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Development of risk assessment model for equipment within the petroleum industry

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Abstract: Maintenance department within petroleum industry seek to increase equipment safety by means of reducing the occurrence of the failure and its undesirable consequences. In this study, a risk assessment model is proposed, which includes the likelihood of the risk and the consequences of failure. A new mathematical equation is proposed to assess the likelihood of risk and identify the optimum inspection interval. In addition, modified mathematical equation to evaluate consequences of risk which allow more generalization and accuracy of weighing the possible losses (performance, financial, ecology and human) is developed. The results demonstrate an improvement at the assessment of the probability of risk and provide better understanding of the impact of the risk on the major identified areas within the petroleum industry.

Keywords: Maintenance Models and Engineering, Risk Assessment, Asset and maintenance management and Maintenance and Related Services

1. INTRODUCTION

Risk assessment within the petroleum industry is an important phase due to the intolerable consequences of failure. Therefore, Maintenance team plans their tasks for preventive maintenance (PM) for the petroleum equipment to identify the most optimum maintenance intervals from the perspective of reliability, availability and cost reduction as well as unpredictability or uncertainty of the occurrence of the failure. One of the maintenance's tasks is to ensure the system's reliability through preventing the possibility of the occurrence of failure and eliminate the consequences of the risk. Thus, ensuring that the equipment would serve as attended or planned till the next maintenance interval.

In order to enhance the reliability of a system, inspection interval would be planned to ensure that the equipment's reliability would meet the expectation of the planned preventive maintenance. Inspection frequency is determined according to risk exposure, which can be used to control any unacceptable risk (Chang et al 2005).

Dawotola et al (2012) defined risk as "the considered expected loss or damage associated with the occurrence of a possible undesired event". Reynolds (1996) stated that risk assessment may be quantitative or qualitative in nature. Khan et al (2001) defined the science of risk assessment (RA), which has emerged in recent years with ever-increasing importance as a process that includes both qualitative and quantitative determination of risks and their social evaluation. Maylor (2010) stated that the majority of risk management activities rely on qualitative data which is obtained based on people's perceptions of risk levels.

In this study, a risk assessment model is proposed to guide the maintenance team to carrying the risk assessment. The rest of the paper is divided to cover the architecture and the proposed model including the new and modified equations. The application and results of the proposed model are presented to validate the proposed models and finally the conclusion is drawn.

2. ARCHITECTURE OF THE PROPOSED MODEL

The proposed model is expected to enhance estimation of the risk and its consequences instead of the conventional method that considers the multiplication of the likelihood by consequences, which can be misleading. Incorporation of modified models and a newly developed equation is proposed in order to assess the risk. The proposed risk assessment model relies on the use of both qualitative and quantitative methods. Figure (1) demonstrates the contents of the proposed model of estimating the risk for equipment within the petroleum industry and the following sections provide detailed description of its components.

2.1 Likelihood Assessment

In this step, an estimation of the probability of failure occurrence is performed by qualitative and quantitative means to build generic conception that consider the majority of the facilities within the petroleum industry.

2.1.1 Qualitative Assessment

Probabilistic failure analysis is conducted using the fault tree analysis (FTA). The use of FTA along with components failure data and human reliability data enables the determination of the frequency of occurrence of an accident (Dawotola et al 2009). The top event is identified based on the detailed study of the process, control arrangement, and behaviour of components of the unit/plant. A logical

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dependency between the causes leading to the top event (failure) is developed in this stage.

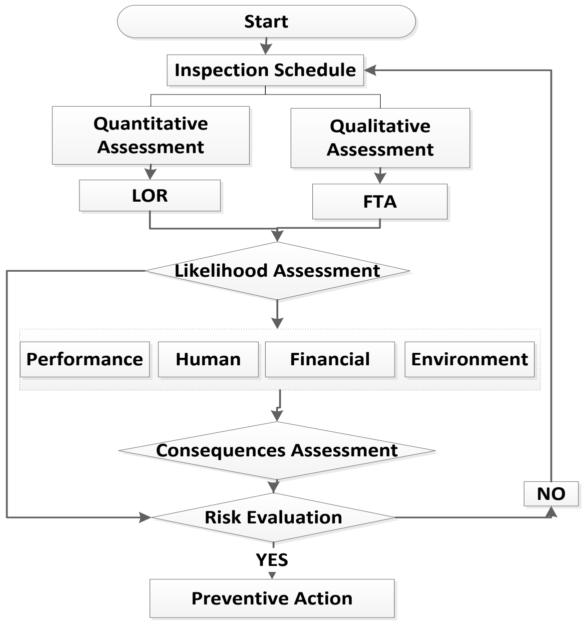

Fig. 1. Description of Risk Estimation Model

2.1.2 Quantitative Assessment

Quantitative analysis is conducted to estimate the probability of the occurrence of the risk. In order to validate the proposed risk estimation model, a degree of acceptance of risk has to be set up against the estimated risk. The developed proposed mathematical model (Likelihood of Risk (LOR)) is based on the assumption that the risk depends exponentially on time P, where P is the physical age of the equipment and d is the design age of a part/machine(the expected life of equipment). The assumption is that risk depends exponentially on time (P) :- (Risk $\propto P$).

$$Risk(P) = F(\Delta P) * G\hat{}(P/d) \quad (1)$$

Where, G is a positive growth factor of the risk and the time required for risk to increase by one factor of G. $F(\Delta P)$ is the probability of the failure of the part/machine.

$$Risk\ (P+d) = F(\Delta P) \times G\hat{}((P+d)/d) \quad (2)$$

d is the designed life of the part or equipment. The time required for risk to increase by one factor of G.

$$Risk\ (P+d) = F(\Delta P) \times G\hat{}(P/d)\ G\hat{}(d/d) \quad (3)$$

Therefore, if d=0 and G>1 then LOR (P) has exponential growth. Thus, formula (3) can be written mathematically as: -

$$LOR = F(\Delta P)\ e\hat{}(P/d) \quad (4)$$

The developed equation (4) is proposed to be applied for two main purposes. The first purpose is to estimate the likelihood of the risk instead of relying on solely failure distribution and the second purpose is to optimize the inspection intervals as extensively shown in section (3-1). Bertolini et al (2009) proposed classification of the occurrence degree of the failure to be compared to the outcomes of probability of the failure $F(\Delta t)$ as shown in table (1). He relies on the Cumulative Weibull distribution model to generate $F(\Delta t)$. However, in this work, the same classification is applied but will be allocated to outcomes of developed equation LOR instead of using the $F(\Delta t)$.

Table.1. Assigning probability classifications

Class	Key Word	Absolute value of $F(\Delta t)$ /LOR
A	Very Unlikely	0.001
B	Unlikely	0.05
C	Neutral	0.3
D	Likely	0.5
E	Very Likely	1

2.2 Consequences assessment

The objective of this phase is to estimate the consequences of failure and its contribution to the system to prioritize equipment and their components on the basis of their undesirable contribution to the system. Khan and Haddara (2003) identified four impacted areas where consequences of the failure have to be evaluated which are: -system performance loss (A), financial Loss (B) human health loss (C) and environmental loss (C). Equation (5) presents the combined loss in order to find the overall consequences of the risk. Equation (5) is modified to enable maintenance team of prioritising the importance of the loss factors while investigating the four loss factors instead of following the proposed equation of Khan and Haddara (2003)which strict them into mathematically weighing the four losses equally.

$$Consequences = \{W_a\, A^2 + W_b\, B^2 + W_c\, C^2 + W_D\, D^2\}^{0.5} (5)$$

Where, W_a weight of performance loss, W_b weight of financial loss,W_c weight of human health loss and W_c weight of environment loss.

2.2.1 System Performance Loss

Factor (A) represents the system performance loss due to the equipment failure. Equation (6) is developed to represents the system performance loss.

$$A = \begin{cases} Function\ performance & Table\ (2) \\ 0 & Otherwise \end{cases} \quad (6)$$

Equation (6) shows two possible scenarios: - If the equipment has a stand-by redundancy, then this factor is considered as zero. The second scenario: - if the equipment is a vital to the system then the proposed quantification scheme by Khan and Haddara (2003) is considered to take the measures of the loss as shown in table (2).

Table.2. Performance Function

Class	Description	Function
I	-Very important for system operation -Failure would shut down the system	8-10
II	-Important for good operation -Failure would adverse consequences	6-8
III	-Required for good operation -Failure may affect the performance and may lead to subsequent failure	4-6
IV	-Optional for good performance -Failure may have no immediate affect	2-4
V	-Optional for operation -Failure may not affect performance	0-2