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Retrospective risk analysis and controls for Semabla grain storage hybrid mixture explosion

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ABSTRACT

A continuation of the Quantitative Risk Management Framework validation is addressed in this paper. The explosion at the grain silo at the Semabla Company in Blaye, France in 1997 was considered as a hybrid mixture (Fermentation flammable gas/wheat and Maize dust) explosion. The risk analysis uses a Computational Fluid Dynamics modeling technique, which is represented in the Dust Explosion Simulation Code software and in conjunction with Probit equations to estimate the severity of consequences, and the Fault tree analysis technique to estimate the hybrid mixture explosion frequencies in a facility. Risk estimations (risk indices, individual risk, and societal risk) have been determined before and after the framework was applied.

The results showed a great reduction in risk if the framework is applied before any expected explosion.

1. Introduction

A hybrid mixture is a combination of a flammable gas and a combustible dust, where gas may be present in an amount less than its lower flammable limit (LFL) and also an amount of dust less than its minimum explosible concentration (MEC). Nevertheless, they may, in combination, create an explosible mixture (Amyotte and Eckhoff, 2010). Eckhoff (2003) demonstrated that the addition of flammable gas to a dust cloud significantly increases the explosion violence. Likewise, Amyotte et al. (2010) showed experimentally the increased maximum explosion pressure (P_{max}) and maximum rate of pressure rise in constant-volume (K_{St}) for ethylene/polyethylene, hexane/polyethylene, and propane/polyethylene mixtures. The methane/coal dust system is the most dangerous and volatile hybrid mixture in underground coal mines. In addition, there are several examples of hybrid mixture formations in the process industries, such as the fermentation process in storage silos which produces flammable gas, which, combined with existing wheat and maize dust, make an explosible hybrid mixture.

Furthermore, one or more secondary explosions may occur following primary explosion pressure waves. These strong shock waves can suspend settled dust in the area, forming a dust cloud which can then be ignited by the released energy of the primary explosion (Abbasi and Abbasi, 2007). Secondary explosions may actually be worse than the initial ones due to increases in the quantity and concentration of combustible dust/hybrid mixtures. Nonetheless, it is theoretically possible to prevent or mitigate a dust or hybrid mixture explosion by disabling at least one of the explosion pentagon elements. Practically, however, a number of different measures are usually implemented to minimize the risk of explosion to a tolerable level.

Frank (2004) and Amyotte and Eckhoff (2010) show that dust explosions occur in a wide range of industries and industrial applications involving numerous and varied products such as coal, grain, paper, foodstuffs, metals, rubber, pharmaceuticals, plastics, textiles, etc. Industries that handle combustible

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dust or hybrid mixtures during at least one of their processing stages are at risk of explosions that can threaten processing plants and harm people as well as damage the environment, production, and/or processing equipment.

Therefore, there is an urgent need in the process industry to develop a tool that combines various safety methodologies, software, procedures, etc., to prevent dust and hybrid mixture explosions. Unfortunately, few published papers in the explosion area deal with dust/hybrid mixture explosion risk assessment, mainly due to the complex nature of these phenomena (Markowski, 2007). In the late 1990s, Khan and Abbasi (1998) developed the software package MAXCRED (Maximum Credible Accident Analysis) to conduct rapid quantitative risk studies and comprehensive risk analyses of the petrochemical industry. A few years later, Khan and Husain (2001) developed another computer program called TORAP (Tool for Rapid Risk Assessment in Petroleum Refinery and Petrochemical Industries), which is used for conducting rapid risk assessment in the chemical process industry (CPI) and is capable of handling many types of industrial fires and explosions. Papazoglou et al. (2003) developed a methodology for integrating a Quantitative Risk Assessment model and a safety management system (SMS) for chemical installations. Bernatik and Libisova (2004) explained the importance of Quantitative Risk Assessment in the operation of six large old gasholders in an area of high population density in the Czech Republic. Pula et al. (2005) revised several fire consequence models for offshore Quantitative Risk Assessment. Gowland (2006) explained the principles of LOPA (Layer of Protection Analysis) and how it can be used within ARAMIS (Accidental Risk Assessment Methodology for Industries). Attwood et al. (2006) explained the development of a quantitative model that can predict accident frequency on offshore platforms.

Risk management is the complete process of understanding risk, risk assessment, and decision making to ensure that effective risk controls are in place and implemented. Risk management begins with actively identifying possible hazards, leading to ongoing management of those risks deemed to be acceptable.

Abuswer et al. (2011) developed a quantitative risk management framework (QRMF) for dust and hybrid mixture explosions. The framework was applied to some industrial case studies and shows great results that reduced the explosion risk to the acceptable region, as indicated in the ALARP measure tool, as shown in Abuswer et al. (2013).

The current work attempts to provide an extensive application of the QRMF to prevent/mitigate dust and hybrid mixture explosions in the process industries. The severe damage that occurred in the Semabla installation (1997) because of a hybrid explosion has been taken as a real industrial case study to analyze and find out what was lacking in safety management at that time.

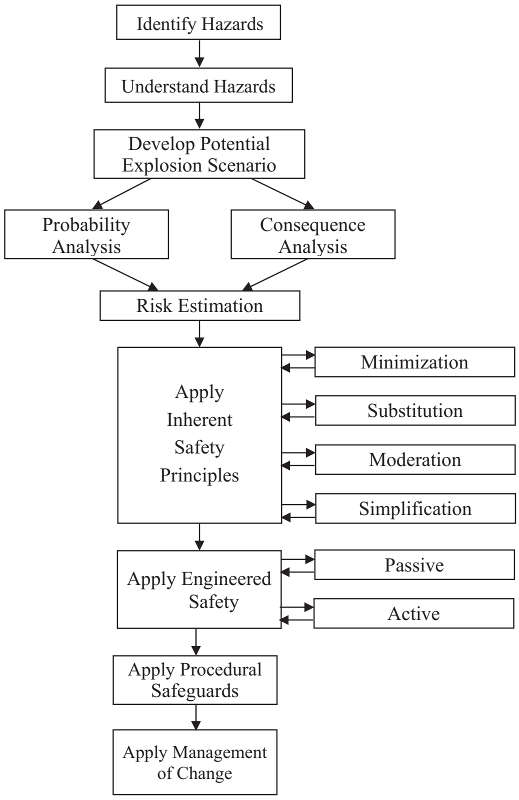

Fig. 1 – Overview of the QRM framework process.

The research uses QRA (Quantitative Risk Assessment), which includes both explosion likelihood and consequences. These are the key features of the framework, together with explicit consideration of the hierarchy of safety controls. Fig. 1 shows an overview of the QRMF (Quantitative Risk Management framework) for explosion prevention.

2. Case study

2.1. *Semabla installation description*

The Semabla Company in Blaye, France in 1997 boasted the largest grain storage installations in France. The complex was located in the port area of Blaye and consisted of vertical silo units with a capacity of 40,000 tons, along with some nearby warehouse buildings with a 90,000-ton capacity, as shown in Fig. 2. The number of workers at the site was 21, and the silo

Fig. 2 – View of the Semabla cells and warehouse-A storage units before the explosion (Masson, 1998).