Contents lists available at ScienceDirect

Process Safety and Environmental Protection

journal homepage: www.elsevier.com/locate/psep

An integrated method for human error probability assessment during the maintenance of offshore facilities

Rouzbeh Abbassi[a,*], *Faisal Khan*[a], *Vikram Garaniya*[a], *Shuhong Chai*[a], *Christopher Chin*[a], *Khandoker Abul Hossain*[b]

[a] *Australian Maritime College (AMC), University of Tasmania, Launceston, TAS 7248, Australia*
[b] *Saipen Canada Inc., Calgary, Al, Canada*

ARTICLE INFO

Article history:
Received 28 September 2014
Received in revised form 7 January 2015
Accepted 20 January 2015
Available online 25 January 2015

Keywords:
Human factor
Errors
Probability
THERP
SLIM
RFID

ABSTRACT

The paper presents a novel approach for Human Error Probability (HEP) assessment by integrating the Success Likelihood Index Method (SLIM) with the Technique of Human Error Rate Prediction (THERP). In this approach, the SLIM has been embedded within the THERP framework to generate the nominal HEP data when it is unavailable. The developed methodology is implemented to an offshore condensate pump maintenance task. In the first step of this study, the human error was estimated considering all the standard tools and procedures which are in place. In the second step, as an additional measures, radio frequency identification (RFID) based tools are utilized and HEP is recalculated. Without the application of RFID tools, the HEP value is found to be 5.7244×10^{22} or estimated as 5.72% with an uncertainty bound of 1.1448×10^{-2}–1.1452×10^{-1}. With RFID tools, it is reduced to 4.6342×10^{-2} or 4.63%, with an uncertainty bound of 2.145×10^{-2}–2.089×10^{-1} which yields a net HEP reduction of 1.09%.

1. Introduction

Human error management is receiving growing interest in industries to reduce the risk associated with the production loss, asset damage, and fatality (Lardner and Scaife, 2006; Noroozi et al., 2014). Over the last few years, a number of major accidents have occurred in different industries as a result of incorrect operations and maintenance errors (Hendershot, 2006). The Bhopal gas tragedy in 1984 and the Texas City Refinery explosion in 2005 are examples of major accidents that human errors were involved (MacKenzie et al., 2007; Okoh and Haugen, 2014). Human error is directly or indirectly related to a number of factors which are called Performance Shaping Factors (PSFs). The PSFs are commonly categorized as external, internal, psychological and physiological factors. External PSFs are the factors associated with the situation and equipment characteristics, procedural and perceptual requirements and quality of the work environment. Internal PSFs are related to the individual characteristics such as skills, motivation, experience, mental strength etc. The psychological factors are the factors which directly affects the mental stress such as task load, task speed, task type etc. Physiological factors affect the physical stress such as discomfort, hunger, thirst, extreme temperature etc. (Swain and Guttmann, 1983).

In maintenance activities, PSFs are considered as the major contributors to human error (Boring and Blackman, 2007; Broberg and Kolaczkowski, 2007; Saurin et al., 2008). Therefore, to reduce the human errors, attempts are made to analyze the PSFs involved in a specific maintenance activity. In order to improve the PSFs, the industries have taken initiatives in three major directions; (i) change of equipment, tools, or process (ii) change of procedure and (iii) change of management

* Corresponding author. Tel.: +61 363249635.
E-mail address: Rouzbeh.abbassi@utas.edu.au (R. Abbassi).
http://dx.doi.org/10.1016/j.psep.2015.01.010
0957-5820/

system (Liang et al., 2010). The change of equipment or tool has brought simpler deigned equipment and use of more accurate and easy handling tools in maintenance. The procedural change has involved more comprehensive research to introduce the simple and systematic procedure to carry out any complex tasks, including involvement of a team rather than an individual accomplishment. Administrative control is focused on the management of human activity and skill, stress, and work environment. Researchers investigated factors related to situation awareness (SA) by aviation maintenance teams for a major airline (Endsley and Robertson, 2000). The analysis recommended a training program is important to improve the situation awareness in the maintenance procedures.

Some studies have linked mental workload to be an important factor in human work performance (Desmond and Hoyes, 1996; Xie and Salvendy, 2000; DiDomenico and Nussbaum, 2005; O'Neal and Bishop, 2010). The European Joint Aviation Authority depicted that error rates may increase when the technicians or engineers undertake more or less workload than the usual. This is a particular feature of some industry areas, such as line and base maintenance (CAA, 2002).

To reduce the human error in maintenance activity, the use of work permit is very common in different industries (Raman et al., 1991; Iliffe et al., 2000). It is a detailed document that authorizes certain people to carry out specific tasks at a particular time, which demonstrates the hazards associated with the tasks and the precautions to be taken for a particular situation. However, the typical work permits cannot provide detailed information and do not meet user expectations (Patel et al., 1994; Drury et al., 2000).

Computer-Based Procedure (CBP) and Computer-Based Training (CBT) as well as aiding programs have been developed for inspection and maintenance. These replace the use of paper based work permits. The CBP/CBT provides detailed information along with graphical presentation which is easy to follow and update. Research has been carried out on the computer-based aiding approach in maintenance activity (Chandler, 2000; Andresen et al., 2002; Liang et al., 2010). Liang et al. (2010) have proposed an online aiding system for human error management. In addition to the computer based training and aiding, the online aiding system provides the list of potential errors in each step of a task and provides with the quantitative human error risk index for each error type. This creates the risk informed awareness among the individuals and makes them careful to carry out the task without error.

Along with the procedural development, significant effort has been made to simplify the design of the equipment and tools to reduce human error in maintenance activity. Improper selection of equipment, component and spare parts are also a significant contributor to the human error in maintenance activity. Therefore, research has been carried out to develop the computerized inventory management and asset tracking system.

The emergence of RFID system is replacing the technology based on barcode identification systems. The RFID tag is accurately readable by RFID reader from near or far locations. This helps to have the updated information of the tagged items at any specific time (Konarski et al., 2009; AIM, 2010). The usefulness of RFID system is demonstrated through wide case studies in asset or item tracking, inventory control, personal identification, time and attendance system, and process control in numerous facilities etc (AIM, 2010). However, so far, no case study is available to demonstrate the applicability of the RFID technology in industrial operations and maintenance to reduce the human error. Alongside the improvement of the PSFs, significant effort has been devoted to develop approaches to quantify the HEP in industrial activities. The approach should be reasonably accurate to predict the HEP value; the underestimation might lead to a severe accident.

In this paper, the HEP for an offshore pump maintenance activity is estimated using the THERP technique. THERP is a well-known technique to estimate the HEPs, which conceived mainly for the nuclear industry (Swain and Guttmann, 1983; Konstandinidou et al., 2006) and validated repeatedly by applying to different cases in industries (Kirwan, 1997; Strater and Bubb, 1999). The present paper outlines a new methodology to solve one of the main challenges of using THERP to estimate HEPs, which is the unavailability of nominal error data for all types of tasks. To demonstrate the application of this new methodology, a case study of estimating HEPs in the maintenance procedures of an offshore oil and gas condensate pump is considered. In real scenario, the work processes can be far more complex and structured than what is assumed in this work. However, the developed methodology has the ability to be applied for a broad range of applications in maintenance procedures of any process facilities. In the first step of this case study, the HEPs are quantified considering all the standard tools and procedures which are in place. In the second step, as an additional measure, RFID based tools are incorporated and HEPs are recalculated to demonstrate the applicability of the RFID to reduce the HEP in a maintenance activity.

2. Human error probability assessment methods

Human reliability assessment techniques include probabilistic risk assessment and the cognitive modeling and simulations (Kirwan, 1998). The human error quantification techniques are based on two principles; (i) subjective judgment and (ii) human error database. The techniques which employ subjective judgments depend on a number of experts having complete knowledge about the task for which HEP is evaluated. Then the experts analyze the task and the relevant PSFs and opinion are provided; which are subsequently manipulated within the framework of a specific method to obtain the HEP value. The common methods in this category are; Absolute Probability Judgment (APJ), Paired Comparisons (PC), Success Likelihood Index Method (SLIM) and AHP-SLIM methods. The major problems associated with the expert judgments are the inconsistencies in the opinions among different experts. The absolute judgment method is based on the direct judgment of experts without manipulating the opinion further in any specific framework (Seaver and Stillwell, 1983). This method is relatively quick; the results could be qualitatively useful to take the improvement measures to reduce the human error. The PC technique involves the paired comparison of the judgment of experts, which are further manipulated to develop a HEP scale (Hunns, 1982). It uses at least two empirically estimated known HEP values for calibration and with the help of logarithmic correlation the final HEP values are obtained. This method can estimate the relative importance of different human errors specific to the tasks. PC may not be suitable for predicting the human error in a complex situation.

SLIM is one of the most flexible techniques and is widely used for expert judgment. In the SLIM approach, the judges