RISK OF FAILURE INDICES APPLIED TO SELECTION OF MATERIAL FOR PIPELINES

M. V. Biezma, J. R. San Cristóbal, R. Martínez
Degradation and Corrosion Research Group. E.T.S. Naútica. University of Cantabria
Germán Gamazo s/n. 39904 Santander. Spain
E-mail: biezmav@unican.es

ABSTRACT

The use of pipelines is, to some extent, the most economical way to transport hydrocarbons. Pipelines deteriorate over time, and in particular, an important failure or damage mode in pipelines is corrosion. Corrosion defects, in axial and longitudinal directions, diminishes the original thickness of the pipeline producing a remaining strength lower than the original. In some cases, the pressure of failure can be reached. Pipeline managers require assessments of integrity and safety in order to make appropriate decisions. The selection of materials for petrochemical pipelines is a laborious and difficult task. However, at the time to make the decision about the material to select for this application, the risk of failure of these materials, which work under aggressive environments, has not been considered. The unexpected failures can cause important losses, not only economic but also environmental and social.
The aim of this paper is to show different indices related with the risk of failure. These risk measures are evaluated and used as criteria in the selection of a specific material for a petrochemical API 5L pipelines.

KEY WORDS: Pipelines, Risk of Failure, Material Selection.

1. INTRODUCTION

The exploration, exploitation and transportation of crude oil and gas in petrochemical industry produce impact potentially negative, to personal, environment, with important economic repercussion. Millions of barrels crude oil has been dumped to selvage zones, rivers, lakes and oceans. The repercussion of that sometimes will be appears some years after produced the accident. Occidental Europe imports 97% of its needs from Africa and Medium Orient. USA, Russian, Canada, Mexico and Venezuela for example, have reserves at thousands of kilometers from the centres of consumption deposits.

In petrochemical activity is necessary to devote attention to the pipeline material selection, since the there are a lot of variables that can affect their useful life. One of the mayor problems is linked with corrosion phenomenon. Corrosion defects, in axial and longitudinal directions, diminishes the original thickness of the pipeline producing a remaining strength lower than the original. In some cases, the pressure of failure can be reached. Pipeline managers require assessments of integrity and safety in order to make appropriate decisions. The selection of materials for petrochemical pipelines is a laborious and difficult task. However, at the time to make the decision about the material to select for this application, the risk of failure of these materials, which work under aggressive environments, has not been considered.

There are four fundamental aspects to the correct operation of a piping system: security, supply continuous, economic efficiency and compliance with laws and international regulations. Despite the continuous improvements implemented in the aspect of safety, specifically in the monitoring and inspection processes, accidents and cracks in gas pipelines and oil pipelines continue to occur, either due to different variables in relation to material in nature, inadequate materials selection, manufacturing process, design, and a lack of inspection and maintenance [1]. In this case the decision maker has to consider several conflicting objectives, as social, economic, technological, environmental etc.

In this paper, we focus in materials selection taking into account the risk of failure under aggressive environments, in particular the selection of API 5L steel pipelines used in petrochemical industry.

2. MATERIAL SELECTION IN THE PETROCHENMICAL INDUSTRY

Pipelines, like other structures in nature, deteriorate over time. This natural deterioration in a metallic pipeline usually occurs as a result of the damaging effects by the surrounding environment. Corrosion is recognized as one of the most important degradation mechanisms that affect the long-term reliability and integrity of metallic underground and submerged pipelines. The environment in contact with a pipelines used in transportation of crude oil and gas has a very important amount of H_2S, a very corrosive acid gas soluble in water, whose origin is in the own fuel or produced by metabolism of SRB Sulphate Reduced Bacteria. Thus, it is necessary a correct inspection and maintenance of the pipe and its protections, with the purpose of preventing leakage or escapes, due to unexpected failure with the corresponding environmental impact.

To ensure the reliability of pipelines, many research efforts have been devoted to predicting pipeline failure using deterministically and probabilistically tools. Pipeline operators throughout the world are confronted with the expensive and risky task of operating aged pipelines because of corrosion and its potential damaging effects. Furthermore, growing uncertainty adds to the problem.

The major effect of corrosion is the loss of metal cross-section. This results in a reduction of pipeline carrying capacity and safety. However, for a pipeline containing active corrosion defects, the major concern of a pipeline operator is the need to have a simple technique which can be used to evaluate the pipeline's current reliability. The problem then is to determine how the sizes of corrosion defects affect the integrity of a buried pipeline and pipeline with anticorrosive measurements, protective barrier and cathodic protection, since is very important to assess of remaining life of a pressurised pipeline containing active corrosion defects, [2-5].

There are different methods to estimate the remaining strength of corroded pipeline with internal active corrosion defects. The most employed are ASME B31G, [6], RSTRENG, PCORRC, DNV RP F-101, and SHELL-92.

The steels employed in petrochemical pipeline are API 5L, *American Petroleum Institute*, with different grades, attending the mechanical strength, consequence of their chemical composition [7-8]. Throughout last years has been increase their weldability due to low carbon equivalent value, but with higher mechanical strength, due to presence of different chemical elements. The Table 1 presents the yield strength and mechanical strength of different grades API 5L steels, and Table 2 present the chemical composition (%wt) of API 5L x100.

Table 1. Mechanical properties of API 5L steels

Grade	Yield Strength (MPa)	Mechanical strength (MPa)
X42	289	413
X56	386	489
X60	413	517
X65	448	530
X70	482	565
X80	551	620
X100	690	760

Table 2. Chemical composition of API 5L X100

C	Mn	Ni	Cu	Mo	Nb	Ti
0.06	1.96	0.39	0.17	0.11	0.04	0.01

3. APPLICATION

For analytical purposes we have considered three different materials to be employed in 10 kilometres of a crude oil transport pipeline. Table 3 shows the estimated costs of the three alternatives and the six possible scenarios which can occur depending on the probability of failure. The cost of failure refers to the different types of costs which may surge as a consequence of a failure, say , repairs, downtime, new materials, whereas the cost of no failure refers only to the cost of the material. Material A is the material with a greater probability of failure (0.60). The cost of no failure for this material is the lower (25,000), whereas the cost of failure is the highest (75,000). Material B is an "intermediate" material between the most expensive one (Material C) and the cheapest (Material A). Finally, Material C is the material with the lowest probability of failure (0.10) and the lowest cost of failure (40,000). Figure 1 shows the decision tree corresponding to the three decision alternatives at the time to select a material.

Table 3. Materials to Select, Probability of Failure and Associated Costs.

Material	Outcome	Probability	Costs (€)
A	Failure	0.60	75,000
	No Failure	0.40	25,000
B	Failure	0.20	60,000
	No Failure	0.80	30,000
C	Failure	0.10	40,000
	No Failure	0.90	50,000

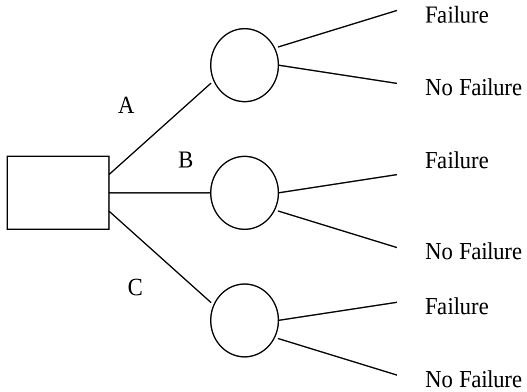

Figure 1. Decision Tree.

The three possible indices [9] that may be used as attributes in the decision process are: the Expected Cost, the Best Cost of each alternative, and the Standard Deviation of the Cost. Table 4 shows the values of these three risk indices calculated from the data of Table 3 for the three different materials

Table 4. Risk indices for the different materials

Material	**Expected Cost**	**Best Cost**	**Standard Deviation**
A	45,000	25,000	35.36
B	36,000	-	21.21
C	49,000	-	7.07

Once we have calculated the different risk indices, the next step is to select the material in accordance to the criteria. Each one of the three different criteria implies a different material to select. Following the Expected Cost criteria, the material to select is Material B, whereas the Best Cost criteria imply to select material A and attending the Standard Deviation criteria imply to select material C.

Table 5. Material to select depending on the criteria

Criteria	Material to select
Expected Cost	B
Best Cost	A
Standard deviation	C

4. CONCLUSIONS

The selection of materials for a given application is a challenging and difficult task, in particular in the selection of materials under high risk of failure, like petrochemical pipeline, due to the high corrosion activity inside pipeline. The unexpected failures can cause important losses, not only economic but also environmental and social. In this case the decision maker has to consider several conflicting objectives, as social, economic, technological, environmental etc.

In this paper, we focus in materials selection taking into account the risk of failure under aggressive environments. We have considered three different risk indices, the Expected Cost, the Best Cost of each alternative, and the Standard Deviation of the Cost. We show how different measures imply different selection of materials.

REFERENCES

[1] U. S. Office of Pipeline Safety. *Accident Summary Statistics by Year,* U. S. Department of Transportation, 2006.

[2] Benjamín, A.C., Freire, J.L.F., Vieira, R.D., Diniz, J. L., de Andrade, E. Q. "*Burst Test on Pipeline Containing Interaction Corrosion Defects*", 24 th International Conference on Offshore Mechanics and Artic Engineering (OMAE), Halkidiki, Greece, June, 2005.

[3] Shu-Xin, L., Shu-Rong, Y., Hai-Long, Z., Jian-Hua, L., *Predicting Corrosion Remaining Life of Underground Pipelines with a Mechanically-Based Probabilistic Model*. Journal of Petroleum Science and Engineering 65, pag. 162–166, 2009.

[4] Cosham, A., Hopkins, P., McDonald, M.A., *Best Practice for the Assessment of Defects in Pipelines Corrosion*. Engineering Failure Analysis, 14, pag. 1245-1265, 2007.

[5] Kiefner, J.F., Vieth, P.H., *Evaluating Pipe Conclusion: PC Program Speeds New Criterion for Evaluating Corroded Pipe*. Oil & Gas Journal, 88, pag. 91-93, 1990.

[6] ASME B31G -1991. *Manual for Determining the Remaining Strength of Corroded Pipeline.* Ameritas Society for Mechanical Engineers, New York, 1991.

[7] American Petroleum Institute. *Summary of Technical Differences between API 5L (43rd ed.) and ISO 3183" (2nd ed.) / API 5L (44th ed.).* August 2008

[8] Terada, Y., Yamashita, M., Hara, T., Tamehiro, H., Ayukawa, N. *Development of API X100 UOE Line Pipe*. Nipon Steel Technical Report No. 72, 1997.

[9] M.A. Matos, *Decision under Risk as a Multicriteria Problem.* European Journal of Operations Research 18, pag. 1516-1529, 2007.