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Method for identifying errors in chemical process development and design base on accidents knowledge

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ABSTRACT

It has been claimed that the high accident rate in the chemical process industry is due to poor dissemination of accident knowledge that affects directly the level of learning from accidents. In response to this situation, this paper utilized past accident knowledge as a basis to develop a safety oriented design tool whereby the accident information were directly disseminated into plant design. The method was developed based on our previous accident analysis of design error in which the common design errors were ranked in accordance to their frequency and its origins during normal plant design project. Based on the design error ranking and its origin at a specific design phases, a method for design error detection is proposed. The method is expected to be able to identify the possible design error and its causes throughout chemical process development and design. The main objective is to trigger safe design thinking at the specific design phases so that appropriate action for risk reduction could be timely implemented. The Bhopal and BP Texas tragedies are used as case studies to test and verify the method. The proposed method can detect up to 74% of design errors.

1. Introduction

The accidents rate in the chemical process industry (CPI) has not been decreasing although large majority causes of accident (95%) have been identified (Drogaris, 1993) and could be prevented by using existing knowledge (Kletz, 2004; Pasman, 2010). Among the basic causes of high accident rate is poor learning from accident (Jacobsson et al., 2010). According to (Lindberg and Hansson, 2006) the weakest link of feedback based on experience in the process learning cycle is related to dissemination of accident information. In fact, a recent study found out that only one third of the accident cases studied is considered to provide lessons learnt on a broader basis (Jacobsson et al., 2010). It is been suggested by Lindberg et al. (2010) and Jørgensen (2008) that the current experience feedback system needs to be modified, so that it can be systematically integrated with risk analysis methods. In response to above statement, research has been carried out to enhance the dissemination of accident knowledge directly to the design activity. Therefore, in this paper, the accident information were used as a basis to develop a design oriented safety tool thus, the accident knowledge was disseminated into next chemical plant design.

This paper discusses the development of error detection method by utilizing past accident knowledge. Our previous accident analysis shows that the contribution of design to

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Table 1 – Design as contributor to accidents.

Paper	Industry	Findings
Drogaris (1993)	Chemical (process)	• 70% of accidents have the root cause attributed to erroneous design
Duguid (2001)	Chemical (process)	• 52% as a primary cause of accidents arise in the design stage
HSE (2003)	Chemical (general)	• 71% of the accidents are caused by error during the design stage
Kinnersley and Roelen (2007)	Aviation, Railway and Nuclear	• 51% of the root causes of accidents arise in the design stage for aviation system • 46% of the root causes of accidents occur in nuclear industries are design related • 50% of the root causes of accidents arise in the design stages at railway
Taylor (2007a)	Chemical (process)	• 50% of accidents have the root cause attributed to erroneous design
Hale et al. (2007)	Chemical (process)	• 60% of accidents have the root cause attributed to erroneous design
Love et al. (2012)	Construction projects	• 80% of the accidents are caused by error during the design stage
Kidam and Hurme (2012a)	Chemical (process)	• 79% of accidents cases analyzed were contributed by design error

accident is significant (Kidam and Hurme, 2012a). As seen in the table, different literatures claim that the design related errors are responsible for at least 46% of accident. In root causes category, studies by Drogaris (1993), Duguid (2001), Kinnersley and Roelen (2007), Taylor (2007a) and Hale et al. (2007) show that large majority (46–70%) of design failure are due to erroneous errors in design. Besides, around 71–80% of the accidents are caused by error during the design stage as highlighted by the HSE (2003) and Love et al. (2012). However, a clear picture to describe design error contributors to accident in design phases is not so simple. In all cases, there are significant contributions of design to accidents, however in reality, it is very subjective and always questionable. Based on Table 1, it is therefore reasonable to conclude that accident contributor in design phases are significant in a range 50–79% in the CPI.

In considering the significant contribution of design to accident as well as poor dissemination of accident knowledge, this paper proposed the systematic error detection method for chemical process development and design based on accident knowledge. The main objective of the method is to utilized the past information and disseminate the knowledge directly into project design. The design oriented safety method can be used to identify the common design related error at different phases of plant design project. The method can be used as design check that is usually overlooked by the designer. The idea is to encourage the design thinking at the specific design task, so that timely, cheaper and effective risk reduction strategies could be applied suitably at the appropriate design project phases.

2. Common method for design evaluation

There is several design methods that are commonly accepted by process designer for design evaluation. In practice, several design evaluation methods are undertaken throughout the design phases of a particular project. Selection of the best method requires a huge work experience on the similar process families. In practice, there are common safety methods for design evaluation such as process hazard checklist, hazard survey, hazard and operability study (HAZOP) and safety review. Table 2 shows the commonly used design evaluation methods for design project. The table presents the advantages and limitations of the design methods depending on their safety evaluation criteria and in which particular stage of the plant design lifecycle (Crawley and Tyler, 2003).

Based on the summary presented in Table 2, it can be concluded that most of the safety methods are complex, knowledge-intensive, time consuming, requiring training and vast working experience. In addition, large majority of the methods cannot be used in the early process concept development. According to Hurme and Rahman (2005), every safety method requires a different amount of process information, which makes it best applicable only at certain design stages. As an example design method such as HAZOP is well accepted for design review in the basic engineering phase; however, it is ineffective to be applied at preliminary design phase due to lack of process information. In practice, HAZOP required process flow diagram (PFD) and effective to detect the design error up to 85% (Taylor, 2007b), which is only generated at the basic engineering and detailed engineering phases. At the process concept development i.e. pre-design, HAZOP are lack of mechanism or consideration for design decision such as on process chemistry, equipment type selection, scale-up, product and raw material specification etc. These issues needs to be address by using others hazard identification methods such as checklist, hazard ranking, hazard review etc.

In respect to the error detection as research area in the CPI, there are limited research has been done on design error (Bourrier, 2005; Busby, 1998). As a result, there are very limited design oriented safety methods that are purposely developed for design error detection in the CPI. Basic discussion available in Safety Science Journal Special Edition Volume 45 Issue 1–2: Safety by Design Based on a workshop of the New Technology and Work Network. In general, majority of the method is focus on the accident modelling and fault detection. In the CPI, error detection is a popular concept used in process control which is mainly for fault detection during the detailed engineering phase of plant design, not at the predesign and basic engineering. In civil and mechanical engineering, most of the design error analysis and detection are related to the structural and mechanical error (Love et al., 2012).

The systematic design based error detection method is still very much lacking especially at process concept development and design. Therefore, the design error detection method for CPI is needed to support the designer to design an error-less chemical plant. In design project, the designer makes error because of limited time to check their work (Kletz, 2004) and probably overlooked same design element that not routine, rare or unexpected process condition at some design phases (Haastrup, 1984). To detect design error that related to non-routine, rare or unexpected process condition, the best ways to do it by reviewing similar past accident cases. However, the current format of accident information (e.g. accident reports) is not user-friendly to the practitioners especially process engineers and designers. The search for a safer design