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Quantified approach to pipeline health and integrity management

Edet Afangide, Jyoti K. Sinha*, K.B. Katnam

School of Mechanical Aerospace and Civil Engineering, The University of Manchester, Oxford Road, Manchester, M13 9PL, United Kingdom

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ABSTRACT

The quantified approach for health monitoring of subsea pipelines has been proposed, it considers four key time based degradation parameters selected from an array of mechanisms due to its ramification in deterioration and ageing of pipeline assets in general. The inspection data obtained for the selected parameters are simulated in a proposed health condition and pipeline risk assessment matrix that complies with tested and verified safe operating criteria defined in relevant pipeline integrity technical guidance documents. The health indicator denoted by H and H_{Cn} for annual assessment and cumulative lifespan assessment respectively. This 'prescriptive' approach is tested with a health condition assessment indicator and a quantified model to determine the pipeline integrity status for decision-making. It is evident from the findings that a cost effective integrity management model which improves on the existing qualitative and semi quantitative assessment methods can simplify and also reduce cost of pipelines integrity management.

1. Introduction

The quantified health and integrity assessment of pipelines is proposed in this paper to further improve on the existing health management methods. Due to increased expansion of pipeline transportation globally, the need for a cost effective and reliable integrity management processes cannot be overemphasised, considering the importance of the pipelines industry globally in oil, gas or chemicals transportation. From recent industrial practices reviewed, recent technology and cost requirement for installing and maintaining these infrastructures are huge; therefore an approach to forestall any rampant failure through effective condition assessment is proposed. In the proposed model, the input data is a randomly generated inspection data for a 24" Gas X65 material grade pipeline transporting natural gas, and operated in a marine environment. Report on Oil and Natural Gas Infrastructure; Status, Trends and Economic Benefits compiled for American Petroleum Institute stated that the capital investment in oil and gas asset was about $89.6 billion in 2013; these cost include pipelines and other physical assets from the well head, which makes the conveyance of crude oil and gas in the finished and semi-finished stages possible (American Petroleum Institute, 2013; Robert, 2005; Devold, 2013). Maintaining the integrity and health status of these critical assets effectively requires critical assessment, and expert technical judgement which can be quantified and simulated in smart mathematical model.

Existing research papers and relevant pipeline technical standards reviewed defined the link between 'ageing and the rate of degradation' and describes failure associated with pipeline ageing as a function of time dependent threat (ASME B31.8S, 2010). The risk identification process in gas pipelines defined in ASME 31.8S (ASME B31.8S, 2010; Hopkins, 2012) identified internal corrosion, external corrosion, and uniform or non-uniform wall thickness thinning or wall thickness loss as well as cracks or defect as the degradation parameters responsible for sudden rupture in some cases. The quantified concept is compliant with the guidance notes outlined in ASME 31.8S (ASME B31.8S, 2010), DNV-RP-F116 (DNV-RP-F116, 2009) and API1160 (API -1160, 2009), which is consistent with the 'prescriptive' integrity and health assessment approach suggested in (ASME B31.8S, 2010). In a paper on the reliability consistent mitigation criteria for corrosion defects on natural gas pipelines (Zhou et al., 2015; ASME 31G, 2012), the criterion for pipelines reliability and failure pressure ratio (FPR) was associated with corrosion defects. Zhou et al. (2015) also stated that the linear regression equations can be used to establish the threshold FPR corresponding to the reliability index for this pipelines to facilitate risk and reliability assessment of pipelines. Although (Zhou et al., 2015) discussed wall loss or thinning effect on pipelines reliability more extensively, the impact of all time dependent parameters needs to be understood. Yao et al. (Liao et al., 2012) found some of the quantified models currently used to assess health and reliability of pipelines to include numerical, deterministic or probabilistic platform using artificial neural network (ANN), statistical methods and MATLAB based fuzzy logic etc. An example is Wang et al. (2007) work on risk evaluation in failure of mode effects analysis using fuzzy weighted geometric mean. Similarly, ASME B31.8S, 2010 also recommended that an effective risk assessment process shall provide risk estimates to facilitate decision making.

* Corresponding author.
E-mail addresses: edet.afangide@postgrad.manchester.ac.uk (E. Afangide), jyoti.sinha@manchester.ac.uk (J.K. Sinha), kali-babu.katnam@manchester.ac.uk (K.B. Katnam).

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The semi-quantified risk assessment method currently practiced simply calculates risk from the known likelihood and consequence of failure ASME B31.8S, 2010; this is extensively enhanced in this work and fed in as a useful semi quantitative risk assessment input. A related study considered other advance metric and integrates the probability and reliability factor to determine pipeline health due to deviations of threat parameters in a semi quantitative or qualitative method, but in this paper the geometric mean impact of the degradation is escalated. In the same vein, technical standard ASME B31.8S, 2010 guidance which states that subject matter expertise, scenario based assessment; relative assessment and probability assessment are captured as the qualitative input for this model.

2. Concept for quantified approach

The proposed approach aims to simulate pipelines inspection data into a compliant health condition indicator matrix and a quantified model for a cost effective health and integrity assessment of natural gas pipelines. Various scenario based model from event trees, decision trees, and fault trees are modified to derive the H and H_{cn}. Therefore, the quantified model will create strong synergies for a deterministic health assessment for ageing gas pipeline with capability to predict the accurate and a reliable healthy or unhealthy status.

This method is developed for the analytical stage of the modified pipelines integrity management process shown in Fig. 1; which incorporates pipeline audit and previous assessment updates segmented into four key stages namely; pipelines review and data collation; to reassess existing records and reports, development of integrity management strategy; to define and apply technical models and tools, and the analytics to determine integrity status, and the remedial or intervention built on the inspection repair and maintenance (IRM) framework.

The quantified approach is specifically a systematic tool that comes off the integrity assessment strategy segment and the integrity analysis aspect of the integrity management system (IMS) modified in Fig. 1. The IMS pipeline health and integrity strategy framework in Fig. 2 provides an outline for the development and implementation of the quantified approach from basic data quality verification to review the associated four degradation parameters which is consistent with the recommended technical guidance and integrity acceptance criteria defined in technical standards ASME B31.8S, 2010; DNV-RP-F116, 2009. It is denoted by the annual health indicator H and the lifespan health indicator H_{cn}, which connotes healthy, satisfactory or unhealthy status for a short term inspection data and the cumulative lifespan health status for n years in service respectively. Based on reviews of current practices and industry experience, this work presents a cost effective method of enhancing cost, safety and the environment in pipeline operations.

3. Selected degradation parameters

The technical background for modelling the conditions of the pipeline is described in this section with respect to the parameters considered to determine the health status as discussed in Section 2. These four parameters selected are considered as time dependent and seen to grow worse as the pipeline ages hence its criticality to pipelines safety according to ASME B31.8S, 2010. Crack growth rate can be calculated with time and is seen experimentally to either stagnate or proceed with tendency to cause accelerated failure due to ageing. Similarly, corrosion rate, external coating degradation rate and the amount of wall loss are all time dependent and have been proven in several researches to be exacerbated by ageing and varied plant operating conditions. In a paper by Liu and Meeker (2014) on using degradation models to assess pipeline life, corrosion initiation and growth behaviour were listed as critical factors. In the work on methods of assessing integrity of pipelines systems (Timashev and Bushinskaya, 2016), causes of pipeline failures were cited, and some of the parameters listed are external corrosion, mechanical damage, defects as well as internal corrosion and

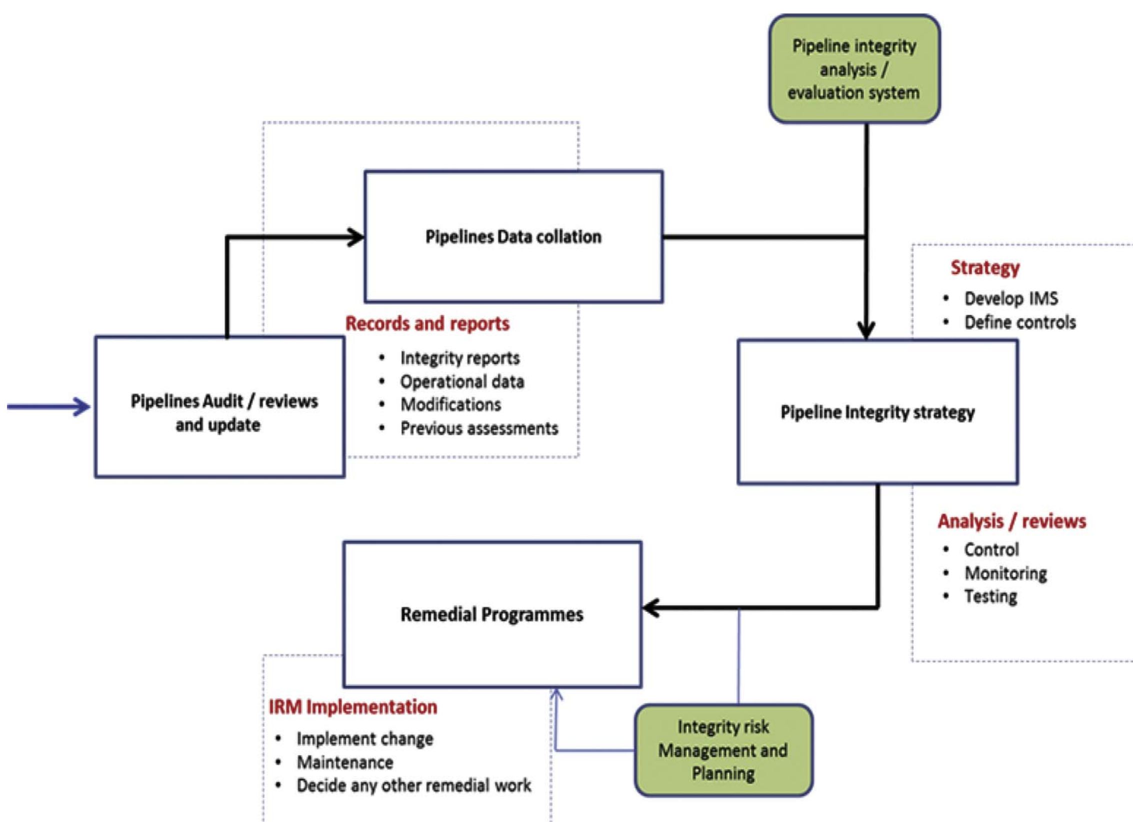

Fig. 1. Proposed modified pipeline health and integrity assessment process.