An Economic Consideration Guideline for the Selection of Corrosion - Control Strategies

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ABSTRACT

Corrosion has an enormous economic impact on our industries. Hence, it is very important for engineers to apply the appropriate corrosion prevention techniques to protect the metallic process equipment from corrosion. Usually, engineers spend their effort seeking for the corrosion control strategies. In fact, the effective corrosion prevention projects should be technically and economically evaluated. Engineers can assess the corrosion prevention strategies in terms of technical validity. Nevertheless, the economic consideration of the anti-corrosion strategies seems to be one of their problems. The purpose of this article is to present the economic techniques which can be employed as a quick guide to make decision of their corrosion prevention projects. The other purpose is to review the corrosion mitigation methods and the economic considerations of the financial investment in the corrosion prevention strategies. The application of these techniques is also illustrated in a selected practical example.

Keyword: Corrosion, Engineering Economy, Corrosion Mitigation Approaches, Economic Consideration

1. Introduction

Corrosion is a serious problem commonly encountered in many industries [1]. Oil and gas network pipelines, refineries, petrochemical plants as well as power plants are subject to corrosion problems. For examples, internal corrosion in hydrocarbon pipelines of petrochemical plant is induced by the presence of water and condensed carbon dioxide. H2S often attacks carbon steel pressure equipment in the acidic conditions. The flow- accelerated corrosion can rapidly destroy the surface of pipelines. Erosion-corrosion as well as cavitation can accelerate the local attack of pump impellers.

Obviously, corrosion can shorten the service life time of equipment, resulting in a significant increase in the maintenance budget of industries. Leakage of chemical substances from corroded pipes directly affects the human safety and our environment. In addition, the corrosion failure of the process equipment can lead to the immediate plan shutdown, causing the considerable financial losses for industries [2-3]. Thus, consequences of corrosion losses in all industries are substantial and it is vital for engineers to adopt proper anti-corrosion methods, i.e. the use of cathodic protection, inhibitor as well as selection of high corrosion resistant materials. Frequently, each corrosion problem may have more than one corrosion resistant material or corrosion control technique which can solve such problem [4]. Basically, the engineers have to establish the corrosion mitigation recommendation and submit this request to ask management for financial support for their corrosion control project. In practice, the chosen corrosion control project has to be technically and economically justified [5] and shown in the simple ways so that management can readily understand. Unfortunately, most of engineers specialize in this technical problem, but they may not be familiar with the financial analysis of their project, particularly in the economic assessment of the corrosion solving methods. So, the decision-making tool based on the engineering economy is imperative for them.

This paper aims to fill this gap by providing the review of economic techniques which can be used as an important method for decision-making. The other aim is to review the corrosion mitigation methods and the economic consideration of the investment in the corrosion prevention strategies. Furthermore, the application of these techniques is also demonstrated in practical examples which can possibly be found in the industries.

2. Review of engineering economy

Engineering economy is an effective tool to justify the corrosion control methods for the long-term profits. This calculating tool is greatly related to money and time. The value of money can change with the time, depending on the interest rate. In order to systematically analyze the time value of money for a corrosion protection strategy, the establishment of the simple cash flow for this strategy is required. Important parameters based on the engineering economy are given as follows [6]:

P = Present worth

F = Future worth

A = Annual worth

n = the number of periods for using this project

i = interest rate per year

In fact, the certain amount of money has its own value in particular time. By using mathematical techniques from the engineering economics, the amount of money at any specific time can be converted to an equivalent amount of money at another period. Thus, it is feasible to calculate the future worth from the amount of money today. Similarly, the amount of money in the future can be computed to obtain its present worth. The mathematical techniques can allow us to obtain the long – term economic evaluation of the corrosion control projects [7].

2.1 The relationship between the Present worth (P) and the future worth (F)

The future worth can be acquired from the present worth as illustrated in Eq. (1)

$$F = P(1+i)^n \quad (1)$$

Where $(1+i)^n$ is known as (F/p , i % , n)

The present worth can be gained from the future worth by using Eq. (2)

$$P = F(1+i)^{-n} \quad (2)$$

Where $(1 + i)^{-n}$ can be expressed as (F/P, i % , n)

2.2 Annual cost

The equivalent uniform annual cost can be derived from following two cases.

The present worth (P) and The annual cost (A)

$$A = P (i(1+i)^{n} / (1+i)^{n} -1) \quad (3)$$

Where $(i(1+i)^{n} / (1+i)^{n} -1)$ is termed as (A/P , i % , n). Likewise, the present worth can be calculated by Eq. (4)

$$P = A (P/A, i \%, n) \quad (4)$$

Where (P/A, i %, n) is the reciprocal of (A/P , i % , n)

The future worth (F) and The annual cost (A)

$$A = F (i / (1+i)^{n} -1) \quad (5)$$

Where $(i / (1+i)^{n} -1)$ is recognized as (A/F , i % , n)

$$F = A (F/A , i \% , n) \quad (6)$$

Where (F/A , i % , n) is the reciprocal of (A/F , i % , n)

3. The corrosion mitigation approaches

Corrosion is electrochemical in nature. So, three simultaneous conditions are necessary to cause the corrosion of metal [8]. Firstly, an electrolyte must be present. The electrolyte can provide the path for ion movement as well as current flow. Secondly, an electrochemical corrosion cell must occur. This cell is composed of Anode (corroded areas, producing electrons) and cathode (sites for electron-consuming reaction). Finally, a conductive path between anode and cathode must exist. As corrosion occurs, the metal dissolution of anode gives rise to free- electrons, which will be consumed at the cathode. So, reducing the rate of electrons released from anode can mitigate the corrosion problem. In addition, the prevention of the electrochemical contact between metal and electrolytes is also useful. Thus, both concepts can bring following three common corrosion protection methods [9-10].

3.1 Barrier Coating

Normally, thin-film coating, painting, or inhibitor can be applied as the barrier layer, which can prevent the direct contact between the metal and the electrolyte. This method is often applied on the anodic substrate such as carbon steel. Nevertheless, the maintenance activities after coating or painting are needed to maintain the effectiveness of the protective condition.

3.2 Material selection

The selection of the appropriate materials is crucial because it involves the anti-corrosion and financial concern. The high corrosion resistant material is normally expensive, but it can provide the longer lifetime. However, the routine inspection and proper maintenance activities potentially extend the service life of the less corrosion resistant material.

3.3 Cathodic protection

Cathodic protection is an electrochemical technique used to control the corrosion of a metal surface of the metallic equipment by making it the cathode of an existing corrosion cell. The metallic equipment can be protected by connecting it with sacrificial metals acting as the anode. So, the sacrificial metals preferentially corrode, but metallic equipment becomes protected. The sacrificial metals usually have the limited life time. Hence, a periodic replenishment becomes necessary. The impressed current can also change the metallic equipment to be a cathode material. This system requires the installation of the source of power supply and rectifiers. Routine monitoring is also important to check the status of the impressed current system.

All methods can be possible alternative approaches to solve corrosion problems. However, in many situations, each corrosion problem can be effectively alleviated by more than one corrosion protection method. Therefore, the economic comparison of each method should be made to find out the most suitable method for the corrosion problem.

4. Economic consideration of the corrosion prevention strategy

Figure 1 The general cash flow of anti- corrosion projects

In general, each candidate for corrosion prevention projects has its own stream of financial cost, as depicted in the cash flow diagram in Figure 1. From Figure 1, financial costs of each corrosion prevention project consists of the installation cost at time of zero (I), Maintenance cost (A), and Salvage value (S). As mentioned above, the value of money varies with the time (n), depending on the interest rate (i %). The present worth (P) from the cash flow diagram in Figure 1 can be mathematically expressed as follows [11]:

$$P = - I - A\ (P / A,\ i\%,\ n) + S\ (P/F,\ i\%,\ n) \qquad (7)$$

The first term of Eq. (7) represent the initial investment. The second term is concerned with the cost of maintenance activities, i.e. re-coating, re-painting, and welding repair. The third term is related to the salvage cost, which is often ignored for the corrosion work. So, the third term is normally zero. Principally, economic consideration of alternative anti-corrosion projects having the same expected life time can be made by comparing the magnitudes of their present values obtained from Eq. (7). However, the candidate anti-corrosion projects have unequal life expectancy. Thus, it is crucial to develop the equivalent annual cost from the present worth for the economic comparison [12-13]. To gain the equivalent annual cost (A), the mathematic formula listed in Eq. (8) can be used [14].

$$A = P\ (A/P,\ i\%,\ n) \qquad (8)$$

Comparison of the equivalent annual cost (A) of alternative projects can be made. The economical choice is the alternative project with the lowest equivalent annual cost [15-16].

5. The application of economics consideration for material selection

A new pump is required for the expansion project of a petrochemical plant. The fluid in this pump contains the suspended particles, which can cause the erosion-corrosion to the pump. Due to the erosion-corrosion, the expected service life time of the Ferritic steel pump is 3 years. Another alternative is to use the high erosion-corrosion resistance materials, in this case the martensitic cast stainless steel with hard facing. This choice can last 6 years without frequent inspection. The installation cost and expected life of both alternatives are assumed and given in Table 1. The salvage of both projects is zero, and the interest rate is assumed to be 10 %. From Table 1, it is clear that the expected life time of both alternatives is unequal. Hence, the economic analysis of both alternatives should be computed by comparing the equivalent annual cost of both alternatives.

Table 1 The installation cost and anticipated life of both alternatives

Project (pump installation)	**Installation cost (USD)**	**Anticipated Life (years)**
Ferritic steel	8,000	3
Martensitic stainless steel	18,000	6

Ferritic steel pump: Salvage cost is zero and no maintenance activities are performed. So, S and A in Eq. (7) are zero. In case of Ferritc steel pump, the equivalent present worth (P) in Eq. (7) is equal to –I or - 8,000 USD. P can be converted to the equivalent annual cost of Ferritic steel pump (A_{FS}) by using Eq. (8). So,

$$A_{FS} = -8000\ (A/P\ ,\ 10\%,\ 3\ )$$

Based on Eq. (3), the value of (A/P, 10%, 3) is 0.4021.

Thus, A_{FS} = -8,000 (0.4021) = -3,217 USD

The equivalent annual cost of Ferritic pump is equal to 3,217 USD.

However, from the corrosion engineering standpoint, the rapid thinning rate of pump induced by the erosion-corrosion can lead to the premature failure of the Ferritic steel pump [17]. Hence, Yearly maintenance activities, such as inspection of coating, re-coating, and welding repair, have to be employed to maintain the pump conditions [18]. Therefore, the annual cost of yearly maintenance for the Ferritic steel pump should be included in this economics consideration.

Figure 2 exhibits the new cash flow of Ferritic steel pump with the addition of the annual maintenance cost. In this example, the maintenance cost of Ferritic steel pump (A_{F1}) is assumed to be 1,600 USD / year. Based on Eq. (8), the new total equivalent annual cost of the Ferritic stainless steel pump (A_{TF}) can be gained as follows:

$$A_{TF} = -A_{FS} - A_{F1}$$
$$= -3,217 -1,600$$
$$= -4,817 \text{ USD.}$$

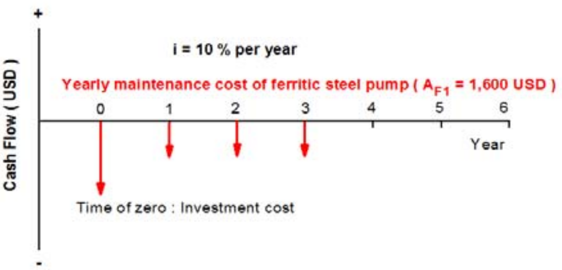

Figure 2 The new cash flow of Ferritic steel pump with the addition of the annual maintenance cost

Martensitic stainless steel pump: Similarly, P of this pump = -18,000 USD. Then, we obtain the equivalent annual cost of Martensitic stainless steel pump (A_{MSS}) as follows:

$$A_{MSS} = -18{,}000\ (A/P\ ,\ 10\%,\ 6) = -18{,}000\ (0.2296) = -4{,}592\ \text{USD}$$

The equivalent annual cost of Martensitic stainless steel pump is equal to 4,592 USD. By comparison, it can be found that the Ferritic steel pump has the lower annual cost in case of no consideration the cost of maintenance and become more economic.

However, it is clear that if the cost of maintenance activities is included to maintain the reliability of the Ferritic pump, the Martensitic stainless steel pump becomes more economical.

6. Conclusion and Discussion

The mathematical techniques based on the engineering economy have already presented in this paper. These techniques are very useful for the long-term investment evaluation of the anti-corrosion strategies. Generally, the efficient anti-corrosion project should be economically justified. These mathematical techniques permit direct assessments of potential alternatives of anti-corrosion projects in financial terms. Technically, each candidate for corrosion prevention projects has its own financial detail, i.e. initial investment, and maintenance cost. In practice, the alternative projects have the different expected life, requiring the comparison of the equivalent annual cost of alternative projects. Maintenance cost can be regarded as the annual cost. This cost is important, especially for the common material because maintenance works are necessary to keep the unit operative. After economic comparison of alternative projects is already made, the anti-corrosion project with the least expensive will be the project of choice.

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