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Internal Corrosion Rate Of Api 5l X-42 Steel In Crude Oil Production Installation Pipe

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ABSTRACT

Steel pipes remain the preferred choice for distribution and crude oil installation pipes in the oil and gas industry due to their strength, surface hardness, and cost-effectiveness. However, their susceptibility to corrosion in harsh environments poses significant challenges. This research focuses on analyzing the corrosion rate of API 5L X-42 steel in a crude oil environment at a temperature of 40°C. The corrosion rate was determined using the weight loss method, revealing that the rate varies over time. The findings of this study provide crucial insights for the industry, particularly in preventing leaks in crude oil installation pipes caused by corrosion. By understanding the corrosion behavior of steel pipes under specific conditions, the oil and gas industry can implement more effective maintenance strategies and material selection, ultimately enhancing the safety and longevity of pipeline infrastructure. The study highlights the importance of regular monitoring and the adoption of preventive measures to mitigate corrosion-related issues, thereby ensuring the continuous and safe operation of oil and gas installations.

Keywords: Corrosion Rate; Corrosive Environment; Crude Oil; Steel Pipe

INTRODUCTION

Corrosion is an important problem in oil and gas production and transportation systems, causing significant economic losses. Corrosion in the oil and gas industry, which occurs from the exploration process on offshore rigs to production at refineries, has caused losses of billions of dollars a year (Hamied, Alhassan, and Al-Bidry, 2018:155).Construction equipment made of metal is highly susceptible to various corrosion phenomena, causing 65-85% of corrosion incidents in the oil and gas industry. This is triggered bycontaining environmentaggressive substances, as well as operating processes with varying temperature and pressure ranges. These conditions place oil and gas factories as work areas with a high level of danger, because they are prone to fires, explosions, the presence of toxic substances that are dangerous to human health and environmental damage (Groysman, 2017: 100).

Currently, components made from alloys based on carbon steel are still widely used for oil and gas extraction processes. Although there are efforts to switch to metal alloys that are more corrosion resistant, this is very expensive. Therefore it needs to be donea comprehensive review of corrosion problems in oil and gas production(Popoola, et al, 2013:1). On the other handThe oil and gas industry is required to produce quality oil and gas, reduce environmental pollution, and use equipment construction and operation safely.

The problem of corrosion is a challenge for the entire oil and gas industry in the world and must be addressed seriously. Corrosion problems occur in the fields of: production, transportation and storage, as well as refinery operations (Prabha et al, 2014:300). As an anticipatory step towards corrosion problems, corrosion analysis of materials used as main components in industry is requiredthe oil and gas. Based on this, the aim of this research is to obtain corrosion rate analysis data from API 5L X-42 steel which is used as a crude oil production installation pipe inoperating temperature 40 oC.

Internal corrosion caused by fluids is the most detrimental corrosion problem in the oil and gas industry, because internal mitigation methods cannot be easily applied (Perez. 2013: 1034). One of the forms of corrosion that occurs in the oil and gas industry is when metal equipment or piping installations come into contact with a watery environment. When a metal is exposed to a corrosive solution (electrolyte), the metal atom at the anode location will lose electrons, and these electrons are absorbed by other metal atoms at the cathode location. The cathode, which is in contact with the anode through the electrolyte, carries out this exchange in an attempt to balance its positive and negative charges. Positively charged ions are released into the electrolyte and bond with other groups of negatively charged atoms (Popoola et al, 2013:3). The anodic reaction for iron and steel is:

$$Fe \rightarrow Fe2+ + 2e-$$

After the metal atom at the anode location releases electrons, there are four cathode reactions, namely:

$O2 + 4H+ + 4e- \rightarrow 2H2O$ (reduction of oxygen in acid solutions)
½ $O2 + H2O + 2e- \rightarrow 2OH-$ (reduction of oxygen in neutral or basic solutions)
$2H+ + 2e- \rightarrow H2$ (evolution of hydrogen from acid solution)
$2H2O + 2e- \rightarrow H2 + 2OH-$ (evolution of hydrogen from neutral water)

In the oil and gas industry, the environment generally contains carbon dioxide (CO2) and hydrogen sulfide (H2S), as well as water as a corrosion catalyst. When water combines with CO2 and H2S, the environment forms as follows:

H2CO3 reaction: $Fe + H2CO3 \rightarrow FeCO3 + H2$
H2S reaction: $Fe + H2S + H2O \rightarrow FeS + 2H$

It is possible that a combination of the two reactions above will occur if both gases are present. These resulting molecules stick to the cathode or are released into the electrolyte and the corrosion process continues. Therefore, the oil and gas environment which is dominated by CO2 and H2S gas is the main cause of degradation of metal materials (Calderon et al, 2022: 1; Asmara, 2018: 37).

It is a big challenge to classify the types of corrosion in the oil and gas industry. However, corrosion can be grouped based on the appearance of material surface damage due to corrosion and the mechanism of attack. Corrosion mechanisms that occur in piping systems vary according to fluid composition, service location, geometry, temperature and pressure. In the oil and gas production industry, the main forms of corrosion include: sweet corrosion, sour corrosion, galvanic corrosion, crevice corrosion, erosion corrosion, microbiologically caused corrosion, and stress crack corrosion.

The corrosion process that occurs at the interface of metal and solution causes the metal to experience a change in mass. The methodology for measuring the corrosion rate from immersion test experiments can be carried out using the weight loss method. The corrosion rate calculation used is:

$$Cr = \frac{k.m_{loss}}{A.t\,.\rho}\ mmpy$$

Where k is the constant 8.76 x 104, mloss is the metal mass loss in grams, during time t, in hours, A is the surface area of the material in contact with the solution, in cm2, and ρ is the density of the material, in g/cm3. (Malaret, 2022: 2). The corrosion rate provides an illustration of the decline in the quality of the pipe material used over time. The level of resistance of a material to corrosion is shown in Table 3.

Table 3. Corrosion Resistance Level Based on Corrosion Rate

Corrosion Resistance	***Equivalent Metrics***			
	mpy	***mmm*/year**	**µm/yr**	**nm/yr**
Outstanding	< 1	< 0.02	< 25	< 2
Excellent	1-5	0.02-0.1	25-1000	2-10
Good	5-20	0.1-0.5	100-500	10-50
Fair	20-50	0.5-1	500-1000	50-100
Poor	50-200	42125	1000-5000	150-500
Unacceptable	200+	5+	5000+	500+

(Source: Afandi et al, 2015:2)

METHOD

Research on the rate of internal corrosion in crude oil production installation pipes was carried out using the weight loss method. The test specimen is API 5L X-42 steel, with the chemical composition as shown in Table 1.

Table 1. Chemical Composition of API 5L X-42 Steel (wt %)

Fe	C	Si	Mn	P	S	V	Nb	Ti
Bal	0.24	0.4	1.2	0.025	0.015	c	c	0.04

The corrosion process is carried out by immersion methodconforms to ASTM G31-72, incrude oil solutionfrom PT. Kilang Pertamina Internasional RU. II Pakning River, Riau Province, with specificationsas shown in Table 2.

Table 2. Physical properties of Duri Crude Oil

Characteristics	Mark
API Gravity at 60o	20.0 o F
Pour points	18 oC
Mercury content	8,214 ppb
Sulfur content	2081.3 ppm
TAN	2.1 mg KOH/g
Flash Points	68 O.C
Kinematic viscosity 50 o	201.6 Cst
Salt content	4.6 ptb
BS and W	0.60 % Vol

(Source: PT. Pertamina RU II Laboratory. Production Sungai Pakning)

Before testing, the test specimen in the form of a pipe is first cut into coupons measuring 20x10x2 mm. The surface of the test specimen was then leveled and smoothed using sand paper sequentially with grades 1000 and 1500. Testing was carried out by placing the test specimen in a Pyrex Beaker Glass containing 250 ml of crude oil. During soaking, the solution temperature was maintained at a constant 400C using a Hot Plate Stirrer: Favorit, model HS070V2. Testing was carried out with four time variations (phases), namely: 144 hours, 216 hours, 288 hours and 360 hours. Each testing phase uses three test specimens. To obtain data on weight loss of test specimens, weighing was carried out before and after immersion, using a Kern–German digital scale, model ADB 200-4.

RESULT AND DISCUSSION

The results of measuring the corrosion rate of crude oil installation pipes at oil refineries are shown in Figure 1.

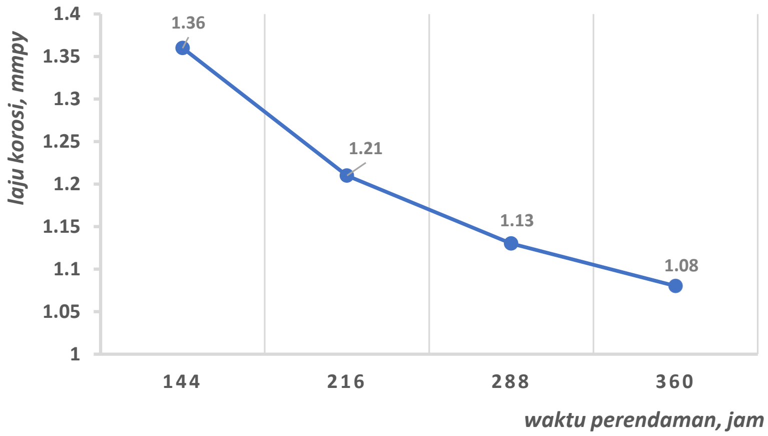

Figure 1. Graph of Corrosion Rate of API 5L X-42 Steel in Crude Oil

From the graph it can be seen that corrosion testing is carried out in four stages. In the first stage with an immersion time span of 144 hours, the test specimen experienced a corrosion rate of 1.36 mmpy, then in the second to fourth stages with an immersion time span of 216, 288 and 360 hours respectively, the corrosion rate occurred in the test specimen respectively 1.21 mmpy, 1.13 mmpy and 1.08 mmpy.

An overview of the condition of the surface of the corroded specimen from the test results at each immersion time is shown in Figure 2.

(a) (b) (c) (d)

Figure 2. Corroded Specimen Surface Test Results:
(a) 144 hours, (b) 216 hours, (c) 288 hours, (d) 360 hours

At the initial immersion for 144 hours, the test specimen experienced a relatively high corrosion rate, namely 1.36 mmpy. The specimen appears to have experienced corrosion evenly on its surface. This indicates that the corrosion reaction took place on almost all surfaces of the specimen, with a weight loss of 0.03 grams. Furthermore, after immersion for 216 hours, although the corrosion rate was 1.21 mmpy, the level of damage to the surface of the specimen was deeper. This phenomenon indicates that the corrosion reaction occurs on a smaller surface area, so that the surface damage to the specimen becomes deeper. This is supported by data on weight loss of 0.04 grams. Next, after soaking for 288 hours, the corrosion rate was lower, namely 1.13 mmpy, but the damage to the surface of the specimen was wider and some were deeper, with a loss of specimen weight of 0.05 grams. This phenomenon indicates that the corrosion reaction was initially even, but in some parts it became deeper. Furthermore, immersion was carried out for 288 hours, resulting in a corrosion rate of 1.08 mmpy. Even though the corrosion rate was lower, the level of surface damage to the specimen was more severe, where a weight loss of 0.06 grams occurred. This phenomenon also indicates that the corrosion reaction initially occurred evenly, then in certain parts local corrosion occurred which resulted in the surface of the specimen experiencing deeper damage.

Based on analysis of the corrosion rate, it is known that immersion for up to 144 hours, the corrosion rate that occurs is relatively high, namely 1.36 mmpy. However, by immersion for 216 hours, or the next 72 hours, the corrosion rate decreased to 1.21 mpy or 0.15 mmpy lower than before. Likewise, by soaking for the next 288 hours or 72 hours, the corrosion rate decreased to 1.13 mpy or 0.08 mmpy lower than before. The same thing also happened with immersion for the next 360 hours or 72 hours, the corrosion rate decreased to 1.08 mpy or 0.05 mmpy lower than before. This data shows that the longer the test specimen is soaked in the solution, the corrosion rate decreases.

This decrease in the corrosion rate is caused by the fact that during the initial immersion process, some of the corrosion products will enter the solution and some will settle on the surface of the test specimen (Hou et al., 2016: 10). The deposited corrosion products will form a thin protective layer on the surface of the test specimen, which inhibits interaction between the surface of the test specimen and the solution, thus slowing down the subsequent corrosion process (Zhang et al, 2022: 378; Asmara, 2018: 41).

Based on corrosion rate data obtained from testing for 144 hours, namely 1.36 mmpy, and referring to the level of material resistance to corrosion, it can be stated that the corrosion resistance of API 5L X-42 steel is included in the poor category.

CONCLUSION

The results of the tests carried out show that API 5L X-42 steel is very susceptible to corrosion in a crude oil solution at a temperature of 40 oC. In just 144 hours, the steel surface that came into contact with the solution was already quite badly damaged. Thus, we must think about how to control the corrosion that occurs so that the steel pipe can be used for a relatively long period of time without causing failure.

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