論　文　要　旨 Dissertation Abstract

令和　2020　年　01　月　10 日
Date (YY/MM/DD): ___2020-01-10_____

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論文題目 Dissertation Title	Accident Modelling and Uncertainty Assessment in Risk and Reliability Quantifications to support New Technology System using Bayesian Approach

The overall objective of this Ph.D thesis has been to develop strategies for addressing uncertainties in the risk assessment. It addresses Accident Modelling and Improvement in Risk and Reliability Quantifications based on Probabilistic and Statistical Modelling to support New Process Technology Risk Assessment. The concept of the research aims at addressing uncertainties in risk and accident modelling by using dynamic bayesian based assessment.

Leak rate estimation, Failure frequency estimation and Risk based Inspection modelling are some of the important measures of risk and reliability quantification. Risk quantifications involve many uncertainties, and assessing probabilities to represent these uncertainties is itself a complex task utilizing a variety of information sources. At a practical level, uncertainties are driven by three important modelling issues; accident, failure probability and risk based model. The current modelling issues are related to model structuring, probability assessment, information gathering, and sensitivity analysis. The doctoral research is focused on addressing uncertainty in these areas of risk and reliability quantifications to support risk assessment.

By virtue of the new knowledge developed during the Ph.D, the decision makers are expected to gain a better insight into the pros and cons of accident analysis using statistical models, improvement areas in risk assessment, how uncertainty in risk assessment influences major accidents, the risk based inspection model, the degree and distribution of the causes of human factors in the hydrogen station unwanted releases.

The key objectives of this thesis include:

- *Propose a model for lack of data uncertainty and its treatment.*
- *Statistical interpretation of data and use of advanced frequency based models for accident and failure data analysis.*
- *Develop quantitative insights in the study to set performance standards for availability and reliability in operation and maintenance of the Hydrogen stations.*
- *Verification of risk and reliability quantifications using aging/life parameter method.*
- *Improvement in risk and reliability quantification using Bayesian update process.*
- *Propose a risk based inspection model to optimize inspection test for identified safety critical components.*
- *Propose a methodology for human error critical task assessment using bayesian networks.*

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This PhD project contributes to the scientific evaluation of the presented work by a detailed description of the model, an assessment of the content, and a description of the limitations and benefits of the model. The research aim to benefit academic risk analyst and process industry engineers who constantly perform various risk assessments on engineering system. Taking into account the practical engineering challenges, the research attempts to keep the work as simple as possible.

The concept of the research is focused on three things:

1. New technology system (or engineering system)
2. Treatment of uncertainties in risk and reliability quantification
3. Bayesian dynamic modelling

The originality of the research is the application of dynamic modelling for treatment of uncertainties in the field of risk and reliability quantification for new technology system. The bayesian technique is quite old and has been commonly used across various applications. Fundamentally though these technique often are ‘black boxes’ and are not easily understood by safety engineers, in applications such as accident modelling or risk and reliability field. This could be due to the complexity of the approach or lack of availability of software in the risk field. Another limitation in the ‘industrial risk learning’ case is that it involves collecting abundant data for statistical interpretation. You need a good reliability data to justify risk model for example. New engineering system lacks such good quality data and hence not compatible with the existing statistical modelling approach.

These limitations make it difficult or impossible to make models that work with only a small amount of data and leverage domain-specific expertise. They also adversely affect models in

dangerous or legally complicated contexts such as risk or insurance. The models that yield predictions must come with confidence that allow one to assess risk. For example, it's important to know the uncertainty estimates when predicting likelihood of a hydrogen release having a high consequences.

Until recently the practical engineering challenges of implementing these systems were prohibitive, and required a large amount of specialized knowledge. Thus we introduce probabilistic dynamic modelling to risk science. Probabilistic dynamic modelling (PDM) hides the complexity of Bayesian inference, making these advanced techniques accessible to a broad audience of risk and reliability analysts. PDM allows to incorporate your domain knowledge with your observed data. It is powerful for three reasons:

- For allowing to incorporate domain knowledge
- Works well with small or scarce datasets
- It is interpretable

In the past 10 years, several researchers have introduced the concept of bayesian in the academic science, however they were conceptually applied without addressing practical challenges in the risk and reliability field. If we go beyond these limitations, we open the door to new kinds of products and analyses that is the subject of this thesis. The fundamental ideas of probabilities and distributions of results are the basic building blocks of models utilized in this paradigm. One of the impactful idea in this research has been deep learning for risk analysis. This can change the way we perceive and treat risk in the near future.

In this PhD project, it was possible to perform case studies where the method can be tested for a specific application. In this case, the results may be validated qualitatively or by expert judgments, or preferably, compare the results with outcomes from other recognized and comparable methods. The development of frameworks and methods is based on logic

arguments, initial assumptions, existing methods, and knowledge to derive new relationships or insight. In such cases, the validity of the method is confirmed by comparing with other suitable methods.

In the early phase of design and operation, a new technology system is aimed on only the positive aspects of the risk such as profit, usability, social benefits etc. However, it should be understood that these are not the only benefits the technology can bring to the society. The negative aspects of the risk such as injury, leakage etc. can also bring benefits to the society over the long run by reducing production downtime, increasing safety, environmental protection and company reputation through public confidence. The process safety is a vast field with numerous areas that can be addressed to improve safety and risk. The PhD project focuses on safety and reliability engineering areas. The idea of introducing dynamic modelling in various safety and reliability engineering aspects was the key motivation in undergoing the PhD project. Therefore, we decided to address several issues that are often highlighted in several research papers however still there is insufficient data. These topics mainly contribute to uncertainty in the risk. Wide range of topics such as lack of data, accident analysis, verification of risk assessment, inspection interval, leak rate analysis etc. are covered and will be addressed using the research principles underlined in the PhD project.