Modeling of Inspection and Maintenance of Static Mechanical Equipment on Aging Oil and Gas Production Plants
Associate Professor Chandima Ratnayake, IKM

Background
Many of the production facilities on the Norwegian Continental Shelf (NCS) the design life of 20-30 years is exceed by many years due to improved oil recovery techniques. Static mechanical equipment such as valves, separators, tanks, vessels, pipelines, etc. have undergone inherent degradation due to aging, corrosion, erosion, etc. Often the degradation rates vary over the lifetime due to changes in the produced oil and gas well stream (e.g. changes in CO₂, H₂S, water, sand content). The operators have large databases containing historical data about corrosion and erosion, wall thickness reduction, etc. This data together with experience is used to identify the critical locations of particular production plant and to develop and update plant maintenance and inspection strategies. However, inspection planning is a difficult process with many uncertainties as well as difficult and costly decision processes – in the worst case bad inspection planning could lead to undiscovered degradation which may cause catastrophic failure with fatalities.

Inspections are recommended based on historical data, engineering judgments and current well stream content (e.g. amount of sand, water, CO₂, and H₂S). For example, it is well known that there is high possibility for: corrosion in dead-legs and blind flanges along piping due to the standstill product; erosion due to sand particles in the pipeline sections just after the choke valves; etc. The degradation is measured based on the remaining wall thickness and the wall thickness degradation acceptance criteria and recommendations are found in for example ASME B31.3. When the remaining wall thickness reaches $T_{min3}$ (see Figure 1), the technical condition is assumed to be virtually zero (see Figure 2). The wall thickness is measured during inspections using Non-Destructive Testing (NDT) methods such as radiography, ultrasonic testing, pulsed eddy current, etc. However, for aging platforms where the design life is passed and the production is reducing fast, it is a challenge to uphold the performance and technical integrity of the facility whilst reducing the costs.

On this background we have observed the following industrial challenges:

1. The preventive maintenance (PM) shutdown periods are very limited due to tight production schedules and budgetary restrictions. Hence, it is not possible to carry out many of inspections within the available shutdown time.
2. There is a high number of static mechanical equipment that has not been inspected since the date of installation.
3. Often we find that the measured wall thickness data is not reliable due to poor interpretation of NDT results.
4. Personnel appointed for inspection planning is frequently changing jobs which results new personnel to take over the inspection planning. This makes the problem more complicated due to problems in transferring knowledge and experience.

5. However, the quality of the inspection programs made by an inspection planner who is new to the profession is not much better than one made by an inspection planner with relatively high experience.

6. Furthermore, the inspection programs made by experienced personnel also seem to be narrowed in their views due to lack of holistic overview about the problem situation and dependability of current findings instead of making real engineering judgment.

7. Based on the time, mood and/or state of mind of the person who is carrying out inspection planning, the extent of the usage of engineering judgment and knowledge can be limited.

8. Wastage of money at planning stage as some of planned points is not being implemented during PM shut-down.

9. In general in the North Sea, the influence of the engineering function has declined to a worrying level and the technical authorities are under pressure, often reacting to immediate operational problems rather than taking a strategic role to provide expertise and judgment on key operational engineering issues (See KP3, 2009).

Based on these observations we propose a research study focusing on modeling inspection planning to improve the situation.

**Research objectives**
The main research objective is to model inspection planning to reduce costs and to increase efficiency of inspection planning. The sub-goals include:

- Identify state-of-the-art and to understand current practices of risk based inspections (RBI) and in-service inspections (ISI) of static mechanical equipment
- Identify if the frequent job-changing of inspection planners affect the technical integrity of a particular production plant.
- Analyze how the quality of historical inspection data affects the inspection results and quality.
- Develop a method to calculate optimum inspection volume based on budgetary restrictions and the “health” of static equipment
- Develop a model to mechanize the inspection planning process to reduce impact of the human element and the quality of data from different sources.
- Integrate expert knowledge and different data sources to mechanize the planning process.

To achieve these goals the following research activities are suggested:
Research activities:
1. A literature survey of current state-of-the-art: risk based inspections (RBI) and in service inspections (ISI) of static mechanical equipments in different applications such as Nuclear Power Plants, Offshore Oil & Gas Production and Process Plants, Gas Processing Plants (e.g. Kårstø and Kollsnes), etc.
2. Carry out a comprehensive analysis to understand RBI categorization of different Production & Process Plants and how ISI are carried out by different companies.
3. Carry out a survey to study frequency of changing jobs those who are carrying out inspection planning and how does it affect the technical integrity of a particular production plant.
4. Assess and analyze the quality and reliability of recorded NDT data, as they are with lack of uniformity.
5. Carry out an analysis to calculate optimum inspection volume based on budgetary restrictions, finding rates, technical condition, and amount of non-inspected static mechanical equipments.
6. Integration of expert knowledge and different data sources to mechanize the planning process using mathematical tools such as: fuzzy set theory, artificial neural network (ANN), Stochastic Petri nets or using a unified modeling language (UML).
7. Develop a comprehensive rule based model to mechanize the inspection planning process to reduce the human involvement to compensate repeated engineering judgment process and to deal with different data bases and sources simultaneously.

Expected outcomes
By having a Fuzzy Rule, Stochastic Petri net, ANN and/or UML based mechanized inspection planning approach, a company should be able to improve the static equipment inspection programs and enable a more proactive and holistic data handling process. Furthermore, such a model should improve the influence of the engineering function by making the data handling easier, and change the working processes to a more proactive planned process instead a “fire fighting process” focusing on reacting to immediate operational problems.

It should also enhance the possibility of taking a strategic role to provide expertise and judgment on key operational engineering issues. This should reduce the possibility of events with catastrophic outcome caused by degraded aging production and process plants and enable a company to maintain sustainable production operations in the NCS.

Reference
Figures

Figure 1: Degradation measurements: limits of piping wall thickness

Figure 2: Wall Thickness vs. Technical Condition