Process Safety and Environmental Protection 102 (2016) 441–449

Contents lists available at ScienceDirect

Process Safety and Environmental Protection

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

Monte Carlo simulation as a tool to show the influence of the human factor into the quantitative risk assessment

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ARTICLE INFO

Article history:
Received 18 November 2015
Received in revised form 18 April 2016
Accepted 25 April 2016
Available online 2 May 2016

Keywords:
Uncertainty
Human factor
Risk assessment
Monte Carlo simulation
Safety
Chemical industry
Accidents

ABSTRACT

The frequency of occurrence of an accident is a key aspect in the risk assessment field. Variables such as the human factor (HF), which is a major cause of undesired events in process industries, are usually not considered explicitly, mainly due to the uncertainty generated due to the lack of knowledge and the complexity associated to it.

In this work, failure frequencies are modified through Monte Carlo (MC) simulation including the uncertainty generated by HF. MC is one of the most commonly approach used for uncertainty assessment based on probability distribution functions that represent all the variables included in the model.

This technique has been also proved to be very useful in the risk assessment field. The model takes into account the uncertainty and variability generated by several HF variables.

In order to test the model, it has been applied to two real case studies, obtaining new frequency values for the different scenarios. Together with the consequences assessment, new isorisk curves were plotted. Since the uncertainty generated by the HF has now been taken in to account through MC simulation, these new values are more realistic and accurate. As a result, an improvement of the final risk assessment is achieved.
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1. Introduction

The assessment of safety in the chemical industry is not a simple task (Papazoglou et al., 1992) because it involves a variety of aspects that have to be considered when analyzing safety aspects such as the processes, hazards or human errors including their interactions. In order to establish how safe a chemical plant is, a parameter called risk has to be used. This concept can be quantified by calculating and then combining (often multiplying) the frequency and the magnitude of all the accidents that could occur in a specific plant, process or equipment (Casal, 2007).

The frequency of an accident scenario is commonly assessed by a generic failure frequency approach and it is a key aspect in risk assessment. The values of generic frequencies that are currently used in the chemical industry are based on historical data of accidents. The accuracy of their calculations is based on the quality and reliability of the data used. The differences between the sources of failure frequencies, such as the Reference Manual Bevi Risk Assessments (BEVI) (RIVM, 2009), depends on the factors considered for their calculation and on the way the situations have been classified.

Different variables are taken in to account for the creation of these values, aspects such as the mechanical failures or

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http://dx.doi.org/10.1016/j.psep.2016.04.024
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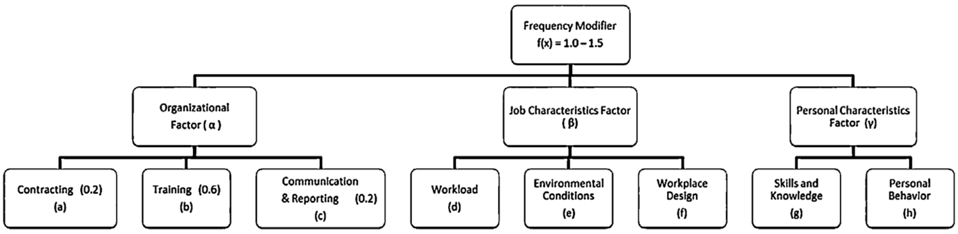

Fig. 1 – Variables for the representative equation.

the human factor are not explicitly detailed, and this creates uncertainty in the frequency calculation. It is a common practice when handling uncertainties to just ignore them or to use simple sensitivity analysis (Frey and Rubin, 1992). A decision making process based on risk is more effective when an accurate characterization of uncertainty has been conducted (Arunraj et al., 2013). The human factor is considered an important source of uncertainty (Konstandinidou et al., 2006); this is commonly excluded because in order to quantify this factor it involves a high level of complexity. However, the management of the human factors has been increasingly recognized as playing a vital role in the control of risk.

The Health and Safety Executive (HSE, 2012), from United Kingdom, has created one of the sources of generic frequencies, which recognizes that it is widely accepted that the majority of accidents in the chemical industry are generally attributable to technical failures but also to human factors. This factor may initiate or contribute to the failures' occurrence, increasing the accidents that can happen in an industry. Analysis of accidents and incidents shows that human factor contributes to failures that lead to many accidents and exposures to substances hazardous to health (HSE, 1999).

Taking this into account, it seems necessary to introduce the human factor in the frequency calculation. To achieve this aim, the Monte Carlo simulation has been used. This technique is one of the most commonly approaches used for uncertainty assessment and it is based on probability distribution functions that represent the input variables. Therefore, the human factor is introduced by the development of a frequency modifier based on the Monte Carlo Simulation.

The Monte Carlo (MC) frequency modifier varies the frequency by including the human factor in their calculation in order to minimize the uncertainty involved. This allows obtaining more accurate and realistic values of frequencies. After combining the new frequency with a consequence assessment of the accidents, a comparison of the results with risk assessment methods can be conducted. One of these methodologies that represent the risk through isorisk contours is the quantitative risk assessment (QRA), which takes into account the frequency and consequence of the accidents.

2. Human factor

The human factor can be described in many ways. The HSE guidance states (HSE, 2005) that a simple way to view the human factor is to think about three aspects: the job, the individuals and the organization, and how they affects people's health and safety-related behaviour. A selection of the variables based on this classification was made in order to create the model for this study based on previous studies (González et al., 2015a,b) from the authors. This selection considers that the overall human factor is composed of three different factors representative of these basic categories: organizational factor, job characteristic factor and personal characteristic factor. Each factor is characterized by the influence of the basic variables shown in Fig. 1 and explained next.

2.1. *Organizational factor (α)*

This factor refers to the conditions provided by the company to generate a safe environment. This includes the communication between the different levels of the hierarchy, the incidents reporting culture, the conditions the company sets to recruit external personnel and the instructions that the organization gives to their employees in order to perform the job in the safest way possible. It takes into account three variables: contracting, training and communication and reporting.

2.2. *Job characteristic factor (β)*

The job characteristics factor refers to the conditions that the company provide to the employees to perform their job and includes the quantity of work assigned to each employee, the conditions that surround the workplace such as noise and air quality, the personal protection equipment that the employees need for the development of their daily tasks (earplugs, helmets, goggles) and the safety equipment of the plant (safety showers, labels). This factor takes into account three variables: workload management, environmental conditions and safety equipment.

2.3. *Personal characteristics factor (γ)*

The personal characteristics factor relates to the cognitive characteristics of the employees, their personal attitudes, skills, habits, attention, motivation and personalities, which can be strengths or weaknesses depending on the task. One of those elements or their combination can markedly influence the human error occurrence. This factor depends on two variables: the skills and knowledge and the personal behaviour.

In order to introduce these human factors into the frequency calculation, a frequency modifier based on the Monte Carlo simulation is needed. Next, the methodology used in order to accomplish this is explained.

3. Methodology

A human factor model has been developed based on the variables previously explained. From these variables a representative equation has been designed, then, uncertainty ranges are assigned to the variables. A process of iterations of these variables through Monte Carlo simulation is conducted to obtain a mean value, which represents the frequency modifier value. The basis of this work can be found in González et al. (2015b). All these steps of the methodology are explained next.

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