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Maintenance grouping optimization for the management of risk in offshore riser system

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ABSTRACT

Riser system failure in relation to major accidents is one of the potential undesirable events in the offshore petroleum industry. It has the potential for high consequence such as several fatalities/injuries, severe environmental impact or gross economic loss. Besides, it may be related to maintenance being insufficient, incorrect, a new hazard source or a triggering event for an accident scenario.

Furthermore, there has been a paradigm shift in the design of unmanned platforms following the Piper Alpha disaster in 1988. Firefighting systems are usually not installed anymore based on the reason that the risk reduction benefit they offer to maintenance personnel is not commensurate with their frequency of visits unlike in manned facilities, i.e. a negative risk balance. In manned facilities, where such safety systems are installed, maintenance personnel are subject to major hazard exposure due to the visits required of them. Hence, there is the need to reduce the risk to personnel as much as reasonable. Maintenance grouping optimization can serve as an alternative contributor to the reduction of maintenance frequencies which should reduce the risk, but on the other hand, as the human error opportunities increase, the likelihood of making errors increases which increases risk.

The main objective of this paper is to investigate how maintenance grouping optimization and the potential human error can be balanced in relation to reducing the major accident risk. The paper builds on a review of literature on maintenance optimization, human reliability and risk.

1. Introduction

The offshore petroleum industry has the potential for major accidents which may be characterized by major release, major explosion or major fire. This is associated with the storage, handling or production of dangerous substances such as hydrocarbons. Offshore riser system failure in relation to major accidents is one of the potential undesirable events in the industry. It has the potential for high consequence such as several fatalities/injuries, severe environmental impact or gross economic loss. The failure may be related to design error, manufacturing defect, construction defect, operational and environmental loading, maintenance deficiencies, collisions, anchor dragging or dropped objects. As regards the maintenance-related deficiencies, maintenance being insufficient, incorrect, a new hazard source or a triggering event for an accident scenario may be seen as typical causes of major accidents (Okoh and Haugen, 2013a,b, 2014). The major components of the riser system include the riser itself, riser isolation valve (RIV) and subsea isolation valves (SSIV) as shown in Fig. 1.

A timeline of some riser system incidents/accidents, include the following: Oil riser fire on Ekofisk A in 1975, North West Hutton gas riser leak in the UK in 1989, Cormorant A

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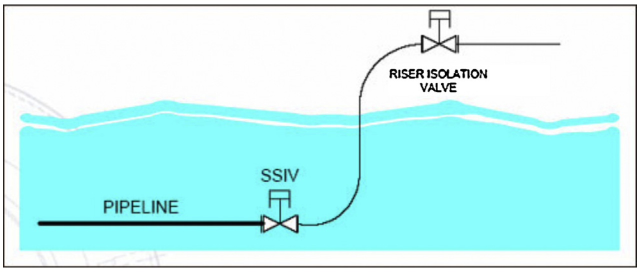

Fig. 1 – An example of an offshore riser system.
***Source*: Aker Kvæner.**

gas riser leak in the UK in 1989, Tartan A gas riser leak in the UK in 1991 (DNV Technica, 1995), Cabinda Gulf Oil Company's GS Fox gas riser rupture in Angola in 2000 (Ward and van Roodselaar, 2005), riser leak at Platform Elly in USA in 2002 (Hoffman and Vasquez, 2002), riser disconnect and spill in USA in 2005 (Woltman and Smith, 2006), riser rupture in Petrobras' Guara Field in Brazil in 2011 (Petrobras News Agency, 2011) and riser rupture in Petrobras's Carioca Nordeste field in Brazil in 2012 (Fikk, 2012). Some of these cases resulted from lack of maintenance allowing failure mechanisms such as corrosion and fatigue to breach the risers. In the case of the Guara field, the incident happened during the maintenance phase itself.

Furthermore, according to Evans and Thakorlal (2004), safety systems such as fire pumps offer negative risk balance with respect to unmanned platforms, i.e. the exposure of personnel due to maintenance visits to such facilities is not justifiable compared to manned platforms. This philosophy, also called "burn down," was borne from reviews following the Piper Alpha disaster in 1988 (Evans and Thakorlal, 2004) and led to a paradigm shift in the design of unmanned platforms whereby firefighting systems are intentionally being omitted. In manned facilities, where such safety systems are installed, maintenance personnel are subject to major hazard exposure due to the visits required of them. Besides, increased maintenance frequency increases the opportunity for making error (Reason, 1997) and this may increase risk. Given that riser systems possess the major accident potential, there is the need to minimize the exposure of maintenance personnel to them as much as reasonable, which underscores the need for maintenance optimization. Maintenance optimization is about balancing the benefit of maintenance with cost or risk. The element of maintenance being optimized may be the interval, the strategy, the manpower, the spare parts, the time of renewal, grouped activities, etc. (Vatn, 2007). Maintenance grouping optimization can serve as an alternative contributor to the reduction of maintenance frequencies which should reduce major accident risk, but on the other hand, as the human error opportunities increase, the likelihood of making errors increases which increases risk.

Although several studies have been carried out on maintenance grouping over time, an article that sufficiently addresses the possible imbalance between the potential human error and grouping maintenance has yet to be seen. Existing methods of maintenance grouping are divided into two: Static grouping and dynamic grouping. Static grouping is further divided into indirect static grouping and direct static grouping (Wildeman, 1996; Dekker et al., 1997). Dynamic grouping differs from static grouping by being flexible to adjustments based on new information and unexpected interruptive events, whereas static grouping is rigid with the grouping remaining unchanged throughout the lifespan of the system (Wildeman, 1996; Vatn, 2008). Detailed introductory theories of both strategies can be found in some of the referenced literature. Besides, beyond just modeling, the practical application of maintenance grouping optimization has been demonstrated on the railway system (Vatn, 2008) and on offshore wind turbines (Hameed and Vatn, 2012). All the earlier research on maintenance grouping optimization had the objective of set-up cost saving, yet none of them addressed the problem of negative economic dependency. This paper intends to address this issue.

The main objective of this paper is to investigate how maintenance grouping optimization and the potential human error can be balanced in relation to reducing the major accident risk in the process industries. This will be applied to the offshore riser system as an example. The rest of the paper will be structured as follows. Section 2 will discuss negative economic dependency in relation to maintenance grouping, Section 3 will analyze human reliability issues, Section 4 will analyze how to balance maintenance grouping optimization and the potential human error, Section 5 will present a case study and finally, Section 6 will conclude the paper with highlights of the findings.

2. Negative economic dependency: a challenge for maintenance grouping

Maintenance grouping is a concept that enhances maintenance optimization by combining maintenance activities based on some policies and criteria leading to savings in set-up cost (Nicolai and Dekker, 2008; Vatn, 2008; Castanier et al., 2005; Wildeman et al., 1997; Dekker et al., 1997). In other words, maintenance grouping usually aims to complete the maintenance of items that have been grouped together within a fixed time interval or a given opportunity, which leads to maintenance being carried out simultaneously to take advantage of shared maintenance set-up cost. The original objective is cost saving.

However, this traditional objective of maintenance grouping (cost saving) can be extended to cover risk reduction benefit as well. Besides, both the cost and risk based objectives can be affected by negative economic dependency as follows. It can be expected that the major accident risk associated with maintenance will decrease as we increase the degree of grouping, i.e. personnel exposure to high risk installations will decrease with reduced frequencies of maintenance visits. However, beyond an optimal degree of grouping, the potential human error becomes unacceptably high. The human error opportunities encompass unsafe increase in an individual's workload, opportunity for variability in maintenance (dependent on the condition of plant revealed by inspection, etc.) and human error dependency between tasks. With respect to workload, the deployment of more personnel (i.e. extra human resources) as a solution may not be viable since this will increase labor cost and exposure to risk (Nicolai and Dekker, 2008). The implication of not being able to manage the aforementioned challenges is incurred costs of damage, unavailability, rework, accident, etc.

All the aforementioned challenges of maintenance grouping constitute negative economic dependency, i.e. a situation whereby it becomes more profitable to maintain components individually than simultaneously. The opposite is positive economic dependency which involves cost saving from joint maintenance (Nicolai and Dekker, 2008; Dekker et al., 1997).