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Article

Reliability Study of Oil and Gas Pipelines Using the Normal Distribution Method

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Nendi Suhendi Syafei[1*], Darmawan Hidayat[2], Nanang Rohadi[2], Khafsah Joebaedi[3], Eddy Supriyana[4]

[1]Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Bandung, Indonesia
[2]Department of Electrical Engineering, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Bandung, Indonesia
[3]Department of Mathematics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Bandung, Indonesia
[4]Department of Geophysics, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Bandung, Indonesia

Abstract. Gas and oil pipelines have decreased function and damaged due to corrosion. This research aims to analyze and predict the life of gas and oil pipelines within a certain time span. The method used is a reliability study using a normal distribution. The analysis results show it is predicted that the pipe reliability probability in 2030 will decrease and the probability of failure will increase. The probability of reliability is 0.843572786617270 and the probability of failure is 0.156427213382730 in 2030. With the long distance pipeline, maximum depth as shown in the attachment the average thick remain is 0.2200 inches, the average corrotion rate is 0.0317 mm/year, with prediction thick remain from 2000 to 2030 in inches.

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Corresponding Author :
Nendi Suhendi Syafei
Departement of Electrical Engineering, Faculty of Mathematics and Natural Sciences, Universitas Padjadjaran, Bandung, Indonesia
Email : n.suhendi@unpad.ac.id

1. Introduction

Gas and oil pipelines will experience a decline in function based on service life. This process is decisive and can have serious consequences if damage and leakage occurs. The pipe age should be assessed taking into account the damage factor, age and interactions in the environment. However, the speciic studies to analyze the age of gas and oil pipelines have not been widely studied[1-2].

Damage to pipes can be analyzed mathematically. A mathematical approach with various equations can predict changes in the inner and outer surface of the pipe, so that the damage estimate can be predicted properly and accurately. In this research, it is analyzed and carried out a mathematical study related to the reliability of pipe age from pipe changes and the mathematical assumptions developed. The approach taken is the normal distribution of the data presented. At the start of operation the equipment is still relatively safe and reliable to operate, but over time operation, the equipment integrity will decrease due to degradation of material [3-7].

In the presence of corrosion, it is very important to analyze the residual reliability of the gas and oil pipelines [8-9]. This is related to how many possibilities the pipe can be used and function properly and safely. In the implementation of the industrial world, especially oil and natural gas, the ability to measure the durability of pipes is the key in determining how industrial management can run well. If the worst condition results in a leak, it will have an impact on the sustainability of the industry. This will result in financial losses and infrastructure damage that could completely halt oil and gas production. This is of course driven by the amount of loss that can be caused by the failure of a tool or channel due to corrosion. [10] The calculation of pipe reliability also needs to pay attention to the impact of corrosion because most accidents on oil and gas pipes are caused by internal and external corrosion[11-12]

In the submarine pipeline network, which is the trend of the safest and most reliable transportation of oil and gas transportation, the aspect of calculating pipe life must always be considered. However, in its use, the pipe is very vulnerable to damage so that it can pose a very big risk. This damage can come from internal or external influences. [13] Reliability analysis is an analysis of the likelihood that a product or service will operate well for a certain period of time under operating conditions without failure [14].

Reliability is the ability of a product or item needed to maintain the system for a certain period of time in operating conditions [15]. The reliability of the extrusion system is 0.00436 or 0.436% at t = 100 hours, meaning that at time t = 100 hours the system operates according to its function of 0.436%, the rest of the system is in shutdown or failure to function operates [16-23].

However, preventive measures to maintain the life of gas and oil pipelines from corrosion remain the main strategy. These include injection of corrosion inhibitors, rehebilitation systems, cathodic protection and better maintenance. This effort is an isolated part of the effort to extend the life of gas and oil pipelines, so that the prediction of life and pipeline damage can be extended and addressed in field implementation. The normal distribution method can be effective, because the reduction in thickness of gas and oil pipes due to corrosion is slow and simultaneous. This research aims to analyze and predict the age of gas and oil pipes using the normal distribution method.

2. Method

This study uses a mathematical modeling method, by determining the normal distribution of changes that occur in gas and oil pipelines. There are several models that complement this study, namely serial configuration, parallel configuration, combination configuration and normal distribution. The stages of this research can be seen from the schematic in Figure 1.

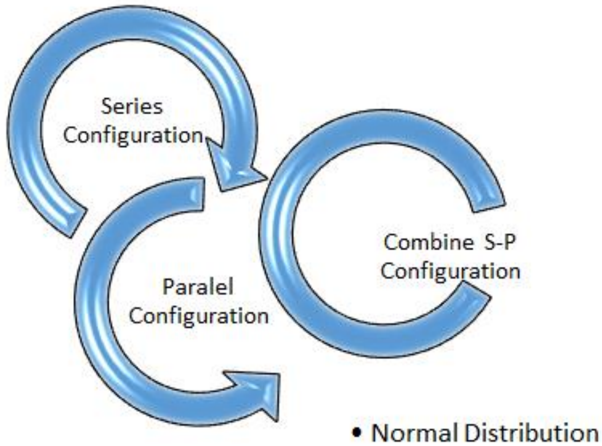

Figure 1. Schematic diagram of research

The series configuration will follow the following pattern :
$R_s(t) = R_1(t)xR_2(t)x \dots . xR_n(t) \leq \{R_1(t), R_2(t), \dots R_n(t)\}$........(1)
The inequality results from $0 < R_i(t) < 1, i = 1,2, \dots ., n$, and multiplication.
If each component has a constant failure rate, tehe system reliability is given :
$R_s(t) = \prod_{i-1}^{n} R_i\,(t)$ ....(2)

In parallel configuration it will follow the following formula:

Generalizing, $R_p(t) = 1 - \prod_{i=1}^{n}[1 - R_i(t)]$ ....(3)

It is always true that $R_p(t) \geq \{R_1(t), R_1(t), \dots \dots ., R_n(t)\}$

Since $\prod_{i=1}^{n}[1 - R_i(t)]$ must be less than the failure probability of the most reliable component.[1]

The combination formula will be applied as follows:

$$\boldsymbol{R_A = [1 - (1 - R_1)(1 - R_2)]\ dengan\ R_B = R_A(R_3)\ danR_C = R_4(R_5)}$$

Since RA and RC are in parallel with one another and inseries with R6,

$$\boldsymbol{R_i(t) = [1 - (1 - R_B)(1 - R_C)](R_6)}$$

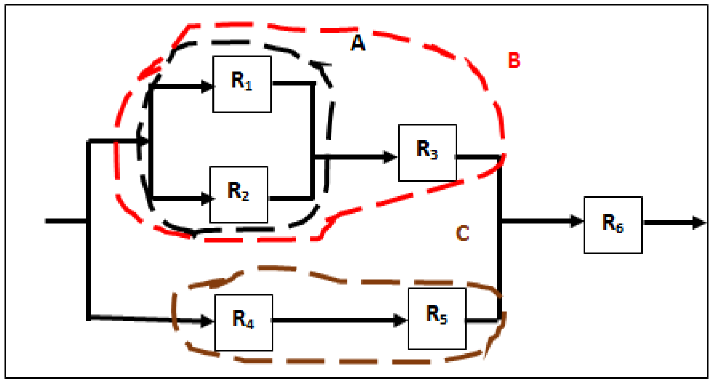

Figure 2. Interaction combination patterns

Approach to Normal Distribution

The probability distribution failure of the normal distribution is :

$$f(t) = \frac{1}{\sqrt{2\pi\sigma}} exp\left[-\frac{(t-\mu)^2}{2\sigma^2}\right], -\sim < t < \sim \text{ ....(4)}$$

The normal cumulative distribution failure is :

$$F(t) = \int_{\sim}^{t} \frac{1}{\sqrt{2\pi\sigma}}\ exp\left[-\frac{(t-\mu)^2}{2\sigma^2}\right], -\sim < t < \sim \text{ ....(5)}$$

Where the mean and the variance are:

$$E(T) = \mu \text{ and } Var(t) = \sigma^2 \text{ ....(6)}$$

The probability Reliability function is :

$$R(t) = \int_{\sim}^{t} f(t)dt \text{ ....(7)}$$

When μ = 0 and σ = 1, the normal distribution is called the standard normal distribution. Then the probability distribution failure becomes :

$$\phi(z) = \frac{1}{\sqrt{2\pi}} exp\left(-\frac{z^2}{2}\right), -\sim < z < \sim \text{ ....(8)}$$

The cumulative distribution failure of the standard normal distribution is :

$$\phi(z) = \frac{1}{\sqrt{2\pi}} exp\left(-\frac{v^2}{2}\right), -\sim < z < \sim \text{ ....(9)}$$

ϕ(z) is tabulated in, for example, Lewis (1987) and Nelson (1990, 2004). Many commercial software packages such as Minitab and Microsoft Excel are capable of doing the calculation. With the convenience of (z), (7) can be written as:

$$R(t) = \phi\left(\frac{t-\mu}{\sigma}\right) \text{ ....(10)}$$

$$F(t) = 1 - \phi\left(\frac{t-\mu}{\sigma}\right) \text{ ....(11)}$$

The normal distribution has an important property frequently utilized in reliability design. If X1, X2,...,Xn are independent random variables and normally distributed with (μi, σ2 i) for i = 1, 2,...,n, then X = X1 + X2 +···+ Xn has a normal distribution with mean and variance[3] :

$$\mu = \sum_{i=1}^{n} \mu_i \quad and\ \sigma^2 = \sum_{i=1}^{n} {\sigma_i}^2$$

Reliability Block Diagram is an approach that can be used to calculate the overall system reliability.

3. Results and Discussion

From the implementation of the model and mathematical calculations carried out on the age of gas and oil pipelines, as shown in Table 1, an increase in the decrease in the thickness of gas and oil pipes will increase with increasing usage over a span of 30 years. Measurements are carried out from 2000 to 2030, with an initial thickness prediction of 0.2101 inch. These changes can then be observed and experience significant changes in 2030, with an impact on the failure of the function of gas and oil pipelines as a means of transportation for gas and oil. This is a note for the petroleum industry and the development of oil and gas transportation in implementation in the field.

Table 1. Decrease the change in pipe thickness from the calculation under normal distribution

Year	Prediction Thick Remain (inchs)	Reliability	Probability of Failure	Parameter Reliability (Beta)
2000		1.000000000000000	0.000000000000000	13.24
2008	0.2101	1.000000000000000	0.000000000000000	10.21
2010	0.2076	1.000000000000000	0.000000000000000	9.48
2012	0.2051	1.000000000000000	0.000000000000000	8.76
2014	0.2026	1.000000000000000	0.000000000000069	8.07
2016	0.2001	0.999999999999931	0.000000000007676	7.40
2018	0.1976	0.999999999992324	0.000000000508783	6.74
2020	0.1951	0.999999999491217	0.000000021990352	6.11
2022	0.1926	0.999999978009648	0.000000695348172	5.47
2024	0.1901	0.999999304651828	0.000000695348172	4.83
2026	0.1876	0.999980312621146	0.000019687378854	4.11
2028	0.1851	0.999172015327711	0.000827984672289	3.15
2030	0.1826	0.843572786617270	0.156427213382730	1.01

From the results of this modeling, it can be seen that the corrosion rate that occurs is 0.0317 mm/year. At this rate, this change will have an impact on the life of the pipe in the field, in particular by increasing the friction between the electrolyte in the sea and the outside of the pipe. However, changes of course occur not only on the outside of the pipe, but also on the inside of the pipe as a consequence of the molecular collision of hydrogen gas molecules in the transport of gas, and collisions between oil molecules and the inside of the pipe. Both external and internal corrosion will cause shrinkage of the pipe thickness each year reaching 0.0317 mm.

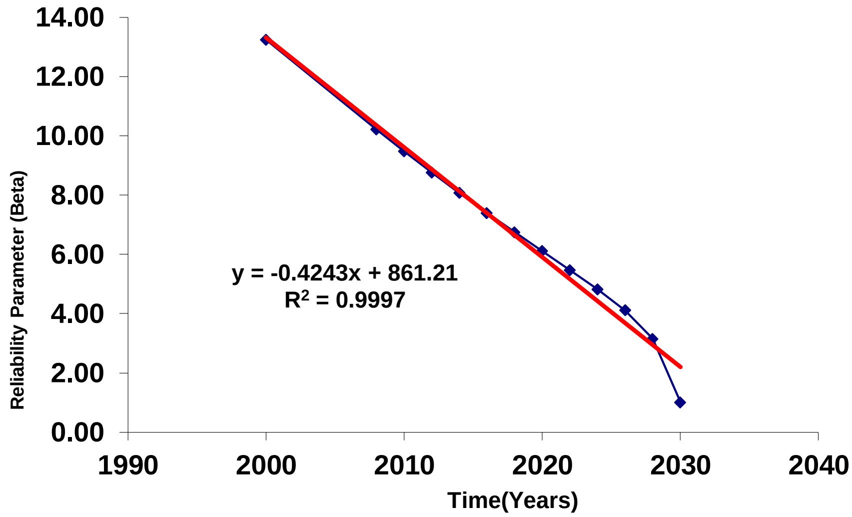

Figure 3. Parameter reliability (beta) to time (years).

The reliability parameter, which was calculated over the span of 30 years, shows a decrease with a quadratic regression rate of 0.9997 (minus). This figure shows a significant decrease in reliability based on the increase in time from year to year. In 2000, the reliability level reached 13.24 according to the mathematical equation shown in Figure 3. In the figure, it can be seen that the decline will continue to occur and in 2030 it will experience a very low lift, namely 1.01. The decrease in reliability will be the probability of failure of the pipeline function after 30 years to become large, as a consequence of the thinning thickness of the gas and oil pipes.

This decrease occurs due to corrosion of pipes in the ocean, electrolyte contact with the outer surface of the pipe, causing increased cathodic corrosion. Cathodic protection can be done to reduce the impact of thinning the outer layer of gas and oil pipelines. But protection with cathodic protection, of course, will cause huge costs if applied to submarine pipes. On the other hand, cathodic protection also causes maintenance costs and the maintenance process is quite difficult with the length of the pipe that is stretched during the transportation of oil and gas. Therefore, the depletion factor and the potential for failure are important points in projecting economic calculations for the underwater gas and oil pipeline installation systems.

An alternative with a protection system to reduce the rate of pipe thinning can be done by injection of a corrosion inhibitor. This protection aims to increase the life of the pipe and reduce the probability of failure of gas and oil pipes based on the age of the pipes. With the existence of systematic corrosion prevention efforts can improve the function of pipes in the long run. In Figure 5, it can be seen that in 2030, the reliability of the pipe reached a significant decline from 1.01 to 0.84. This significant and sharp decrease was due to the failure of the pipe thickness to be maintained due to corrosion, resulting in malfunctioning as a transporter for gas and oil in the submarine pipeline system.

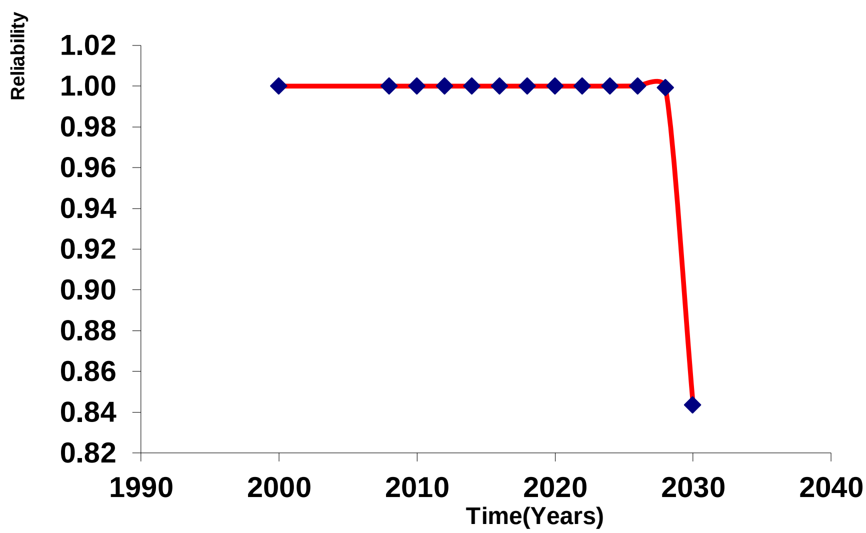

Figure 4. Reliability to time (years).

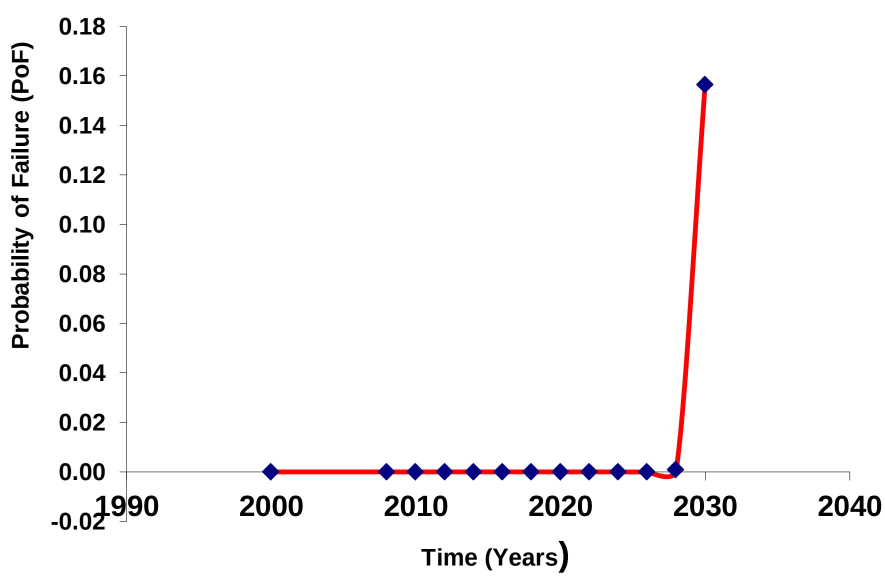

Figure 5. Probability of failure to time (years).

Based on Figure 5, it can be seen that the failure of the oil and gas transportation system using pipelines has started to occur when entering 2030. In that year, the probability of failure has increased significantly from 0.00 to 0.16. The increase in the failure rate is the end point of the security system that must be considered and become a reference in making policies in the oil and natural gas industry. This is a valuable input for the development of a gas and oil transportation system in the underwater pipeline. With this analysis, the process of maintaining and developing the gas and petroleum transportation system through the underwater pipeline system will run carefully. This is related to the consideration of costs and calculation of damage and the probability of system failure in a systematic manner.

4. Conclusion

The life of gas and oil pipelines can be predicted using mathematical modeling with equations in either series configuration, parallel configuration or a combination of both. Based on mathematical analysis in a normal distribution, it can be estimated that the rate of damage to gas and oil pipelines with reference to the corrosion speed of 0.0217 mm/year, so that the value of pipe damage is obtained in 2030.Modeling is carried out from 2000 to 2030, with the maximum achievement of damage in 2030. In 2030, there is a remaining pipe thickness of 0.1826 inches and a beta reliability level of 1.01.

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