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RISK BASED MAINTENANCE (RBM) MODELING OF PETROCHEMICAL INDUSTRY USING FAHP- DELPHI TECHNIQUES

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Abstract: The progress of technology has caused operating of many processes and resulted in more complexity of the process industries and the safe operations of their operation are at least as important as their design. In addition, the cost of maintenance is a considerable part of the total life cycle in industries and researches proved that some critical components are responsible for the most of the downtime at workplaces. Therefore, an improvement in the maintenance practices which focused on risk based approach for critical components improves reliability and safety; at the same time can reduces maintenance costs. Thus, we aim to prepare a domestic risk management model for based on Risk Based Maintenance (RBM) using FAHP technique. The initial steps involve literature review followed by subsequent interviews with experienced practitioners to identify their failures. All of the RBM criteria have been localized by expert team and risk number could be calculated according to these factors. However, there are several tools to analysis the risks of them, but the classic approach always comes with uncertainty. Thus, FAHP model will be introduced as an applicable approach for modeling of the risk management to overcome this limitation. Overall, by applying this technique, it will be anticipated that the safety of system will be improved, the environmental impacts and maintenance costs would be reduced, and the spare parts will be allocated where necessary. Finally, this technique results in prioritization of the process's safety measures according to their risk levels.
Keywords: Risk, Fuzzy, Safety, Process, Hazards

Introduction

The progress of technology has caused operating of many processes and resulted in more complexity of chemical process industries, so that one of the main challenges for these companies are to manage existing assets in the complex infrastructure(1, 2). However, beside of valuable application of these industries, there are potential risks associated with their chemical processes (Figure 1).

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Accidents like in Bhopal and Basle led to the development of a regulatory regime to control the risks in these industries (3). Thus, the safe operations of these systems are at least as important as their design(4)so that designers and operators have to find appropriate solutions to ensure safety of operations as well as being economically viable.

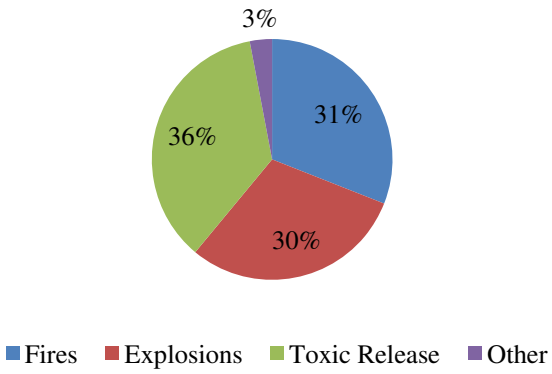

Figure 1: Types of large hydrocarbon chemical plant accident (5)

On the other hand, the cost of maintenance is a considerable part of these industries (6-8). Researches have shown that critical components such as pumps, compressors, vessels account for the most of downtime in this practice. Therefore, an improvement of maintenance practices that focused on risk-based approach for critical components may improve the reliability and safety as well as reduce maintenance costs(1, 2, 9-12).

There are different risk-based approaches ranging from purely qualitative to the highly quantitative. Based on literature, they are different from one industry to another according to its specific critical conditions (13). However, the RBM approach is one of hybrid risk assessment techniques that consider the combination of quantitative and qualitative techniques to reduce overall risks in the operating assets(14).

Studies showed that there is uncertainty in the judgement of experts' knowledge and experience and it's necessary to consider it within expert based risk assessment. However, methods like classical statistic, probabilistic, sensitivity analysis and possibility are recommended to solve this issue, but there are common opinion that fuzzy logic is one of the best ways in order to deal with this kind of uncertainty and the vagueness of human's judgments(15-17). Thus, Fuzzy Logic Toolbox of MATLAB software was used for estimation of risk to overcome this limitation.

Proposed RBM Model

The initial steps involve literature review to identify critical assets and equipment failures. The subsequent interviews discussed these issues with experienced panel,made up of

academic professor, turbine operators, maintenance engineer, and plant and process engineering, to form proposed approach.

This approach was performed in Turbine Unit within Petrochemical Company as a case study in order to demonstrate its usefulness, characteristics and for efficient maintenance scheduling. However, through three rounds of Delphi process experts helped to filter all the information to come up with a series of the most important strategic actions to the RBM of assets. Also, HAZOP[1]and FMEA[2] studies conducted by the Delphi team for identifying failures and calculate final risk using literature review and finally proposed a model (1, 18-22)(Figure 2).

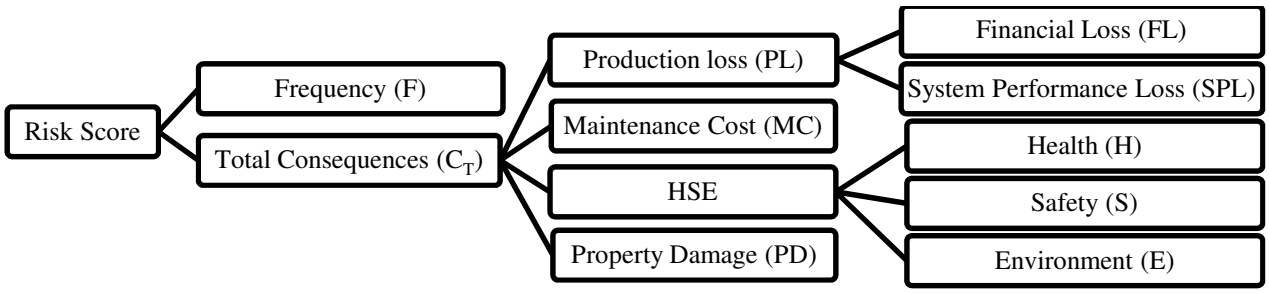

Figure 2: Proposed Model for Risk Analysis of Chemical Process Industries

In order to weight risk indices in different level, all factors are compared with both of Expert Choice software (Version 11.0) and designed AHP algorithm on MATLAB used experts' empirical judgments (23-25). However, expert team proposed the following formula to calculate the Non-Fuzzy Risk (R_{nf}) of every failure by considering its components' weighting factor (W) which came from pair comparison:

$$R_{nf}(failure) = (F \times W) \times (C_T \times W)$$

$$C_{PL} = \frac{(FL \times W) + (SPL \times W)}{\sum W}$$

$$C_{HSE} = \frac{(H \times W) + (S \times W) + (S \times W)}{\sum W}$$

$$C_T = \frac{(C_{PL} \times W) + (C_{MC} \times W) + (C_{HSE} \times W) + (C_{PD} \times W)}{\sum W}$$

The panel finalized guidance tables in order to rank these criteria for calculation in thetotal risk of each failure. For simplification and also reduction of experts' error, all of these scales categorized from 1 to 5 (Five for the high failure rate or higher impact and on the other hand one for less frequent failure or less consequences).

[1]Hazard and Operation
[2]Failure Mode and Effect Analysis

The engineering and expert knowledge base used to establish the set of rules by the collection of IF-THEN statements (e.g. Rule 1 if (frequency is very low) and (consequence is very low) then the risk is very low). Then, the fuzzy risk (R_f) value calculated using the failure consequences and frequency as input and risk number as an output. Finally, the RBM calculated by summing up the individual FR out of the total number of failures (N) within the subsystem as follows:

$$RBM(\text{subsyetem}) = \frac{\sum_{i=1}^{n} R_{fi}}{N}$$

Conclusion

The proposed model applied in the Turbine and Generator Unit of the Petrochemical Company as a case study. Totally, 7 subsystems and 32 P&IDs have been assessed. Results of proposed risk models for maintenance program showed that oil system is the most important component for the maintenance. However, 39 recommendations suggested to mitigate failures in selected asset.

Furthermore, the expert team believed that using Fuzzy Logic and AHP's pair comparison weighting, would improve the performance of the system. Reduction in HSE consequences, cut in maintenance cost, decrease in property damage, and an allocation of spare parts where necessary were the main reasons.

Discussion

Overall, this model contribute to the prioritization of recommended maintenance practices, according to their risk levels and using this technique positively effects the scheduling of these activities. Of course, the robustness, sensitivity analysis, and safety integrity level (SIL) studies for further researches are recommended by the authors in order to find the application of this approach in other industries.

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