2013. – title of counseling: "Modern manufacturin procedures, equipment and materials for welded constructions and products"
This year, we are organizing 8th international counseling with theme:

„DESIGNING, MANUFACTURING AND MAINTENANCE OF WELDED CONSTRUCTIONS AND PRODUCTS, SBZ 2015.“

which will be held in Slav. Brodu at october 21. - 23. 2015.

Proceedings from our previous conferences become desirable professional literature.All proceedings in collection are stored in library of Mechanical Engineering Faculty in Slavonski Brod, and they are all enlisted as a literature, which is recommended to students within regular classes by professors.
Collection of Proceedings with last collection counts 7 books with more then 1 900 pages of professional work. More than 700 known inborn and national scientisc, engineers and experts wrote, and DTZ has published their work on this way, that we consider as a great contribution to the general scientific – professional community.

Svi zbornici s kompletnim radovima nalaze se i u elektronskom obliku na web stranici DTZ SB (http://www.sfsb.hr/dtzsb/) i dostupni su bez naknade svim zainteresiranima.
Ovo je ujedno i zvanična stranica DTZ SB koja sadrži sve aktualne događaje i informacije o DTZ SB.
Na većini savjetovanja su bili i predsjednici naša 4 Društva: HDTZ Zagreb (najveće i vodeće stručne asocijacije), DTZ Istre, Pula, DTZ Dalmacije, Split i DTZ SB za Slavoniju i Baranju, čime smo kao domaćini ponosni.
Osim organizacije navedenih, danas međunarodnih savjetovanja, organizacija pokaznih zavarivanja, prezentacija novih uređaja za zavarivanje i novih dodatnih meterijala , održavanje kratkih stručnih seminara, sudjelovanje na konferencijama raznih nivoa prezentacijom radova kao i aktivna suradnja s ostalim strukovnim društvima dio su današnjeg Programa rada DTZ SB.
Danas je DTZ SB usko vezano za znanstvenu – nastavnu instituciju Strojarski fakultet u Slavonskom Brodu, prije svega Katedru za proizvodno strojarstvo, odnedavno i sjedište Društva.
Galerijom dijela slika iz zbirke DTZ SB namjera nam je podsjetiti se na neke događaje i detalje vezane uz osnovnu djelatnost organizacije znanstveno – stručnih savjetovanja, gdje se mnogi od nas mogu prepoznati.

All proceedings with complete works are published as electronic publication on web page of DTZ SB (http://www.sfsb.hr/dtzsb/), with no charge and available for everybody who is interest for. This is also official page of DTZ SB, which contains all actual events and informations about DTZ SB.
On most of counselings presidents of all 4 Societies were attended: HDTZ ZG (greatest and leading professional association), DTZ Istria, Pula, DTZ Dalmatia, Split and DTZ SB for Slavonia and Baranya, what makes us, as a host very proud.
Except organisation of, today, international counselings, part od today's DTZ SB agenda are also: presentation of new welding devices and new deposit material, organisation of welding demonstrations and short professional seminares, attending on conferences on various level with presentation of work, as well as active coo – operation with other vocational societies.
Today, DTZ SB is closely connected with scientific – educational institution Mechanical Engineering Faculty in Slavonski Brod, especially with Department of Production Engineering, recently headquarter of Society.
With this pictures from gallery of DTZ SB, we would like to remember some events and details related to basic activities of organisation scientific – professional counseling, where many of us can recognise themselves.

Detalj sa otvaranja izložbe 2011
Details from opening of exhibition 2011

Otvorenje savjetovanja 2013
Opening of counseling 2013.

Pozdravni govor dekana SF-a, 2013
Deen's welcome speech (SFSB)

Gost-suorganizator s FS-a Maribor
Guest co – organiser from FS, Maribor is presenting his work

Četiri predsjednika društava u SB
Four presidents of Society in Slavonski Brod

Studenti i đaci pomno prate izlaganja
Students are carefully watching presentation

"Better part" of contestants from one counseling

Details from "Slavonska večer" with tamburitza

Round table with always actual themes

Pred pokazno zavarivanje u ĐĐ TEP-u
Demonstration welding in ĐĐ TEP

SADRŽAJ / CONTENTS

PRESENTATION

ANALYSIS OF CURRENT STATE AND INTEGRITY EVALUATION OF THE PIPELINE AT HYDRO POWER PLANT 'PIROT'

Miodrag Arsić, Srđan Bošnjak, Vencislav Grabulov, Mladen Mladenović, Milan Minić

***Key words**: hydroelectric generating set, crack, repair technology, pipeline integrity*

Abstract:

Hydro power plant Pirot, which was built in 1990, is an accumulation-derivative power plant, which consists of 2 above - ground vertical hydroelectric generating sets that contain Francis turbines with nominal power of 41,5 MW, manufactured in Czech Republic, a tunnel and a sunken pipeline with overall length of 2.030 m and diameter that ranges from 3.000 to 3.500 m. Pipes have been made of S275J2G3 steel. [1] Pipe wall is 22 mm thick. Maximum pressure of 2.5 MPa occurs in front of the turbine cover. [2]

Pipeline has been designed and built without anchor blocks at curvatures, which is rarity elsewhere. Geodetic measurements have been conducted permanently from the day the assembly was finished and pipeline was put into service, both when pipeline is empty and unloaded by hydrostatic pressure and when it is full. Analysis of obtained data regards the movements along the pipeline route showed that from year 2003 there are significantly higher differences in movements comparing the situations when the pipeline is full and when it is empty in comparison with the previous period.

Those differences primarily refers to tangential movements of vertices marked with numbers 6, 7 and 8, which, compared to the period until year 2002, are in the range from 3 mm for vertex 8 to 5 mm for vertex 6. Apart from geodetic measurements, the measurement of pipe diameter in 2 directions is also being carried out permanently. Those data show that from year 2003. the diameter in horizontal direction started to increase significantly, while at the same time the diameter in vertical direction started to decrease less significantly.

This paper contains the analysis of current state and integrity evaluation of the pipeline as a whole on the basis of results of non - destructive tests performed on the vital butt - welded joint in the curvature area at chainage 1+263 m (visual testing, magnetic particle testing, penetrant testing, ultrasonic testing, radiographic testing, metallographic replication testing).

1. INTRODUCTION

Hydro power plant 'Pirot' is located in the near proximity of town Pirot and uses the power of Visocka river at the profile of the dam 'Zavoj'. It has been built in 1990. as an accumulation - derivative power plant, which consists of 2 above - ground vertical hydroelectric generating sets that contain Francis turbines with nominal power of 41,5 MW (figure 1), manufactured in Czech Republic, tunnel and a sunken pipeline with overall length of 2.030 m and diameter that ranges from 3.000 to 3.500 m. [1]

Maximum pressure of 2.5 MPa occurs in front of the turbine cover. Pipes have been made of 22 mm thick S275J2G3 steel sheet metal [2]. Chemical composition and mechanical properties of this steel are presented in Tables 1 and 2.

Pipeline has been designed and built without anchor blocks at curvatures, which is a rarity elsewhere. In order to perform the analysis of current state and integrity evaluation of the pipeline as a whole, non - destructive tests were performed on the vital butt-welded joint in the curvature area at chainage 1+263 m.

In that area of the pipeline, according to the design documentation, the angle of the vertical curvature is $7{,}18^0$, while the angle of the horizontal curvature is $9{,}82^0$. The pipeline diameter changes from 3.500 mm to 3.340 mm.

Table 1. *Chemical composition (values in [%])*

Material	C	Si	Mn	Cu	S	P
S275J2G3	0.210	–	1.600	0.060	0.035	0.045

Table 2*. Mechanical properties, values for normalized and annealed condition*

Material	Yield strength $YS_{0.2}$ [N/mm^2]	Tensile strength TS [N/mm^2]	Elongation A5 [%]	Impact energy $KV_{300/2}$ [J/cm^2]
S275J2G3	min 275	430 – 560	21 - 23	27 (- 20 ^{0}C)

In figure 2 the uncovering of the pipeline segment is shown, while figure 3 show the preparation of the pipeline segment for non - destructive testing.

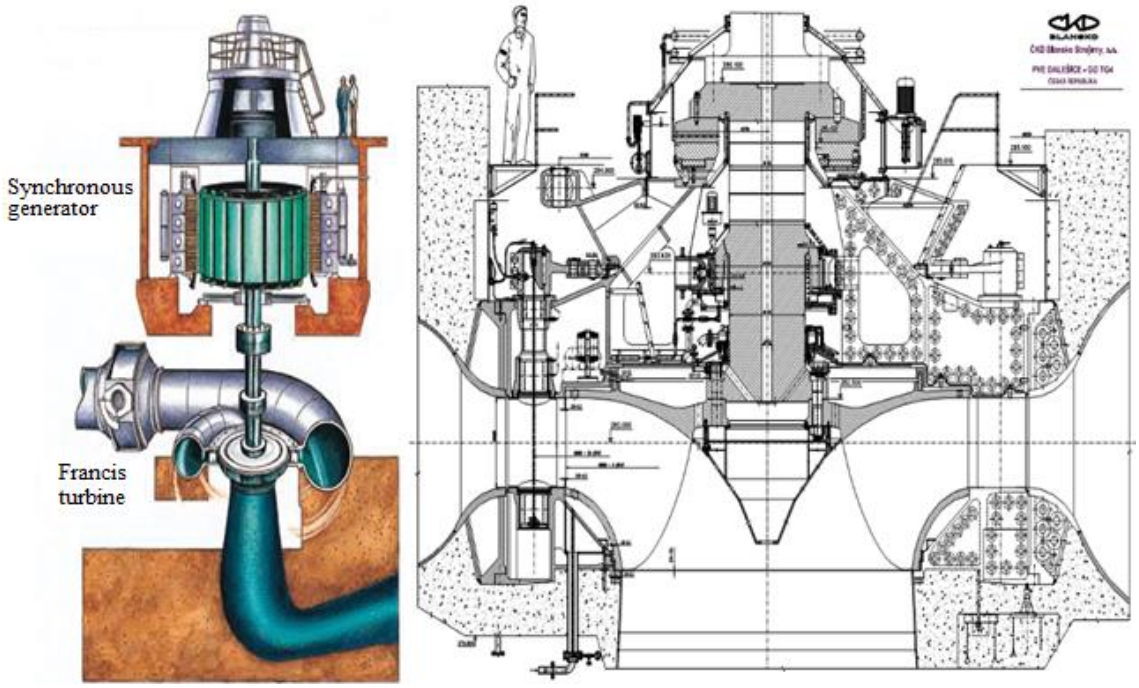


Figure 1*. Francis turbines with nominal power of 41,5 MW*

Figure 2*. Appearance of the vertical Francis turbine, with nominal power of 41.5 MW*

a) Preparation of the external pipeline surface b) Preparation of the internal pipeline surface

***Figure 3**. Appearance of preparation of the vital welded joint by grinding in order to perform NDT*

2. NON – DESTRUCTIVE TEST PERFORMED ON THE VITAL WELDED JOINT

In order to perform analysis of the current state and integrity evaluation of the pipeline as a whole the following non-destructive tests were performed: visual testing (VT), magnetic particle testing (MT), penetrant testing (PT), ultrasonic testing (UT), radiographic testing (RT) and metallographic replication testing.

2.1 Visual testing

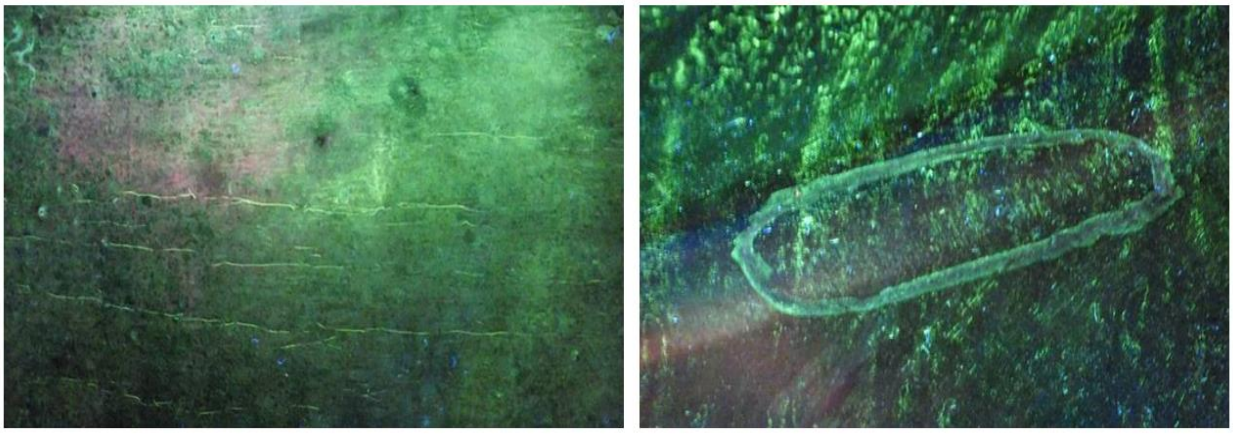
Visual testing was performed on the vital butt-welded joint, in the area of the most pronounced geometric curvature of the pipeline. Linear indications (cracks) were detected on the surface of weld metal at 5 locations in the upper zone of the external pipeline surface, along with a large number of cracks in the heat-affected zone and parent material. [3]

Nevertheless, in the lower zone of the internal pipeline surface the linear indications (cracks) were detected only at the surface of parent material. The deepest crack was 2,5 mm deep, while crack lengths vary. Length of the largest crack, located along the circumference of the parent material, was 540 mm (figure 4).

***Figure 4**. Appearance of a segment of the examined surface of parent material along the circumference of the vital butt-welded joint*

2.2 Magnetic particle testing

Magnetic particle testing [4] was performed in the area of the welded joint, on the external and internal surface of the pipeline, in order to determine locations of linear indications (cracks), (figure 5).



a) Appearance of surface cracks on the surface of parent material

b) Appearance of surface cracks on the surface of weld metal

***Figure 5**. Appearance of magnetic particle testing performed on the welded joint, at the external surface of the pipeline*

2.3 Penetrant testing

Magnetic particle testing was performed in the area of the welded joint, on the external and internal surface of the pipeline, in order to determine locations of linear indications (figure 6) [4].

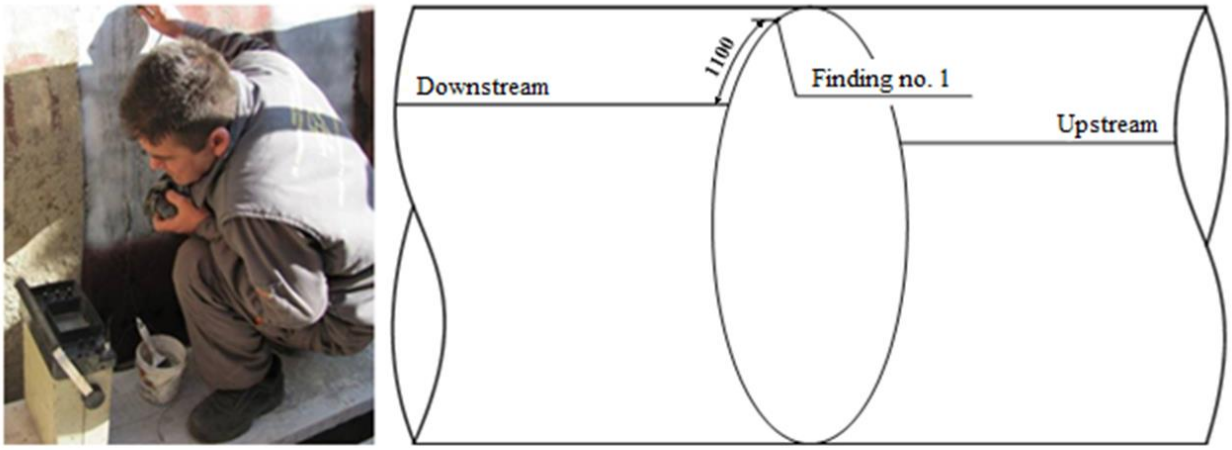
a) Appearance of the crack at the surface of the heat-affected zone

b) Appearance of cracks at the surface of parent material

***Figure 6**. Appearance of penetrant testing performed on the welded joint, at the external surface of the pipeline*

2.4 Ultrasonic testing

Ultrasonic testing was performed on parent material and weld metal [6] in order to determine depths of surface cracks. It was determined that cracks in parent material are 1,5-2,5 mm deep, while cracks in weld metal are 3,5 - 10,0 mm deep. Process of ultrasonic testing of the butt - welded joint, as well as location of the 10 mm deep surface crack are presented in figure 7.



a) Process of ultrasonic testing

b) Location of the 10 mm deep surface crack in the area of the butt - welded joint

Figure 7*. Determination of depths of surface cracks in the area of the butt - welded joint*

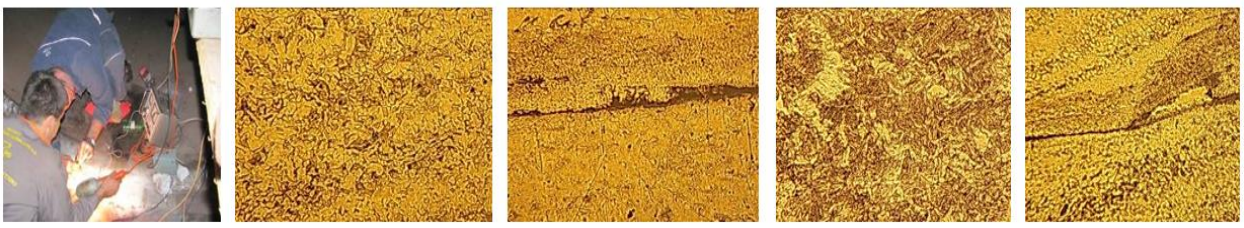
2.5 Radiographic testing

By radiographic testing a few sporadical undercuts were detected in the root area of the butt-welded joint, with lengths that range from 30 - 240 mm. [7]

2.6 Radiographic testing

The microstructure of the parent material of the pipeline was determined by metallographic replication testing. Examination was performed on the metallographic microscope "METAVAL", manufactured by "Carl Zeiss", Jena, through the application of the bright - field technique, which could be carried out after the surface was properly prepared (cleaning, degreasing, series of fine grinding operations, final polishing, rinsing, metallographic etching by 4% nital). [8].

Test results showed that the microstructure of the surface layer is ferrite-pearlite with small non-metallic inclusions and corrosion products present, as well as 12 - 15 mm long macrocracks. Test results also showed that the microstructure of weld metal is coarse grained ferrite-pearlite with small non-metallic inclusions and corrosion products present, as well as 30-35 mm long macrocracks. Characteristic test results are presented in figure 8.



a) Replication process

b) Microstructure of parent material

c) A crack in parent material

d) Microstructure of weld metal

e) A crack in weld metal

Figure 8*. Appearance of characteristic results of metallographic replication testing*

3. TECHNOLOGY FOR THE REPAIR OF CRACKED AREAS AT THE SURFACE MATERIAL OF PARENT AND WELD METAL

The applicability of the welding procedure 111 was determined through the analysis of parameters on which the repair welding/surface welding procedure depends (weldability of material, energetic possibilities of welding procedures, geometric complexity of the structure, economic parameters). Due to limited capability of performing pre - heating and heat treatment after repair welding/surface welding, the optimal solution is to use the basic coated electrode.

Cracks at the surface of parent material were eliminated by fine grinding, while repair welding/surface welding had to be performed in areas at the surface of weld metal where cracks were detected after the grinding was finished through the utilization of welding procedure 111 with electrode EVB 50 (Jesenice electrodes), classified in accordance with the adequate standard [9]. Chemical composition of weld metal is presented in table 3, while mechanical properties are presented in table 4.

In figure 9 repair of the area where longest and deepest crack was detected is shown. During and after the repair of cracked areas visual and magnetic particle/penetrant testing were performed.

***Table 3**. Chemical composition, values in [%]*

Electrode	C	Si	Mn
EVB 50	0.08	0.60	1.0

***Table 4**. Mechanical properties of pure weld metal*

Electrode	Yield strength YS0.2% [N/mm^2]	Tensile strength TS [N/mm^2]	Elongation A5 [%]	Impact energy $KV_{300/2}$ [J/cm^2]
EVB Mo	> 440	510 – 610	> 24	47 (- 20 ^{0}C)

a) Appearance of the repair of a cracked area b) An area prepared for surface welding

***Figure 9**. Appearance of the preparation for surface welding*

4. EVALUATION OF PIPELINE INTEGRITY AS A WHOLE

Acording to Directive for pressure equipment [10], for design and integrity evaluation during service the calculation methods based on empirical formulae, analytical procedures and fracture mechanics should be used. The analytical calculation of pipeline strength was performed on the

basis of results of non-destructive tests and after the repair by fine grinding and welding/surface welding was carried out.

Calculation of shell and dished ends strength in relation to internal pressure has been carried out through the use of standard EN 13445-3 [11].

According to the documentation of the manufacturer, basic technical properties of the pipeline are as follows:

yield strength of shell and dished end material from room temperature: $Y_{S0.2}$ = 275 MPa
tensile strength of shell and dished end material from room temperature: T_s = 430 MPa
outer diameter of the shell: D_o = 3 340 mm
inner diameter of the shell: D_i = 3 308 mm
nominal thickness of shell and dished end sheet metal: t_o = 22 mm
operating pressure at change 1 + 263 m: p = 1,26 MPa
welded joint coefficient: z = 0.8

$$\frac{D_o}{D_i} = \frac{3340}{3308} = 1.01 < 1.2 \text{ - this condition proves the applicability of standard} \quad (1)$$

4.1 Calculation of the pipeline strength in relation to internal pressure

Calculation of strength in relation to internal pressure (equation 2) proved that thickness of the cylindrical section of the shell is sufficient, i.e. the calculated value doesn't exceed the measured one from paragraph 2.4.1. Required thickness is being obtained as follows:

$$s = \frac{D_o \cdot p}{2 \cdot f \cdot z + p} + \delta_e + c = \frac{3340 \cdot 1.26}{2 \cdot 137,5 \cdot 0,8 + 1,26} + 0,8 + 1,0 = 20,8 mm < \mathbf{22\ mm} \quad (2)$$

In equation (2), according to standard [11], value 0,8 is the addition for permissible deviation of material thickness, while value 1,0 is the addition for corrosion damage. Coefficient of strength f is being calculated as follows:

$$f = \min\left(\frac{R_{p0.2}}{1,5}; \frac{R_m}{2,4}\right) = \min\left(\frac{275}{1,5}; \frac{430}{2,4}\right) = \mathbf{(137,5\ ;\ 180) = 137,5} \quad (3)$$

Considering that cracks at the surface of parent material haven't been removed completely by fine grinding, the calculation of strength of the pipeline as a whole (calculation of the minimum necessary sheet metal thickness) was carried out for minimum values of yield strength and tensile strength for material S275J2G3, as well as validity coefficient of the welded joint predicted for quality class "C".

5. CONCLUSION

Integrity of structures is a relatively new scientific and engineering discipline, which in a broader sense encompasses state analysis and behaviour diagnostics, evaluation of service life and structure rehabilitation which means that, apart from the usual situation when it’s needed to evaluate the structural integrity when a defect is detected by non-destructive testing, this discipline also comprises the analysis of the structural stress state.

It was determined that the integrity of the pipeline structure as a whole is not in jeopardy taking into account the analysis of the condition of the vital welded joint and strength calculation, as well as minimum necessary sheet metal thickness.

ACKNOWLEDGEMENT

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6. REFERENCES

[1] Manufacturer's Documentation for the Hydro-Electric Generating Set, ČKD Blansko, 1990.
[2] EN 10025, Hot rolled products of non-alloy structural steels - Technical delivery conditions (Includes amendment A1:1993), European Committee for Standardization, 2004.
[3] EN 970, Non-destructive examination of fusion welds - Visual examination, European Committee for Standardization; 1997.
[4] EN ISO 17638, Non-destructive testing of welds - Magnetic particle testing, European Committee for Standardization, 2009.
[5] EN 571 – 1, Non - destructive testing - Penetrant testing - Part 1: General principles, European Committee for Standardization, 1997.
[6] EN 1714:1997, Non-destructive testing of welds - Ultrasonic testing of welded joints, European Committee for Standardization, 1997.
[7] EN 1435, Non-destructive examination of welds - Radiographic examination of welded joints, European Committee for Standardization, 1997.
[8] ISO 3057, Non-destructive testing - Metallographic replica techniques of surface examination, International Organization for Standardization, 1998.
[9] EN 499, E 42 2 Mo B 42, Welding consumables. Covered electrodes for manual metal arc welding of non - alloy and fine grain steels. Classification, 1995.
[10] The Pressure Equipment Directive 97/23/EC, 1997.
[11] EN 13445-3: Unfired pressure vessels - Part 3: Design, European Committee for Standardization, 2009.