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EXPERIENCES IN WELDING THE TURKISH STREAM GAS PIPELINE AND INTERCONNECTOR SERBIA - BULGARIA

ISKUSTVA U ZAVARIVANJU GASOVODA „TURSKI TOK“ I INTERCONECTOR SRBIJA – BUGARSKA

Professional paper / Stručni rad

Paper received / Rad primljen:

November 2023.

Paper accepted / Rad prihvaćen:

December 2023.

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Keywords: centralizer device for connecting and centering pipes on the gas pipeline, STT device for MAG welding, FCAW-S - filled self-shielding welding wire.

Abstract

The gas pipeline "Turski Tok" was built in the period from 2019 to 2021 with a total length of 403 km (Zaječar-Horgoš). The pipeline has a capacity of up to 15 billion cubic meters, a diameter of 1219 mm and its thickness is 14.27 mm. The steel L485MEPSL2 was used for production. The Serbia-Bulgaria interconnector is 109 km long (Niš-Sofia), with a capacity of 1.8 billion cubic meters of gas, a diameter of 711 mm and the thickness is 8.7 mm. Steel X52 was used for its construction.

Different procedures were used for welding:

- Welding E-111 (cellulose and basic coating).
- MAG 135 with welding of the root of the welded joint with a semi-automatic device STT, and filling with an automatic procedure with two devices.
- Welding with the MAG process of the root of the welded joint on the inside, using the internal centralizer, and on the outside with the automatic MAG process with two devices.
- Welding from the outside with automatic MAG process with two devices, Self-Shielded Flux Cored Arc Welding wire FCAW-114 using an internal centralizer with a copper ring.

The paper presents experiences with gas pipeline welding, with a critical review of selected solutions and suggestions for optimizing welding technology.

Ključne reči: centralizer uređaj za povezivanje i centriranje cevi na gasovodu, STT uređaj za zavarivanje MAG postupkom, FCAW-S -punjena samozaštitna žica za zavarivanje.

Rezime

Gasovod „Turski tok“ je izgrađen u periodu 2019. do 2021. godine u ukupnoj dužini od 403km (Zaječar-Horgoš). Cevovod je kapaciteta do 15 milijardi kubnih metara, prečnika 1219mm i debljine 14,27mm. Za izradu je korišćen čelik L485MEPSL2. Interkonektor Srbija-Bugarska je dužine 109 km (Niš-Sofija), kapaciteta 1.8 milijardi kubnih metara gasa, prečnika 711mm i debljine 8,7mm. Za izradu je korišćen čelik X52.

Za zavarivanje su korišćeni različiti postupci:

- Zavarivanja E-111(celulozna i bazična obloga);
- MAG 135 sa zavarivanjem korena zavarenog spoja poluautomatskim uređajem STT, a ispuna automatskim postupkom sa dva uređaja;
- Zavarivanje MAG postupkom korena zavarenog spoja unutrašnje strane, pomoću unutrašnjeg centralizera, a sa spoljašnje strane automatskim MAG postupkom sa dva uređaja;
- Zavarivanje sa spoljne strane automatskim MAG postupkom sa dva uređaja, samozaštitnom žicom FCAW-114 pomoću unutrašnjeg centralizera sa bakarnim prstenom.

U radu su predstavljena iskustva sa zavarivanjem gasovoda, sa kritičkim osvrtom na izabrana rešenja i predlozima za optimizaciju tehnologije zavarivanja.

The paper was published in its original form in the Proceedings of the International scientific and professional conference: Welding connecting - "Welding and welded structures 2023" held in Sarajevo, BiH, from October 25 to 27, 2023

1. Introduction

With accelerated industry development and the increased foreign investments in new factories development, the demand of energy sources has increased, as well. Since the end of ninetees Serbia has not constructed a single pipeline of regional character, and not to talk about the pipeline inter-connecting the countries. An additional problem is gas supply, coming from the direction of Hungary only and interruption of this pipeline would be a great problem for Serbia. Based on these reasons, as well as on geopolitical situation, the works on the gas pipeline - Turkish stream, from the border with Bulgaria to the border with Hungary, started in 2019.

The gas pipeline Turkish stream was constructed in the period from 2019 to 2021, in the total length of 403 km (Vrška Čuka - Horgoš). The capacity of the pipeline is up to 15 billion cubic meters of gas, the diameter is 1219 mm and the thickness is 14,27mm. The steel L485ME X70 PSL2 was used in construction.

After two years, further diversification of gas supply was continued, in the way that in 2023 the construction of Interconnector Serbia – Bugarska started, the total length of which was 109 km, capacity 1.8 billion cubic meters of gas, diameter - 711mm and the pipe wall thickness – 8.7mm. Steel pipes X52 were used for fabrication of gas pipeline.

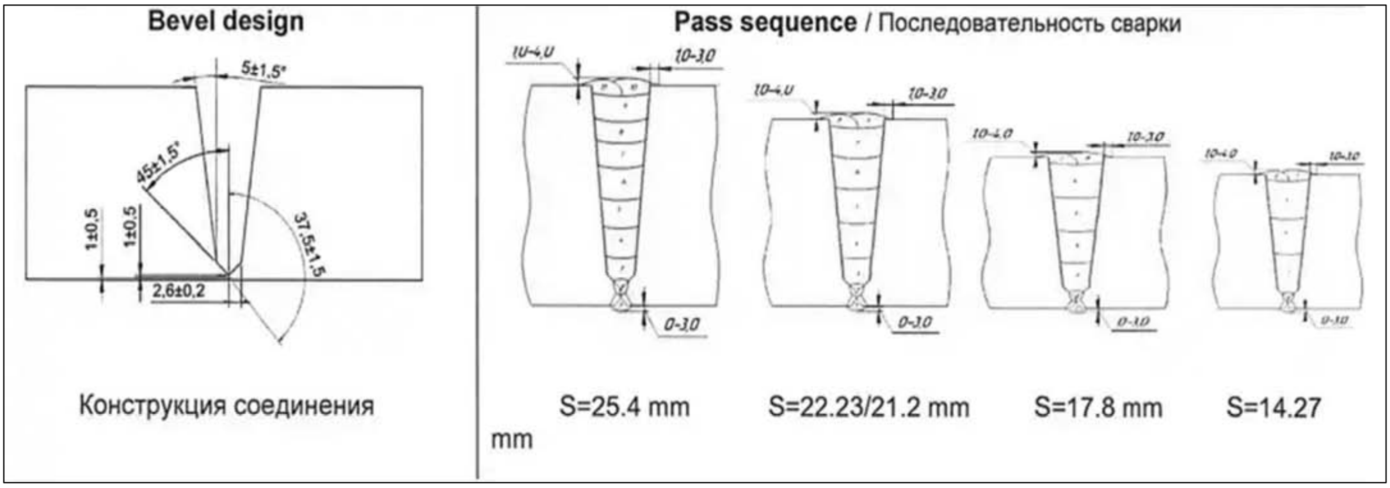

Figure 1. *Pipe ends preparation with IDC for automatic welding*

Slika 1. *- Priprema krajeva cevi kod IDC-a za automatsko zavarivanje*

2. Welding processes used in the pipeline Turkish stream

Since two contractors were engaged in this pipeline construction, there was the difference in welding technologies, SAIPEM was welding from external side only, while IDC had the welding devices CRC-EVANS, by means of which they were welding the weld root from the interior side, while the hot pass, the filler welds and final weld were done from the external side.

On the internal centralizer, IDC had 4 heads, which were welding the weld root from the internal pipe side. Both contractors were using automatic MAG welding process, in that, Saipema weld root was being welded in the way that the internal centralizer had a copper ring on it, which enabled gaining of a quality root weld.

For welding connections – assemby welds, both contractors used the same preparation of the pipe ends, but different welding technology.

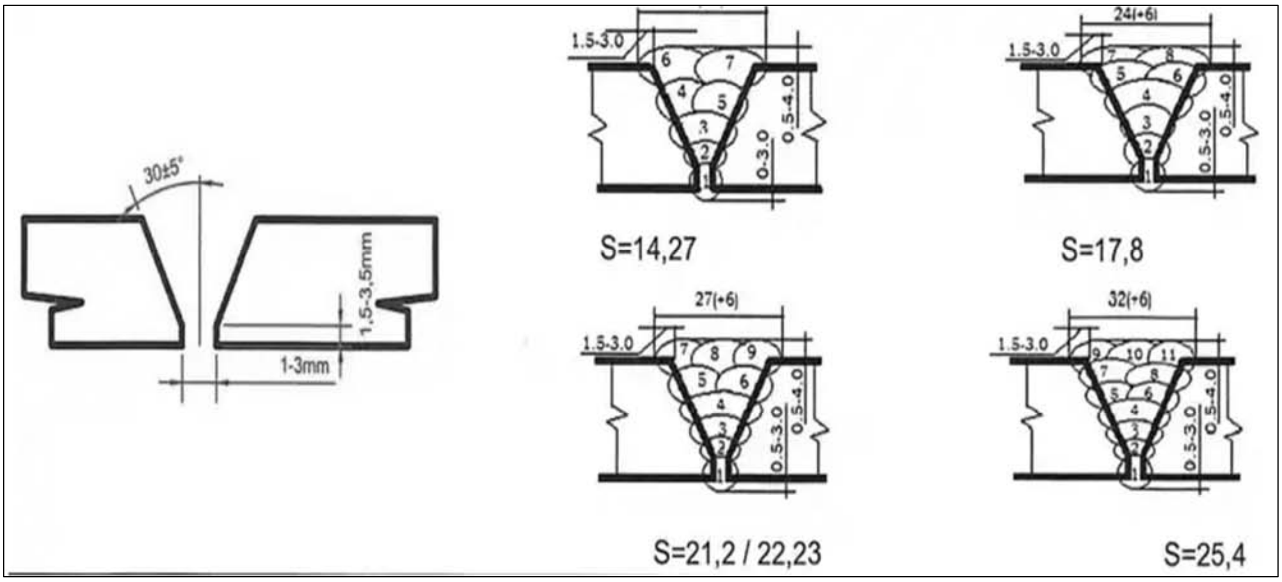

Figure 2. *Pipe ends preparation for E process with IDC and Saipema, respectively*

Slika 2. *Priprema krajeva cevi kod IDC-a i Saipema za E postupak*

Filler metal for pipe interior side welding - welding pass of IDC was wire Thyssen TS-6 ER70S-G Ø 0.9mm, while the wire, used for hot pass welding, filler weld and final weld was Ø1,0mm K-600 EN-ISO 14341-A G 46 2 C1 4Si1 [1]. The following devices were used for root weld: IWM+Lincoln Idealarc DC400/Lincoln V350, while the automatic welding machine Evans P600/P625+Fronius TPS 3200 were used for other welds.Welding position PJ, from top to bottom DC+.

Preheating temperature was 120°C, and the inter-layer temperature was 250°C. Preheating was performed by an induction device PIH120, and the inter-layer preheating was done by two gas burners. Shielding gas was EN ISO 14175 M21.

Depending on what was welded, the welding current strength ranged from 180-220A at root pass, 220-300A at hot pass, 160-220A at filler welds and from 110-150A at the final pass. The voltage ranged from 18V at root pass up to 26V at final pass.

The welding speed at root pass was 60cm/min and up to 35cm/min at the final pass, in that, pulsation was included in filler weld and final weld, and its value was variable, depending on the pipe wall thickness, that is, on the weld width.

Figure 3. *Internal centralizer IDC*

Slika 3. *Unutrašnji centralizer IDC*

For such welding technology, it is anticipated that there is no clearance between the pipes, and the allowed deviation is 0.5mm, but for not more than 100mm. The time that may elapse between the root weld and hot pass welding, may not be longer than 5min.

When welding connections and at spots where the terrain configuration was not easily accessible, the E welding process was used, with the basic coating, namely, the root pass was done by EN ISO 2560-A E 42 5B 12 45 OK 53.70, and other welds were done by means of an electrode EN ISO 2560-A E 50 4 Y B 42 H5 OK 74.70 Ø3,2mm.

The welding current ranged from 90-110A at root pass, 100-120A at hot pass, 110-130A at filler welds and 110-120A at final pass. The voltage ranged from 19V for root pass, up to 24V for the final pass.

Figure 4. *An Operator monitors the welding head operation in MAG process*

Slika 4. *Operater prati rad glave za zavarivanje MAG postupkom*

The welding technology of the second Contractor of works – Saipem differed in terms of the filler materials selection, for mechanized MAG process, in the way implying the electrode wire 14341-A G4Si1 OK Autrod 12.66 Ø1.0mm [2].

For the assembly welds and for weld repairs, there was used E process, namely, for root pass, an electrode with a cellulose coating EN ISO 2560-A E 38 3 C 21 Bohler FOX CEL Ø3,2 mm [3]. The other welds were done with an electrode with basic coating EN ISO 18275-A E 56 6NiMo B 4 2 H5, of Ø3.2 and 4.0mm diameter. Welding position PH, from the bottom to the top, unlike the mechanized MAG welding process.

Welding parameters for mechanized MAG process are, as follows:

The strength of the current, depending on the pass, ranged from 200-260A at root pass, 180-240A at the hot pass, 180-240A for filler weld, and 120-180A for final weld. The voltage of the arc from 22 to 26V, in that, pulsation was used for other passes, except the root pass, and the frequency ranged from 80 to 160 No/min.

The welding speed ranged from 90cm/min for root pass, from 50cm/min for hot pass and filler welds and around 30cm/min for the final weld.

Welding parameters for E process are, as follows:

The strength of the current, depending on the pass, was around 100A at the root pass, 100-120A at the hot pass, 160-180A for filler welds, and 110-130A for the final weld. Arc voltage from 18 to 24V.

Welding speed ranged from 10cm/min for the root pass, around 12-14cm/min for filler welds, and around 10cm/min for the final weld.

Welding position PH, shielding gas, gases mixture 30% Ar and 70% CO_2. As in the case of the first Contractor, the time between the root pass and the hot pass may have not exceeded 5 min.

3. Welding processes used in the pipeline Interconnector Serbia - Bulgaria

In this gas pipeline, the welding was also performed by two contractors, KONVAR Serbia and HABAU Austria-Romania. The welding technogy with both contractors was similar, that is, the root pass was performed by MAG process 135, by solid wire Ø1.0mm, position PJ, and the filler weld was welded by MAG -136 process, by filled wire Ø1.2mm, position PH. The difference was only in the welding equipment, with Habau – it was STT - Lincoln Electric, while in Konvar it was LSC Fronius for the root pass welding. Welding of the hot pass, filler weld and final weld were performed by automatic devices Piper plus, with Habau, and Proteus devices, with Konvar.

Figure 5. *Welding on the route*

Slika 5. *Zavarivanje na trasi*

This welding technology was used for overhead welding in the route, the welding parameters were similar, and the selection of the filler material was different. For welding of the root pass Konvar used Bohler EMK6 EN ISO 14341-A G 42 4 M21 3 Si [3], while Habau used Supramig Ultra EN ISO 14341-A G50 5 M 4 Si1.

For welds of the hot pass, filling and final pass, Konvar used the filled electrode wire Bohler Diamond Sparks 52RC EN ISO 17632-A T 46 4 P M21 H5, while Habau used Fluxofil MHD EN ISO 17632-A T 46 3 PM 1 1 H5 [4].

Root pass welding parameters: current strength 90-120A, voltage 15-17V, welding speed 18cm/min, hot pass and filler welds: current strength 160-175A, voltage 22-25V, welding speed 17-19cm/min. Final weld: current strength 170-190A, voltage 23-25V, welding speed 16-18cm/min with pulsation.

Connection welds, repair of welded joints, as well as the sections of the route in inaccessible mountain conditions were being welded by E process, by means of cellulose coated electrode. The welding technology with both contractors was the same, as well as the selection of additional material. For the root pass the electrode used was the one with a cellulose coating Bohler Fox Cel Ø3,2mm, EN ISO 2560-A E 38 3 C21, and for filler welds and final weld it was Bohler Fox Cel Mo Ø3,2 ili 4,0mm, EN ISO 2560-A E 42 3 Mo C 25.

Welding parameters: root pass – current strength 80-90A, voltage 22-23V, welding speed 8 to 10cm/min; hot pass and filler welds - current strength 95-105A, voltage 23-24V, welding speed 10-12cm/min and the final weld - current strength 100-110A, voltage 25-26V, welding speed 10cm/min.

Self-shielded wire was not used for welding in these two gas pipelines, although the welding process is much simpler, but the aforementioned processes. For this process it is necessary to have the internal centralizer with a copper ring, which Saipem possesed and to have special guns for self-shielded wire.

Figure 6. *Automatic welding device with self-shielding wire*

Slika 6. *Uređaj za automatsko zavarivanje samozaštitnom žicom*

4. Conclusion

Based on the experiences gained in these two gas pipelines, as well as the gas pipeline, constructed by the end of the last century, it may be said that each technology has its advantages and shortcomings.

While at E-process welding by means of an electrode with cellulose coating all failures in preparation of a joint may be corrected by a skillful welder, the problem is productivity, because with pipe wall thickness of 8.7mm and diameter of 711mm, one welder may weld 1 to 2 welds during the day.

This process is unavoidable when performing welding connections and when welding in not easily accessible terrains. MAG welding process when the centralizer does not have the copper ring, requires programmes for weld root welding and sensitivity to the occurrence of porosity, particularly if the gas pipeline passes near big watercourses.

Another problem, incurred here refers to pipe dimensions tolerances, because there are big differences in allowable deviation of pipe circumference, ovality and thickness of the pipe wall. This process is almost two and half times more productive, but it's shortcoming is in insufficient penetration, particularly if the pipe wall thicknesses exceeded 10mm. The welding process with self-shielding wire is the most productive from all the mentioned ones, there are no problems with seam porosity occurrence or insufficient penetration, both in the weld root, and the pipe walls. Possessing the internal centralizer with a copper ring always enables good penetration of weld root and overcoming all problems related to the pipe quality, allowable dimensional deviations. The shortcoming is high cost of self-shielded wire, compared to the price of other filler materials and poor selection of self-shielded wires for welding pipes made of better quality steels -X70.

4. Zaključak

Na osnovu iskustva sa ova dva gasovoda, kao i gasovoda, koji rađen krajem prošlog veka ,svaka tehnologija ima svoje prednosti i mane.

Dok kod zavarivanja E postupkom elektrodom sa celuloznom oblogom, sve greške u pripremi spoja , vešt zavarivač može da ispravi, problem je produktivnost, jer kod debljine zida cevi 8,7 mm i prečnika 711 mm, jedan zavarivač može da zavari 1 do 2 zavara u toku dana.

Ovaj postupak je neizbežan kod zavarivanja konekcija i zavarivanja na nepristupačnom terenu. Zavarivanje MAG postupkom ako centralizer ne poseduje bakarni prsten, zahteva posebne programe za zavarivanje korena vara i osetljivost na pojavu poroznosti, naročito ako gasovod prolazi blizu velikih vodotokova.

Problem koji se ovde još javlja, su tolerancije dimenzija cevi, jer imate velike razlike u dozvoljenom odstupanju obima cevi, ovalnosti i debljini zida cevi. Ovaj postupak ima skoro dva i po puta veću prodiktivnost, ali ima nedostatak u nedovoljnoj penetraciji, naročiti ako su debljine zida cevi veće od 10mm. Postpak zavarivanja samozaštitnom žicom je naj produktivniji od svih navedenih, nema problema sa pojavom poroznosti u šavu ili sa nedovoljnom penetracijom , kako u korenu vara, tako i na zidove cevi. Posedovanje unutrašnjeg centralizera sa bakarnim prstenom omogućava uvek dobar provar i sve probleme vezane za kvalitet cevi, koji se odnose na dozvoljena dimenzionalna odstupanja.

Nedostatak je visoka cena samozaštine žice u poređenju sa cenom ostalih dodatnih materijala i mali izbor samozaštitnih žica za zavarivanjr cevi od kvalitetnijih čelika X70.

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