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Predsednik Društva za obnovljive izvore električne energije pri SMEITS-u
Prof. dr Zoran Stević

President to the Society for Renewable Electrical Power Sources within the SMEITS
Prof Zoran Stević, Ph. D.

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PREDGOVOR

Ubrzani napredak nauke, tehnologije i industrije dovodi do poboljšanja kvaliteta ljudskog života, ali i do stvaranja novih rizičnih situacija. Čovečanstvo je suočeno sa rizicima kakvih u ranijoj ljudskoj istoriji nije bilo. Globalno zagrevanje je tipičan primer. Jedan od glavnih problema vezanih za nove rizične situacije jeste – pitanje odgovornosti. Vlade država u svetu ne smeju teret odgovornosti prepustiti isključivo naučnicima i ekspertima, ali takođe ne smeju same odlučivati i preuzimati (ne)odgovornost. Trebalo bi da se konsultuju sa ekspertima i da dobro procene kada i kakve mere treba preduzimati. Potrebna je jaka politička inicijativa da bi se počeli rešavati ozbiljni ekološki problemi kao što je globalno zagrevanje, ali i lokalno zagađenje životne sredine. Politički dogovori na svetskom nivou koji su do sada postignuti u okviru Kjoto protokola, nedovoljni su za zaustavljanje ovog fenomena. Čiste tehnologije - tehnologije koje su dizajnirane da obezbeđuju superiorne performanse za nižu cenu dok istovremeno kreiraju manji gubitak energije od konvencionalnih ponuda - imaju velike šanse da budu motorna snaga koja će obezbediti ekonomski rast.

Nauka, naravno, pre svih uočava probleme opstanka planete i života na njoj. Ona takođe pokušava da ih reši i uspeva onoliko koliko je to realno moguće, imajući u vidu političke, socijalne, ekonomske i tehnološke faktore. Može se konstatovati da su praktično svi prioriteti posvećeni očuvanju života na Zemlji. Nauka i razvoj tehnike i tehnologije mogu tome doprineti u više segmenata:

– obnovljivi izvori energije;
– energetska efikasnost;
– smanjenje količine otpada;
– smanjenje štetnosti otpada;
– reciklaža;
– prečišćavanje zemlje, vode i vazduha;
– neutralizacija preostalog otpada.

Bitan faktor za donošenje političkih odluka je i javno mnjenje. Zato je jako važno podizanje opšte svesti i što šira edukacija stanovništva o nephodnosti prelaska na obnovljive, ekološki prihvatljive izvore energije, što je jedan od dugoročnih ciljeva ove Konferencije.

Ovaj međunarodni skup po deveti put organizuje Društvo za obnovljive izvore električne energije (DOIEE) Saveza mašinskih i elektrotehničkih inženjera i tehničara Srbije (SMEITS), uz suorganizaciju Instituta za arhitekturu i urbanizam Srbije (IAUS).

U Beogradu, oktobra 2021.

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UPOREDNA ANALIZA PIROMETALURŠKIH I HIDROMETALURŠKIH PROCESA ZA RECIKLAŽU ŠTAMPANIH PLOČA - TEORIJA I PRAKSA

COMPARATIVE ANALYSIS OF PYROMETALLURGICAL AND HYDROMETALLURGICAL PROCESSES FOR PCB RECYCLING - THEORY AND PRACTICE

Silvana B. DIMITRIJEVIĆ[*]
Mining and Metallurgy Institute Bor, Serbia

Elektronski otpada od starih računara povećala se za oko pet puta, a sa odbačenih mobilnih telefona gotovo 20 puta za 2020. Godinu u odnosu na 2007. E-otpad (elektronski otpad) je jedna od najbrže rastućih vrsta otpada na svetu sa oko 40-50 miliona tona godišnje u poslednjoj deceniji, što predstavlja 2-3% ukupnog otpada koji se godišnje generiše širom sveta. Štampane ploče (PCB) su najvrednije komponente E-otpada. Cilj ovog rada je uporedna analiza pirometalurških i hidrometalurških procesa za reciklažu plemenitih metala iz PCB na osnovu eksperimentalnih istraživanja i rezulta

Ključne reči: *Reciklaža; pirometalurgija;, hidrometalurgija; analiza*

The production of e-waste from old computers increased by about five times, and from discarded mobile phones almost 20 times by the year 2020 compared to the year 2007. E-waste (electronic waste) is one of the fastest growing types of waste in the world, about 40-50 million tons per year in the last decade, representing 2-3% of the total waste generated annually worldwide. Printed circuit boards (PCBs) are the most valuable components of E-waste. The aim of this paper is a comparative analysis of pyrometallurgical and hydrometallurgical processes for the recycling of precious metals from PCBs based on experimental research and results.

1 Introduction

In the last few decades KSKS century, as the amount of e-waste grows because animals age device and product shortens processing e-waste is updated. The importance of these technologies is reflected in obtaining the valuable materials and solving the environmental problems. Technologies for the process usually include a combination of methods due to the complexity of processed materials [1, 2].

In the period of the 1970s and early to mid-1980s, the main method for recycling the electronic scrap was the blast furnace smelting with secondary copper or lead smelters. Since the mid-1980s, this trend has been shifted toward the hydrometallurgical processing.

Recovery of metals from e-scrap by pyrometallurgical processing, include the incineration, smelting in a plasma arc furnace or blast furnace, drossing, sintering, melting and reactions in a gas phase at high temperatures [3-4] became a traditional method to recover the non-ferrous metals and precious metals from electronic waste in the past two decades.

The most active research area on recovery of metals from electronic scraps is recovering the precious metals using the hydrometallurgical techniques [5-6]. Comparing with the pyrometallurgical processing, the hydrometallurgical method is more exact, more predictable, and more easily controlled [7].

The solutions, obtained by a series of acid or caustic leaches of solid material, are the subject of separation and purification procedures such as precipitation of impurities, solvent extraction, adsorption and ion-exchange to isolate and concentrate the metals of interest.

In recent times, the recovery of metals by biotechnology has been one of the most promising technologies [7-9]. Biometallurgy has been the subject to growing investigations for the last 20

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VAŽNOST PREGLEDA I ODREĐIVANJE PREOSTALOG VEKA TRAJANJA CEVOVODA NA NAFTNOJ PLATFORMI

IMPORTANCE OF INSPECTION AND DETERMINATION OF REMAINING LIFE OF PIPLINE IN OIL PLATFORM

Marko JARIC[1*], Sanja PETRONIC[2], Saša MARKOVIČ[2], Marta TRNINIĆ[2], Suzana POLIĆ[3]

[1] Innovation Centre of the Faculty of Mechanical Engineering in Belgrade, Belgrade
[2] The Academy of Applied Technical Studies Belgrade, Belgrade
[3] National Museum in Belgrade, Belgrade

Naftna platforma je velika građevina sa objektima za bušenje bušotina za istraživanje, vađenje, skladištenje i preradu nafte i prirodnog gasa koji leži u stenovitim formacijama ispod morskog dna. Bušenje na otvorenom moru predstavlja izazove za životnu sredinu. Iako, srećom, nije bilo mnogo nesreća na oil platforms, šteta koja nastane je ogromna i u ljudskom i u materijalnom i u smislu zaštite životne sredine. Iz tog razloga, inspekcija opreme pod pritiskom je od velikog značaja. The risk to the pressure vessel in service can be failure due to material degradation. Jedan od tipičnih mehanizama degradacije materijala je korozija. U ovom radu će biti prikazana važnost inspekcije opreme pod pritiskom. Na konkretnom, praktičnom primeru će biti predstavljena inspekcija pipeline i određivanje corrosion rate i remaining life u cilju sprečavanja otkaza i materijalnih I ljudskih gubitaka.

Ključne reči: *cevovod, ispitivanja bez razaranja, brzina korozije, preostali vek trajanja*

The oil platform is a large structure with facilities for drilling wells for exploration, extraction, storage and refining of oil and natural gas lying in rock formations under the seabed. Offshore drilling poses environmental challenges. Although, fortunately, there have not been many accidents on oil platforms, the damage that occurs is enormous, both in human and material terms, and in terms of environmental protection. For that reason, the inspection of pressure equipment is of great importance. The risk to the pipeline in service can be failure due to material degradation. One of the typical mechanisms of material degradation is corrosion. This paper will present the importance of inspection of pressure equipment. On a concrete, practical example, pipeline inspection and determination of corrosion rate and remaining life will be presented in order to prevent failures and material and human losses.

Key words: *pipline, nondestructive testing, corrosion rate, remaining life*

1 Introduction

Pipelines are the most efficient way of transporting oil, gas, water, chemicals, etc. Today the offshore pipeline system is highly efficient, safe and environmentally friendly because the possibility of pipeline failure is extremely small. However, if a malfunction occurs, it can have a great impact on the environment as well. Most operations in the process industry take place at temperatures and pressures that differ from normal atmospheric conditions. These operations are often dangerous and endanger the environment. These structures have their limitations according to the material of construction, the method of design and construction, maintenance schedule and their age. Any defect or deficiency in these aspects would mean that these structures would not do their role perfectly, and accidents would occur. The mechanical designer must ensure that the construction guarantees reasonable safety for a reasonable period and does not fail despite continuous or moderate difficulties conditions according to its construction structure (1, 2). Although pipelines are one of the safest modes of transport and have failure rates much lower than rail or highway, failures do occur and sometimes

* Corresponding author's email: mjaric@mas.bg.ac.rs

with catastrophic consequences. Traditionally, most the pipeline operators shall ensure that safety provisions are created at the design stage that provides a theoretically minimum failure rate for pipeline life. When choosing pipes and other fittings the safety provisions are taken into account (3). Various techniques are routinely used to monitor pipeline status. Any deterioration of the line can cause leakage or rupture. Existing inspection and maintenance practices typically followed by most pipeline operators are formulated largely based on experience. However, operators are developing an organized maintenance policy based on data analysis and other internal studies to replace the basic guidelines. Risk factors that can cause pipeline failures are the following: corrosion (internal and external corrosion), poor construction and poor quality material, human and operational errors and natural hazards (4,5). Internal corrosion is usually caused by a chemical reaction between piping material and fluids or gases, such as CO_2, H_2S and 0_2. Corrosion takes the form of general or localized loss of metal from the pipe and can cause cracks in the piping material. The corrosion rate depends on the pipe material, the type of product transported through the pipelines and the corrosion inhibitor. The impact of pipeline failure is determined by factors such as economic loss - total reserves, operation/flow, possible product loss, pipeline function, etc.; and environmental and social effects - environmental severity, human severity, leakage rate and affected area. Regular inspection of the pipeline is very important for the proper operation of the pipeline and safety for people and the environment (6,7). In this paper, the inspection of the pipeline will be presented and, the corrosion rate and the remaining life of the pipeline will be determined.

2 Technical data

The equipment technical data and general pipeline data are listed in Table 1 and Table 2, respectively. Figure 1 presents the sketch of the tested pipeline. The pipeline was tested by the following nondestructive methods: visual, liquid penetrant and ultrasonic inspection.

The chemical composition of the pipeline material is listed in Table 3.

Figure 1 presents the sketch of the tested pipeline.

Table 1. Equipment technical data

EQUIPMENT TECHNICAL DATA			
	Material	Design Thickness (mm)	C.A.
Pipe	ST-Steel SA-312-316L	8.74	0.00
Flanges	ST-Steel SA-403WP-316L		
Blind Flanges	ST-Steel SA-182-F316L		
Flexible Hoses	Plastik		
Expansion joints	ST-Steel SA-403WP-316L		
Injection points	ST-Steel SA-403WP-316L		
Insulation	No	Thickness of insulation:	0.00

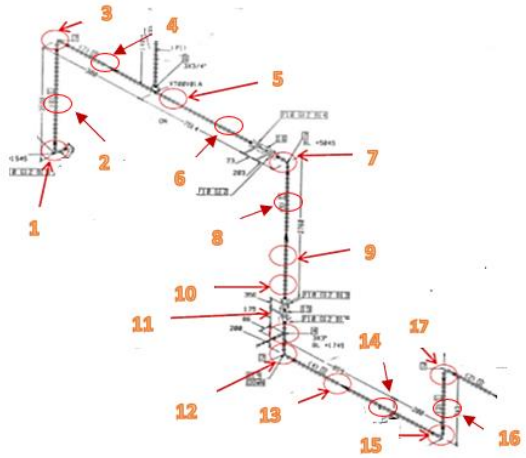

Figure 1. Sketch of tested pipes

Table 2. Pipeline data

GENERAL PIPE/PIPELINE DATA					
Design Code		ASME B 31.3:2016, ASME B16.5:2013			
Inspection Code		API 570:2016, API 574:2016, API 578:2010			
Position in plant	Vertical/Horizontal	Position in relation to the ground	Aboveground/Buried		
Pipe size, DN	65	Nominal thickness	8.74		
Class of pipeline circuit	1	Class of weld joints	A		
Design condition					
Working medium	Liquid/Gas				
Fluid service	M, D, ET, HPr, Hpu, Normal Fluid service				
Minimum pressure, bar	9.78				
Maximum pressure, bar	89				
Minimum temperature, °C	-29.1				
Maximum temperature, °C	100.1				
Operating and test condition					
Operating pressure, barg	9.8	Min. test pressure, barg	89	Max.test pressure	133.5
Operating temperature, °C	55	Min. test temperature, °C	20	Max. test temperature, °C	50

Table 3 Chemical composition of ST-Steel SA-312-316L

Composition	C	Si	Mn	P	S	Cr	Ni	Mo	N
Percentage %	0.08	0.75	2.0	0.045	0.03	16-18	10-14	2-3	0.1

3 Nondestructive testing of pipeline

The periodic inspection of the aboveground pipeline included the following: visual control, liquid penetrate testing and ultrasonic testing. Figure 1 presents pipelines at the oil platform.

Figure 2. Pipelines at the oil platform

After a detailed inspection, it was concluded that the pipeline was in satisfactory condition. Corrosion on the external pipeline was not found. The foundations and supports of the pipe were in good condition. Concrete supports, steel supports of the pipeline and contact points of the pipeline at supports were visually in good condition and corrosion at the contact points on this pipe was not noticed.

The inspection included the soil to an air interface of the pipeline as well. It was in good condition and, corrosion on this pipeline at the soil to air interface has not occurred. Corrosion on this pipeline was not found also 30 cm upwards above this interface and 10 cm down under this interface.

Nozzles, dead legs and pipe caps were found in good condition and, corrosion is not found.

All fittings (elbows, T-joints, reducers) and valves attached to the pipeline were visually in good condition. Weld joints and protective coatings were in satisfactory condition.

The Interior of the pipe was in satisfactory condition.

All of the essential sections/components of the pipe are safe to operate until the next inspection.

Figure 3 presents the results of external visual testing.

Figure 3. Visual testing of external sides of the pipeline. Pipelines are in good condition.

4 Corrosion rate and remaining life

The corrosion rate is calculated according to ASME [8] in two ways: long time corrosion rate and short time corrosion rate according to the following equations:

$$\text{Corrosion rate (LT)} = t_{initial} - t_{actual} \text{ /time between } t_{initial} \text{ and } t_{actual} \text{ (years)} \quad (1)$$

$$\text{Corrosion rate (ST)} = (t_{previous} - t_{actual}) \text{/time between } t_{previous} \text{ and } t_{actual} \text{ (years)} \quad (2)$$

According to API 574, section 12 [9], the required thickness is calculated from the following formula:

$$t_{required} = P*D/(2*S*E) \quad (3)$$

where $t_{required}$ is required thickness in mm,

P is the internal design gauge pressure of the pipe in MPa,

S is the allowable unit stress at the design temperature in MPa [8],

E is the longitudinal quality factor [8].

The initial thickness was 8.74 mm and required thickness is 3.7 mm.

The wall thickness of the pipeline was measured at 17 points designed in Figure 1. The wall thickness was measured in 2004, 2018 and 2021.

According to equitation (1) and (2), corrosion rate (ST=14) is 0.14 mm/yr, corrosion rate (ST=3) is 0.33 mm/yr and corrosion rate (ST=17) is 0.13 mm/yr.

The remaining life of the piping (in years) shall be calculated from the following formula [9-11]:

$$\text{Remaining life} = t_{actual} - t_{required} / \text{corrosion rate} \quad (4)$$

Where t_{actual} is the actual thickness of a CML, in in. (mm), measured during the most recent inspection;

$t_{required}$ is the required thickness at the same CML or component, in in. (mm), as the tactual measurement. It is computed by the design formulas (e.g. pressure and structural) and does not include corrosion allowance or manufacturer's tolerances. [9]

Replacing obtained results in equation (4) remaining life for the pipeline is 15.27 years.

As per Plant Inspection Philosophy maximum interval is 2.5 years for PSV inspection which should be done by the Vendor or at specialist repair workshop approved by the Company according to [12, 13].

5 Conclusion

The paper presents the inspection of pipelines on the oil platform. Although nowadays pipelines are the safest mode of fluids transport, the smallest failure can cause great material and environmental damage. For this reason, pipeline inspection is of utmost importance. The principle of inspection is presented, what everything should include and, the results are presented. Also, the long time corrosion rate and short time corrosion rate were calculated and based on the highest value, the remaining life of the inspected pipeline is 15.27 years.

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KOROZIONA OTPORNOST 1.4713 VATROSTALNOG FERITNOG ČELIKA U 0.5M NITRATNOJ KISELINI

CORROSION RESISTANCE OF 1.4713 FERRITIC HEAT-RESISTANT STEEL IN 0.5M NITRIC ACID

Stevan P. DIMITRIJEVIĆ[1*], Dimitrije STEVANOVIĆ[2], Silvana B.DIMITRIJEVIĆ[3], Aleksandra IVANOVIĆ[3], Zara CHERKEZOVA-ZHELEVA[4], Željko KAMBEROVIĆ[5]

[1] Innovation Center of TMF Belgrade, University of Belgrade

[2] TEKON – Tehnokonsalting d.o.o. Belgrade

[3] Mining and Metallurgy Institute Bor

[4] Institute of Catalysis, Bulgarian Academy of Sciences, Sofia, Bulgaria

[5] Faculty of Technology and Metallurgy, University of Belgrade

U ovom radu su predstavljena eksperimentalna istraživanja korozionog ponašanja i otpornosti feritnog (EN 1.4713/X10CrAlSi7) čelika u azotnoj kiselini koncentracije 0,50 mol·dm^{-3}. Korozione karakteristike ovog čelika ispitane su sledećim elektrohemijskim metodama: potencijal otvorenog kola (POK), ekstrapolacija polarizacione krive u Tafelovom regionu i metoda linearnog polarizacionog otpora (LPO). Pored toga, korišćena je metoda gubitka mase (u trajanju od 10 dana) i upoređena je sa metodama polarizacije. Rezultati merenja pokazali su izvrsno međusobno slaganje elektrohemijskih metoda, sa razlikama u određenoj korozionoj struji u okviru ± 10%. Metoda gubitka mase pokazala je oko polovine vrednosti brzine korozije u odnosu na ove elektrohemijske metode. Iako izgleda kao značajna razlika, može se smatrati dobrim rezultatom, jer je to uobičajena razlika između ovih metoda; jer one određuju brzinu korozije u različito vreme izlaganja uzoraka u korozivnom okruženju. Opšti zaključak je da ispitivani nerđajući čelik otporan na visoke temperature ne pruža visoku otpornost na koroziju u 0,5M rastvoru azotne kiseline. Ovo istraživanje je izvedeno uzimajući u obzir procenu pogodnosti materijala za opremu za obnovljive izvore energije, poput baklji za odlagalište gasa (LGF) i dodatnu opremu tog sistema. Iako čelik 1.4713 ima dobre mehaničke i toplotne karakteristike, za upotrebu u takvim radnim uslovima potrebna je dodatna zaštita od korozije.

Ključne reči: *feritni čelilk; nitratna kiselina; korozija; baklja deponijskog gasa.*

Experimental research of corrosion behavior and resistance of ferritic (EN 1.4713/X10CrAlSi7) steel in nitric acid with the concentration of 0.50 mol·dm^{-3} is presented in this paper. The corrosion characteristics of the steel were tested using the following electrochemical methods: open circuit potential (OCP), extrapolation of the polarization curve in the Tafel region, and linear polarization resistance (LPR). Additionally, the weight-loss method (with a duration of 10 days) was used and compared with the polarization methods. The measurement results have shown excellent agreement between electrochemical methods with the differences in determining corrosion current within ±10%. Although it looks like a significant difference, it can be considered a good result since that is the usual difference between these methods because they determine the corrosion rates at different times of the samples exposal in corrosion environment. The general conclusion is that examined heat-resistant stainless steel does not provide high corrosion resistance in the 0.5M nitric acid. This research was performed considering assessing the suitability of the material for renewable energy equipment like landfill gas flares (LGF) and additional equipment for that system. Although the 1.4713 steel has good mechanical and thermal characteristics, it requires additional corrosion protection for use in such working conditions.

Key words: *Ferritic steel; Nitric Acid; Corrosion; Landfill gas flare.*

[*] Corresponding author's email: stevad@gmail.com

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