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Plant Screening for Ageing Impact in the Process Industry

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The degradation of onshore process plants due to ageing-related mechanisms such as corrosion, erosion and fatigue is becoming a key issue at a worldwide scale. Despite its increasing importance, ageing issues are seldom incorporated or anchored in a company's Management System.
This limited engagement of the onshore process industry towards ageing issues is to a large extent due to the absence of a governing legal framework, which otherwise is in place for offshore facilities, power plants and nuclear plants. The latter are under more scrutiny as the accompanying external, economic and environmental risks are more pronounced as compared to onshore process plants.
A recent HSE study however demonstrated that risks related to ageing onshore plants are far from negligible: roughly 60% of all loss of containment incidents are related to technical integrity issues, 50% of which have ageing as a contributory factor. This triggers the need to establish a Plant Lifetime Management methodology, accounting for ageing issues in this industry sector.
The overall approach for Plant Lifetime Management as described here contributes not only to the prevention and control of major accident hazards but, allows also for prioritization of investment efforts and, hence, sound decision-making with respect to managing critical assets.
This paper presents a new screening tool to assess the adverse impact of ageing on global plant performance and the collateral impact on major accident prevention programs. The newly developed BIP Scorecard (Business Impact Potential) provides a Predictive Ageing Score, composed of a set of 50 performance indicators (leading & lagging) which altogether leads to a risk profile which values the adverse effects of ageing.
This paper also highlights a new approach for Plant Criticality Analysis, designed to enable asset risk managers to prioritize their financial investments. This criticality assessment is consequence based only and allows for a first criticality ranking at 2 levels: 1) a high level screening at plant level (full scope) identifying the most critical units in the entire plant, and 2) a focused screening at unit or equipment level (reduced scope) allowing to identify the most critical equipment in a specified unit or critical components in a specified equipment. A subsequent risk assessment for the highest ranked assets considering the probability of failure of these target assets leads to a list of critical assets (risk based). These critical assets are the ones to be further considered in investment decisions and for establishing asset life plans.

1. Introduction

The Health & Safety Executive (HSE, 2006) ageing and ageing plant as follows: "ageing" is not about how old equipment is; it is about its condition, and how that is changing over time. Ageing is the effect whereby a component suffers from material deterioration and damage (usually, but not necessarily, associated with time in service) with an increasing likelihood of failure over the lifetime. Overall, **"**ageing plant**"** refers to a plant which is, or may be, no longer considered fully fit for purpose due to age-related deterioration in its integrity or functional performance.
The potential degradation of plant and equipment due to age-related mechanisms such as corrosion, erosion and fatigue is becoming a key issue at worldwide scale, but most particularly in the USA, Europe and Scandinavia where a huge number of high-risk companies were built after World War II. These companies are now older than 50 years and ageing is an undeniable fact.
Nevertheless, ageing issues are seldom incorporated in an integrated HSE Management System, nor are they consistently traceable / retrievable as causal factor in incident investigations. Most often, a separate

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systematic approach for managing major accident hazards is being introduced long after the Seveso dioxin disaster in 1976. Process Safety Management is introduced as part of enforcement initiatives from local authorities (Seveso Directive in Europe, COMAH Regulation in the UK and OSHA 119.1910 in the USA). Asset integrity issues are here incorporated to a large extent as a key element of Process Safety Management.
In this contribution, DNV describes a methodology based on literature search as observed from 3 key sources: the Nuclear Industry (IAEA, 2004), the benchmark project for the process industry (INERIS, 2009) and internal best practices for ageing offshore units [DNV, 2008 & 2009]. The methodology proposed in this article addresses plant lifetime management throughout the entire lifecycle of a typical onshore process plant, and introduces a suggested strategy to tackle the future needs of the ageing process industry.

2. Problem setting

2.1 Sense of urgency and importance

The relationship between ageing assets and major incidents has been examined recently across 3 main databases for major incidents reporting (MARS, RIDDOR and MHIDAS). The degree of comprehensiveness of the data search and the main conclusions are given hereafter in the Plant Ageing Study (HSE, 2006).
The MARS database (European Seveso sites) revealed that 28% of all reported "major accident loss of containment events" was estimated to be due to ageing plant. As the MARS database provides the more detailed and comprehensive insight into the incidents and causal factors of potential major accident hazard events, it is considered that this represents a more realistic indication of the extent and severity of ageing plant and its contribution to major accidents.
The MHIDAS database (worldwide) disclosed that due to the limited text field available it was perceived very difficult to identify the role of management systems, structures or safeguards in the incidents. Most of the data were considered insufficiently detailed or consistently recorded to allow any general conclusions on the extent to which ageing related failures have contributed to the incidents. This shortcoming was confirmed while examining the RIDDOR database (UK only) which indicated that between 1996 and 2008 there were 173 loss of containment incidents (5 % all loss of containment events) reported that could be attributable to ageing plant.
The Health & Safety Executive (HSE, 2006) concluded that plant ageing does constitute a threat to health and safety performance of hazardous installations onshore. Within the uncertainties of the review, a reasonable statement to describe the size of the ageing issue is that "approximately 60% of major hazard loss of containment incidents are related to technical integrity issues and, of those, 50% has ageing as a contributory factor". It therefore concluded that plant ageing mechanisms are a significant issue in terms of major hazard accidents.

2.2 Shortcomings in the regulatory framework for onshore process plants

From our literature search it came to light that compared with the offshore and nuclear facilities, very little information could be found on methodologies, articles and case studies pertaining to Plant Lifetime Assessment & Asset Lifetime Extension for the onshore process industry. Plant lifetime assessment & asset lifetime extension appeared to be predominantly visible for the nuclear and offshore process industry and to a much less extent for the onshore process industry.
The applied methodology for lifetime extension for offshore facilities is subject to a severe regulatory scheme, starting with a condition assessment and gap analysis (legal requirements and other requirements), and subsequently a criticality screening followed by risk assessment & risk mitigation to justify for life extension. This methodology is similar to the one applied in the nuclear industry; in both business areas the design lifetime is well defined upfront, after which a decommissioning takes place. An extension of lifetime can be considered only after a thorough assessment of the asset integrity and compliance considerations pertaining to the new extended life.
Within the power/nuclear and offshore process industry, the perception of risks towards the environment and people are more pronounced, meaning that the issue of lifetime extension is followed with a lot of scrutiny by authorities and the public.
In the process industry this same logic does not fully apply. Onshore process plants are usually not designed with a planned design life and a decommissioning time limit in mind. The average estimated design life of a typical process plant is about 25 years. Turnarounds are usually the triggering points to assess the integrity status of critical assets and those with the highest deterioration rate. There is a continual "rejuvenation" that takes place during these large turnarounds every x years. Onshore process

plants are continuously maintained and repaired as soon as ageing of assets is observed, and the inspection regime imposed by authorities is rather limited.
From our high-level review of the regulatory framework in Europe and the USA, we have concluded that apart from pressure vessels and to some extent the related process safeguarding systems, the attention focused by authorities is rather limited for a large fraction of process equipment. Almost no legal requirements exist for civil structures, for small bore piping and other pipework onsite the process plants, for rotating equipment and for Electrical Control & Instrumentation systems. It is recognized that inspection regimes may vary by country; as example we can mention that OSHA in the USA has not the same specific emphasis on boilers and heat exchangers as applicable in Europe. This is also highlighted in the process benchmark study (INERIS, 2009).

2.3 Business needs

Besides the increased risk of a major accident happening due to ageing and the lack of a sound regulatory framework , some other key business needs for a comprehensive approach in Plant Lifetime Management (PLM) are identified hereafter (non-limitative list):
PLM means risk-based decision-making: it provides insight in the assets lifecycle and consequently enables sound decision making. What-if questions such as: what if we don’t replace this asset, what would be the business impact. Or what would be the safety impact of not doing a certain work. What is the risk of operating beyond the planned design lifetime of an asset? This may avoid unnecessary capital investment when deciding upon lifetime extension.
PLM enables prioritizing investment efforts: (short or long-term) on a risk-based approach. Risk-based thinking helps in prioritizing and justified decision-making. Recognizing when and where investment is really needed may help in sound decision-making.
PLM provides transparency to shareholders: Being proactive in foreseeing when to extend the lifetime of the plant or specific assets suffering from ageing, builds credibility of senior management and reduces the risk of unpleasant surprises.
Anchoring PLM as part of an integrated risk management framework means prevention and controlling major accident hazards in a proactive way.

3. Proposed approach and methodology

3.1 Exploring the potential for Plant Lifetime Management (PLM)

Our approach provides a pre-screening step of the entire plant or targeted units to be scrutinized for potential adverse effects of ageing.
The BIP Scorecard (Business Impact Potential) provides a scoring based on a set of leading and lagging indicators of ageing; a set of 50 ageing indicators (classified in 6 categories) is used for this purpose. The following 6 categories of ageing indicators are considered here: plant & assets condition; availability & reliability; maintenance & inspection; major accident hazard potential & controls; operations integrity and environmental efficiency. Full details on ageing indicators can be found in DNV’s Research & Innovation report (Candreva, 2011).
A performance assessment is made with scores varying from 0 to 3 for all the ageing indicators. The higher the score the larger the adverse effects of ageing. By doing so one can calculate the overall ageing score and compare and benchmark against other plants or with other units in the same plant. An example is worked out hereafter for a company with a relatively high ageing score (bad performance for company A) and a company with a low ageing score (company B, good performance), see example in the figure below.
From the above example it seems obvious that company A with a relatively high ageing score is worth being further investigated with the PLM methodology.

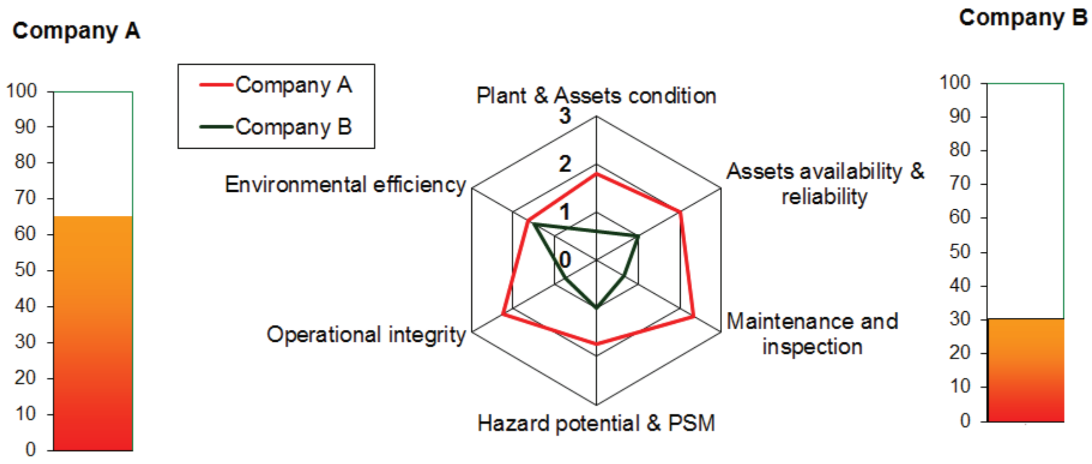

Figure 1: BIP Scorecard

3.2 PLM Methodology

Overall Approach:

The approach suggested here is built on the following leading principles:

1. The PLM methodology should be defined as broad as possible, covering the entire plant lifecycle (from concept to decommissioning / life extension)
2. The PLM methodology should be flexible enough to address the entire plant (full scope) or to zoom into a specific system, structure, equipment or component (reduced scope)
3. The applicable scope should be broad to cover the entire onshore process industry (refineries, chemical and petrochemical industry, gas terminals and other high-risk industrial activities as indicated by the Seveso II Directive or COMAH Regulation).

As mentioned, our approach is based on literature search and best practices as observed from the Nuclear Industry (IAEA,2004), the benchmark project for the process industry(INERIS, 2009), the DNV offshore best practice (DNV, 2009) and the Recommended Practice for Risk Based Inspection (DNV, 2009). This approach boils down to the following steps:

► Define the scope for the PLM application
► Divide the plant into manageable systems or units
► Consider one system or unit
► Identify the critical equipment / components via a criticality screening process
► Evaluate the risks / failure scenarios for selected target assets
► Assess the remaining lifetime
► Identify mitigation measures for lifetime extension & establish Asset Life Plans

Scoping for PLM

The scope of work should be defined based upon the level of detail that is requested by an organization; this can be triggered by the outcome of the BIP Scorecard eventually. Basically, there are 3 options:

1. PLM at plant level (full scope)
2. PLM at system or unit / structure level (reduced scope)
3. PLM at equipment and / or component level (reduced scope)

A full scope means that a Plant Lifetime Management study covers all structures and systems of the entire plant. A breakdown of the plant in manageable systems or units will be suggested; the level of detail of the underlying subsystems, equipment and /or components will be discussed with the client, aiming at establishing a complete plan of work with priorities and timeline. In the process industry systems often apply to a group of equipment with the same degradation mechanisms (so-called “corrosion circuits”). The term “structures” may refer to functional units or areas including the civil structures.

A reduced scope of work can vary from 1 or more systems or units, or it may be detailed at equipment level. In case the study is scoped to a specific target equipment / subsystem considered as a highly critical asset, the same 5-phased approach applies. The risk assessment would then be focused to a FMECA study to identify the critical components of a specific equipment or subsystem.

PLM methodology

A short description of the 5 phases is given hereafter:

1. Data collection & condition assessment

This first phase aims at delivering a Plant / Asset Condition Report that will serve as input to the next PLM phases. The data collection activity is partly done off-site / upfront and partly on-site the plant while conducting desktop surveys and expert site visits. Technical surveys & testing will be done as needed based on the scope definition. This Asset Integrity Review enables one getting insight in the most important degradation mechanisms and provides data related to the following topics: technical /mechanical integrity, operational integrity and design integrity.

2. Criticality screening

A criticality screening methodology is suggested here, aiming at defining the most critical structures, systems and equipment/ components. The objective is to enable plant executive management to improve their ability to manage assets by criticality and to prioritise financial investments to the most essential elements. This methodology is a new development, inspired by literature search on criticality ranking methods (IAEA, 2004 and Seifeddine, 2003).

The Criticality Analysis Model defines criteria and characteristics that will be used to analyze each maintainable group of assets. It is worth noting that the criticality screening tool is consequence-based. The criticality rank number of a system or equipment is a function of the system's or equipment's impact on the business when the system or equipment fails, regardless of how often the failure occurs. Criticality ranking rules are defined to assist in assigning criticality ranks to systems or equipment during the analysis (Candreva, 2011).

3. Risk Assessment & Ranking

It is worth noting upfront that while the criticality screening tool is consequence-based, the risk assessment & ranking method considers also the failure frequencies. The classical risk assessment techniques can be used for risk assessment & risk ranking, provided that an appropriate risk matrix is used.

4. Remaining lifetime of critical assets

The Remaining Lifetime of critical assets with a high risk ranking can be estimated based upon considerations, as described in literature (IAEA, 2004 and HSE, 2006).The assessment of remaining lifetime can be made at any stage once the type, scale and rate of the deterioration mechanisms have been identified.

5. Mitigation measures for plant lifetime extension (asset life plans)

Once the remaining lifetime is known the key issue is to decide what to do: what are the options to address ageing? Once the existence, extent and mechanism of damage in a component or equipment have been established, the available options range from decommissioning to damage removal (with or without replacement), temporary repairs, undertake fitness-for-service assessment, changing operating practices etc. . Deciding for lifetime extension implies a detailed investment plan for the identified critical assets with a high risk ranking. Asset Life Plans are established detailing the planned mitigation measures and related costs for risk reduction.

4. Conclusion

It can be concluded that due to shortcomings in the regulatory framework for the onshore process industry, the effectiveness of companies managing the integrity of ageing assets is highly dependent on own initiatives and their application of industry best practices.

The authors, therefore, recommend establishing a Joint Industry Project to pilot the value of a comprehensive Plant Lifetime Management approach as presented here. In addition, it is highly recommended to conduct a study to estimate the cost and business impact for companies not managing plant lifetime in a coherent and sustainable way.

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