Risk Analysis of Central Java Gas Transmission Pipeline by Risk-Based Inspection Method

Mediansyah¹, G D Haryadi¹, R Ismail¹ and S J Kim²

¹Department of Mechanical Engineering, Diponegoro University, Jl. Prof. Soedharto, Tembalang, Semarang 50275, Indonesia
²Department of Mechanical and Automotive Engineering, Pukyong National University, Busan, 608-739, Korea

Email: mediansyah@rocketmail.com

Abstract. During the operational period of gas transmission pipeline was found a potential hazard that could result in pipeline failure. As a consequence, the problem of the pipeline failure happening more and more. Economic and environmental factors, as well as human life, be considered to involve the current challenges as structural integrity and safety standards. Therefore, the reliability of structural integrity and security of gas pipelines under various conditions, including the existence of defects should be carefully evaluated. The results of this study were the steps for setting a Risk Level on any instrument using the Risk-Based Inspection API 581 standard and the subsequent results are recommended as an effective inspection planning by Risk Level and Remaining Life Time.

Keywords: Pipe, risk, risk level, risk-based inspection, remaining life time.

1. Introduction

Oil and gas sector is an activity that has the potential hazards of high risks, capital-intensive, high-tech, as well as requiring human resources with competence and specific qualifications. The activities in this sector should constantly be monitored so as not to cause significant harm, either to workers, the public, property or the environment [1].

Natural gas is a clean fuel that has been used by many countries as fuel for power generation. This trend makes the supply of natural gas will be increasingly in demand. One crucial thing is the distribution of natural gas transportation system. Duct piping is one method that is most practical and affordable that has been applied in oil and gas transportation system since 1950. The pipe has been used as one method that is most practical and needs the lowest cost for oil and gas transportation. Installations of pipes for oil and gas transmissions increased dramatically in the past three decades [2].

Pipe is a technology that is used to drain fluid such as oil, gas or water in large amounts and long distances by sea and specific regions. The pipeline is a silent mean of transport that serves to distribute the fluid in the form of liquid or gas [3] that is widely used to transmit fluids in oil and gas industry. Its use is quite diverse, among others, used to channel the fluid from the wells to the treatment plant or offshore building (offshore facility) or of offshore platforms built directly on the land (onshore facility) [4].
The Risk Based Inspection (RBI) is a practical way to assess the possible application of the inspection process and the impact that can occur on an instrument failure, evaluate the level of risk and recommend the type of action taken for the development of preventive measures and risk management. Risk Based Inspection (RBI) using a risk to plan and assist in the assessment of the results of the inspection, testing and monitoring [3]. The advantages of such RBI method are the increasing operational time and the work of a processing facility, which at the same time there is an increase or absence of treatment at the same risk level. The Concept of Risk Based Inspection can be seen in figure 1.

The results of this study are expected to be useful for damage prevention measures, especially in terms of materials and the development of material sciences in addition to the complete simulation data checks based on risk known as Risk Based Inspection (RBI).

2. Experimental Method

2.1 Corrosion

The piping system is a part of the most sensitive structural element of the power plant. Therefore, this system analysis and quantification of their vulnerability regarding failure probability are essential [4]. Corrosion is defined as damage to the material that results from their chemical reaction with the surrounding environment of the material. In the event of corrosion, metal would undergo oxidation, while the oxygen (air) is reduced. Metal rust is usually in the form of oxides or carbonates. The chemical formula of iron rust is $\text{Fe}_2\text{O}_3\cdot n\text{H}_2\text{O}$, a brown-colored solid red. Corrosion is an electrochemical process. In the iron corrosion, certain sections of the metal act as the anode, where the metal undergoes oxidation.

$$\text{Fe}(s) \rightleftharpoons \text{Fe}^{2+}(\text{aq}) + 2\text{e}$$

(1)

Electrons are released in the anode flow to other parts of the iron which act as the cathode, where oxygen is reduced [6].

$$\text{O}_2(\text{g}) + 4\text{H}^+(\text{aq}) + 4\text{e} \rightleftharpoons 2\text{H}_2\text{O}(l)$$

(2)

$$\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(l) + 4\text{e} \rightleftharpoons 4\text{OH}^- (\text{aq})$$

(3)

The corrosion rate is the propagation velocity or speed of decline in the quality of materials on time.

$$\text{CR} = \frac{d - d_0}{T - T_0}$$

(4)

where $\text{CR}$, $T$, $d_0$, $d$, and $T_0$ respectively represent corrosion rate, year of first examination, initial thickness, examination thickness, and recent year of examination.
2.2 Risk
Risk is a possibility of an unwanted event that will affect an activity or object [7]. Mathematically, the definition of risk is as follows:

\[
Risk = Probability \times Consequence
\]  

The reference in figure 2 can be used for determining the risk level. While the numerical values of probability and consequence categories can be shown in table 1.

2.3 Probability of failure
The probability of failure is a possibility of equipment or component to fail (API, 2008). Analysis of the occurrence of a failure in the component can be performed if they are currently in working conditions. The equation of the probability of failure in API RBI is given by the following equation [8]

\[
P_f(t) = g_{ff} \times D_f(t)
\]  

where \(P_f(t)\), \(g_{ff}\), and \(D_f(t)\) respectively represent probability of failure, generic failure frequency, and damaging factor.

2.4 Consequences of failure
The consequences of failure are the impacts that can be caused by an equipment failure. The semi-quantitative RBI API calculation involves only consequences of flammability and toxicity [9].

2.5. Remaining lifetime
Remaining lifetime can be defined as equipment tolerance to the type of damage. Remaining lifetime will determine the next inspection interval of time [10].


\[ \text{Remaining Life Time} = \frac{d_i - d_j}{d_0} \quad (7) \]

where \(d_0\), \(CR\), and \(d_R\) respectively represent current actual thickness, corrosion rate, and required thickness.

### 2.6 Risk-Based Inspection

Risk Based Inspection (RBI) is a relatively new method of conducting an inspection. This method is based on a risk analysis which includes the analysis of the magnitude of the possibility of a failure and the magnitude of the effects of emerging risks [5]. In general, the RBI management can be seen in figure 3.

### 3. Results and Discussion

#### 3.1 Data

The data of inspected equipment are shown in Table 2.

| Component                        | P. Design (psig) | P. Operation (psig) | T. Design (ºF) | T. Operation (ºF) |
|----------------------------------|------------------|---------------------|----------------|------------------|
| Line pipe (inlet KP.20 Ø20")    | 900              | 450                 | 650            | 250              |
| Tee (inlet KP.20 Ø20")          | 900              | 450                 | 650            | 250              |
| Line pipe (outlet KP.20 Ø20")   | 900              | 450                 | 650            | 250              |

#### Figure 4. Matrix risk

Note: (1) *Inlet Automatic Shutdown valve KP-20 Ø20”*, (2) *Tee KP-20 Ø20”*, and (3) *Outlet Automatic Shutdown Valve KP-20 Ø20”*. 

---

**Figure 3.** Management of *Risk Based Inspection* [10]
3.2 Risk level
The risk level in three components can be seen in the Risk Matrix as presented in figure 4. From the risk matrix, we can know that the level of risk of all the three components is medium with the overall value of 1819.654 ft$^2$. The consequences of failure and the value of the probability of failure were 1.

3.3 Remaining lifetime
The data of the remaining lifetime of each component can be seen on the graph to make it easier to set priorities for the next inspection as illustrated in Figures 5, 6, and 7. From the graph of Remaining LifeTime Gas Pipe Straight (Automatic Shutdown Valve Inlet KP-20 Ø20”), we can know that the pipeline would fail in the years between 2025 to 2026 which was marked by an actual pipe with thickness values that approached the minimum thickness of the pipeline design.

From the graph of remaining lifetime connection Tee (KP-20 Ø20”), we can find that the pipeline would fail in the years between 2054 and 2055 was, which was marked by actual pipe thickness values that approached the minimum thickness of the pipeline design.

In the graph of Remaining LifeTime Gas Pipe Straight (Outlet Automatic Shutdown Valve) KP-20 Ø20", we can know that the pipeline would fail in the years between 2030 and 2031, which were marked by the actual pipe thickness values that approached the minimum thickness of the pipeline design.
3.4 Risk-Based Inspection

Inspection planning recommendations for each component based on Table 3 and Table 4, namely:

**Table 3. Static Equipment Integrity Inspection of RBI**

| Risk Level | Type of Inspection                  |
|------------|------------------------------------|
| High       | Internal Entry                     |
|            | External NDT                       |
| Medium     | Internal Entry                     |
|            | External NDT                       |
|            | Limited Internal Inspections        |
| Low        | Internal Entry                     |
|            | External NDT                       |
|            | Limited Internal Inspections        |

**Table 4. Test Results for the Type of Failure in Critical Levels**

| Probability of Failure | Consequences of Failure | Inspection Method          | Inspection Frequency (Month) | Wide Inspection Area |
|------------------------|-------------------------|-----------------------------|------------------------------|----------------------|
| High                   | High                    | Ultrasonic Testing          | 12                           | Full                 |
| High                   | Medium                  | Ultrasonic Testing          | 12                           | Partial              |
| High                   | Low                     | Ultrasonic Testing          | 12                           | Small                |
| Medium                 | High                    | Ultrasonic Testing          | 12                           | Full                 |
| Medium                 | Medium                  | Ultrasonic Testing          | 12                           | Partial              |
| Medium                 | Low                     | Ultrasonic Testing          | 12                           | Small                |
| Low                    | High                    | Ultrasonic Testing          | 12                           | Full                 |
| Low                    | Medium                  | Ultrasonic Testing          | 12                           | Partial              |
| Low                    | Low                     | Ultrasonic Testing          | 12                           | Small                |

From Tables 3 and 4, it can be recommended:

| Pipeline (Inlet SDV KP-20 Ø20”) | Tee (KP-20 Ø20”) | Pipeline (Outlet SDV KP-20 Ø20”) |
|---------------------------------|-----------------|----------------------------------|
| Frequency                       | every 36 months | every 36 months                  | every 36 months              |
| Inspection Method               | External NDT    | External NDT                     | External NDT                 |
| Next Inspection                 | before the year | before the year                  | before the year              |
|                                 | 2020            | 2035                             | 2023                          |
4. Conclusion

Based on the Level Risk analysis, it can be seen that all components have a medium risk level (1C) with an overall value of 1819.654 ft². The consequences of failure and the value of the probability of failure was 1. The most critical component is the Straight Gas Pipeline (Automatic Shutdown Valve Inlet KP-20 Ø20") with the Remaining LifeTime of 9.8 years, as a result of the magnitude of corrosion rate on these components. The prioritizations of API 581 Risk-Based Inspection are the Gas Pipe Straight (Inlet Automatic Shutdown Valve KP-20 Ø20") that will be inspected in 2020 by the NDT inspection method, Gas Pipe Straight (Outlet Automatic Shutdown Valve KP-20 Ø20") that will be inspected in 2023 by NDT inspection methods and lastly Connection Tee (KP-20 Ø20") that will be inspected in 2035 via NDT inspection methods. It is concluded that RBI is an efficient method to assess risk and target inspection resources on critical items. When correctly implemented, the RBI approach is a powerful mean for increasing the safety and reducing the inspection and maintenance costs of process plant equipment.

5. References

[1] Tim Independen Pengendalian Keselamatan Migas 2015 Atlas Keselamatan Migas
[2] Pluvinage G and Elwany M H 2013 Safety, Reliability and Risk Associated with Water, Oil and Gas Pipelines Vol. 53 Springer 1689-99
[3] Wibowo F, 2015 Kajian Resiko Pipa Gas Transmisi PT Pertamina Studi Kasus Simpang Km32-Palembang 3(1) 726–33
[4] Yun F W 2008 Correlated sampling techniques used in Monte Carlo simulation for risk assessment Int.J.of Pres.Ves. and Pip. 85(9) 662–669
[5] Kamsu F B 2016 Information structuring and risk-based inspection for the marine oil pipelines Phys Procedia 56 132–42
[6] Vinod G, Bidhar S K, Kushwaha H S, Verma A K and Srividiya A A 2003 Comprehensive framework for evaluation of piping reliability due to erosion–corrosion for risk-informed in-service inspection 82 187–193
[7] API 2008 Risk-based inspection technology
[8] Prayogo G S, Haryadi G D, Ismail R, Kim S J 2015 Risk analysis of heat recovery steam generator with semi quantitative risk based inspection AP/ 581
[9] Noori S A Price J W H 2006 A risk approach to the management of boiler tube thinning Nucl Eng Des. 236(4) 405–414.
[10] Perumal K E 2014 Corrosion risk analysis , risk based inspection and a case study concerning a condensate pipeline Proceedia Eng. 86 597–605
[11] Shiw W T, Wen T H and Chih H T 2007 Study of a risk-based piping inspection guideline system ISA Transaction 46 119-126
[12] API 2000 Risk-based inspection based resource document

Acknowledgments

The authors gratefully wish to acknowledge the excellent support provided by Electrical Analysis and Engineering Measurement for Reliability Analysis Laboratory at CORES Diponegoro University, Indonesia. The authors extend their sincere thanks to Strength of Material and Reliability Evaluation Laboratory, Pukyong National University, South Korea, for the support and the constructive feedback on the work.