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RISK-BASED DECISION IN THE CORRODING GAS PIPELINES MAINTENANCE

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ABSTRACT
The conventional method of assessing the integrity of corroded oil or gas offshore pipeline is based the deterministic method using the ANSI/ASME B31G-1984. Previous studies have shown that a decision of when and where to repair or replace the damaged pipeline based on this approach, was very conservative. Furthermore, the cost of repair and replacement is extremely expensive. Recent applications in aerospace and nuclear industries have shown that reliability method is probably a more superior approach for the integrity assessment of corroding pressurized offshore pipelines. This method quantifies the probability that the structure will not perform its desired function, i.e. the probability of failure. This alternative approach can be extended into risk-based methodology in the asset maintenance to ensure safety and reliability. The proposed risk-based inspection procedure carried out in the study is more systematic and reliable to account for a huge amount of collected data usually obtained in an on-line inspection using the intelligent devices. The outcomes of this risk-based methodology can be very useful in the decision-making process by the operation management. This in turn will produce an efficient inspection, repair and maintenance program and enhanced the optimized return in investment.

KEYWORDS
Assessment, Corrosion, Inspection, Pipelines, Reliability, Risk-based method

1. INTRODUCTION

Pipelines provide the efficient and reliable transport of oil and gas. Nevertheless, an ageing transmission oil and gas pipelines may experience significant metal loss due to corrosion which reduce its strength. Such corrosion cause pipelines failure where this deteriorating process may induce hazard and risk to the health and safety of people, the environment or the operation. The UK Health and Safety Executive reported in PARLOC 96 that 55% of pipeline loss of containment incidents in the North Sea was due to corrosion or material defects in the pipelines (OTH551, 1996). During the period 1980 to 1997, there were 12,137 failures of pipelines in Alberta, Canada averaging 674 failures per year (AEUB, 1998). Approximately 63% of all the pipeline failures were caused by corrosion, with 50% of the failures caused by internal corrosion. Repair and replacement of subsea pipelines can be extremely expensive. In the United States of America, the capital cost involving corrosion is estimated at US$93 billion and the replacement cost in 1998 was estimated at US$541 billion (Thompson, 2001). To reduce these hazards to an acceptable and reliable level, the operators conduct regular inspection activities to assess the corroded oil and gas pipelines. The total annual cost of corrosion to the operation and maintenance budget for the USA pipeline industry is estimated at US$3.6 billion. Figure 1 illustrates the effects of corrosion on the long-term virtual costing of the operation.

The emergence of the high-resolution inspection systems that provide a quantitative assessment of pipeline conditions has advanced the integrity assessment methodology in recent years. Such tools provide data that are claimed to be sufficiently accurate to allow estimation of corrosion growth rates from subsequent inspections. However, present interpretation of the collected data as well as strength evaluation of the corroded pipelines is likely still too simplified. Therefore, there is an urgent need to have a systematic assessment procedure and utilizing the results obtained in the decision-making process by the maintenance management.

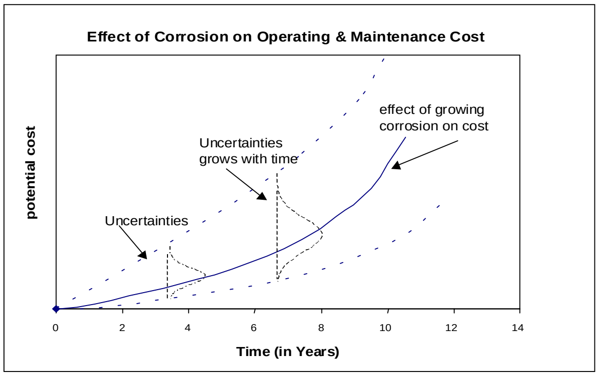

Figure 1: Effect of Corrosion on the Cost of Maintenance and Operation of a Pipeline

2. VARIOUS APPROACHES IN CORRODED PIPELINE ASSESSMENT

The original procedure for determining the remaining strength of corroded pipelines as presented in ANSI/ASME B31G-1984 code for pressure piping have been developed in the early 1970s. The application of the original B31G criterion became widely accepted in the pipeline industry (Kiefner and Vieth 1989). After a series of research publications on the subject, the procedure in the original criterion has been modified to suit the recent findings and updated technology, and has dealt with sources of conservatism. Other methods of evaluating corroded pipelines that have been proposed in recent years are the finite element method (Chouchaoui and Pick 1994) and probabilistic methods (Ritchie et al, 1998). Because of the huge amount of corrosion information data generated by inspection devices with various associated uncertainties, these alternative methods, especially the probabilistic approach has been gaining momentum in the industry.

3. RISK-BASED METHODOLOGY OF A CORRODING PIPELINE ASSESMENT

A generalized procedure for the risk assessment of an offshore pipeline subjected to deteriorating corrosion condition can be briefly summarized as described in the following sections. A summary of an overall procedure is illustrated in
Figure **2**.

3.1 Hazards and Limit States Identification

Based on the available information, all the hazards, hence the potential modes of failure that affect the integrity of the pipeline should be identified. The appropriate limit states should be accordingly selected to each hazard. One of the limit states usually used in the design of pipelines is the Ultimate Limit States (ULS). The ULS corresponds to the maximum load bearing capacity and covers the design against bursting, unstable fracture and plastic collapse, buckling and tensile rupture. Material degradation due to corrosion mechanism is one of the hazards, which affects the structural integrity and operations of the pipelines, hence is linked to the ULS.

3.2 Data Analysis and Assessment using Reliability Method

Although there are many hazards associated with various limit-states in pipeline, this paper considers the risk caused by corrosion mechanism that affects its structural integrity. Information from pipeline inspection data is utilized to obtain the current and future integrity of the pipeline using the appropriate procedure. The procedures are subdivided into three separate parts. The first stage of analysis is the statistical analysis of the inspection data. Defect populations are analyzed; the corrosion rates and growth prediction are determined. Then, more advanced statistical analysis using the extreme value statistics based on the Peaks-over-threshold approach are applied. Then, the probability density function of extreme value for the largest value is obtained. A detailed description of procedure and presentation of results are the subjects of other papers (Wolfram and Yahaya 1999).

Then, the procedure proceeds to the structural reliability analysis. A brief description taken at each step in structural reliability assessment can be summarized as follows.

a. Determination of Probability of Failure

Depending on suitability, a Monte Carlo simulation can be used in the reliability analysis. Monte Carlo simulation samples at random a large number of experiments.

b. ***Evaluation of System Failure Probability***

For each failure mechanism, the failure probabilities for each event are combined to evaluate the total failure probability for the whole pipeline. Then for each limit state, the system probability can be obtained by combining the failure probabilities for each failure mechanism.

c. ***Assessment on the Effect of Time on Reliability***

The reliability analysis can be repeated to assess the deterioration in reliability with time by taking the analysis at (say) yearly interval. For the limit state considered, the variation in failure probability is plotted against time, and compared with the target probabilities. Then, the critical hazard and the time that reliability level target exceeded can be identified. A result obtained for a set of inspection data is shown in Figure 3.

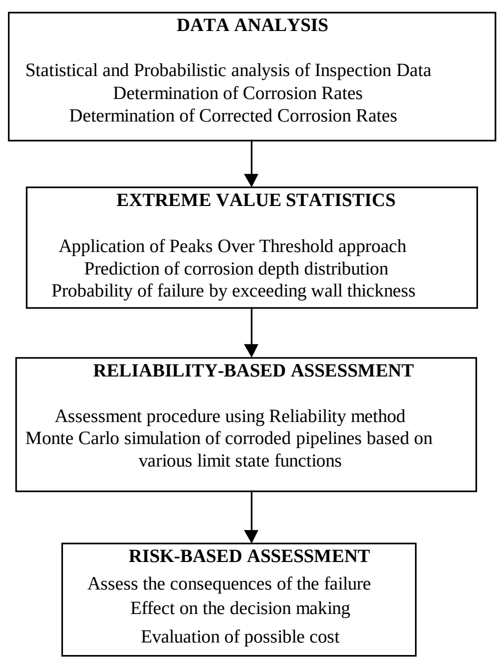

Figure 2: A Summarized Procedure in the Assessment of Corroded Pipeline

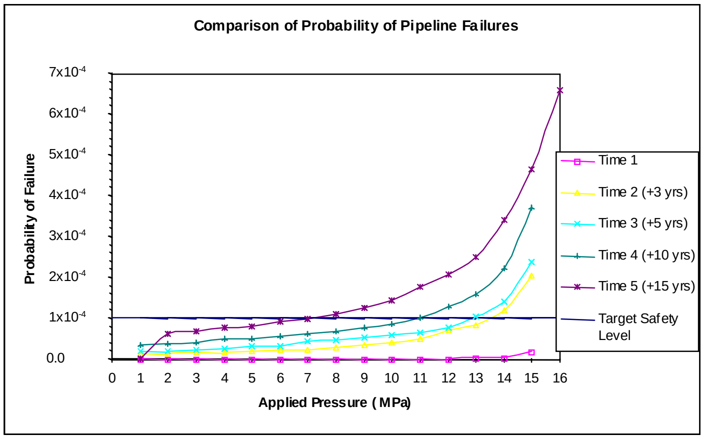

Figure 3: Comparison of the Effect of Time on the Probability of Failures for Increasing Applied Pressure

3.3 Risk assessment

Risk assessment is an identification of hazards and consists of estimation of risks arising from them with a view to their control, avoidance, or to a comparison of risks. Risk assessment can be viewed in several stages:

a. Evaluation of Risk

Risk evaluation is the quantitative and qualitative measurement of risk. The pipeline failure affects economic consequences, environmental damage and loss or injury to human being, depends on the type and location of the failure and on the pressure and contents of the pipeline. If the pipeline zone is nearer to the manned platform, then the pipeline failure poses a greater risk to human being and economic losses. If sufficient data is available, risk may be quantified in terms of financial costs involving equipment damage, pollution clean up, downtime period or legal and insurance consequences.

b. Assessment of Consequences of Failure

The evaluation of the consequence of failure is usually made with regard to:

i. Human injury, which depends on type of failure, operational condition, pipeline content, location of failure relative to the platform,
ii. Environmental impact, which depends on pipeline location and content,
iii. Reputation of company and of the country concerned,
iv. Economic loss, which depends on repair costs, loss of revenue and/or demand in the repair period.

4. RISK-BASED MAINTENANCE PLANNING

The objective of inspection, repair and maintenance (IRM) is to control the probabilities of failure occurrence due to structural deterioration directly related to the level of maintenance. The whole idea of analyzing the inspection data is to attain a reliable inference about the present and future condition of the pipeline without actually digging out and physically inspect them directly. The information can be used in planning the IRM program for the pipeline concerned. This is one of the major advantages of using the risk-based approach. However, the most advance inspection devices will only provide mass of information about the pipeline. Without the systematic analysis and assessment techniques, the inspection data will not provide useful assistance to the operators in their repair and maintenance planning.

Having systematically studied the inspection data, analyzed the pattern of deterioration and evaluated the risk involved, if the pipeline is found to be worse than anticipated, then the repair has to be commenced. By using the proposed procedure, the reliability analysis considering time varying effects on the pipeline integrity can be determined as shown in Figure 3. Sensitivity study for different applied pressure as shown in Figure 3 presents that the reliability of the corroding pipeline decreases as the pipeline aged. The applied pressure at which the pipeline can sustain within the target reliability level is steadily decreases with increasing age.

5. DISCUSSION

The risk-based decision making to execute the maintenance and repair work is the final stage in the whole procedure. A systematic risk management will eventually provide an efficient and economical operating cost in any organization.

Risk management is the term normally applied to the whole process of risk identification, estimation, evaluation, reduction and control (The Royal Society 1992). This includes the probabilistic assessment for a quantification of the chance of a failure occurring. Risk evaluation is the judgment of the significance of the assessed risks and risk-benefit analysis. One of the major initial decisions to take prior to the risk evaluation is the determination of an acceptable risk. The decision on the acceptable risk for the pipeline concerned is important because many subsequent decisions will depend on the chosen level. Decision process should also consider the most appropriate failure model to be used, as it is also affects the possible consequences and eventually the probability of failure.

The results of the risk and reliability assessment are useful in the decision processes whether the detected defects are tolerable or require repairs. The subsequent decisions are to manage the future inspection, repair and maintenance planning in the risk reduction control. Considerations in maintenance planning, based on the results obtained in the risk-based assessment are the frequency of inspection in the future and the right type of inspection device to be used. Other considerations are the total costs involved, including the inspection, mobilization of equipment, the quality of reporting, and a reliable assessment of inspection data, the repair cost and the cost of subsequent future inspections.

The final stage in the risk management is making decision on risk control. Risk control strategies may be divided into a few main areas namely risk avoidance, transfer and reduction. The proposed methodology suggests the process utilising the real inspection data and how to assess the pipeline's structural reliability. The decisions can be made to accept an assessed risk and to execute the implementation to reduce the consequences and/or the probability of occurrence. As a result, a strategy in inspection, repair and maintenance planning can be executed in the most cost-effective way within the acceptable risk threshold. The process is continuing and does not stop at the decision to implement the IRM policy only. There should be an auditing system to monitor the effectiveness of the strategy, which in turn if necessary may alter the procedure in the initial reliability assessment.

6. CONCLUSION

Risk-based evaluation of corroding pipelines is one of the most reliable interpretation approaches of inspection data. This approach is reasonably flexible to account for various uncertainties usually occurred. The outcomes of the risk-based assessment can be utilized in managing the future inspection, repair and maintenance program of a pipeline. A systematic assessment procedure can be a valuable tool to the pipeline operators.

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