Risk Analysis of Vapour Cloud Explosions for Oil and Gas Facilities

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Preface

In the oil and gas industry, a vapour cloud explosion (VCE) induced by oil and gas leaks is one of the major threats to process safety that may lead to catastrophic consequences. Risk evaluation of such gas explosions is complicated as a large number of factors and sequential consequences, including gas leak, cloud formation, ignition location and strength, structure congestion and confinement, humanity and environment conditions, etc., should be considered. Further complexity arises from the specific site characteristics of different process facilities, i.e. petrol stations, process factories, underground pipelines, offshore platforms, which have strong influences on the explosion risk.

The main purpose of this book is to introduce new risk analysis and load prediction methods proposed and developed by the authors. It provides brief descriptions of VCE mechanisms and the currently prevailing risk analysis models and tools, wherein no attempt is intended to cover all aspects of explosion risk analysis. Readers are expected to explore in-depth information according to the literature referred in the context.

This book is divided into 13 chapters. Chapter 1 is a brief introduction and review of the current state-of-the-art for the risk analysis of the oil and gas explosion. Chapters 2–13 elaborate and exemplify mainly load predictions and risk analyses. Focus is biased on the load prediction part because blast effect is the most significant factor in consequence prediction, and it is the base for evaluation of structural damages, human losses, environmental issues, etc. The contents of each chapter are briefed below for reader's quick reference to identify relevant contexts.

Specifically, Chap. 1 is an introductory section, which gives the background for the researches in this book and the basic information of VCE mechanisms, such as cloud formation, ignition and structure condition. Followed are Chaps. 2–6 discussing load prediction methods of both empirical and computational fluid dynamics (CFD) in details, wherein new approaches for gas explosion prediction and accuracy improvement by using CFD model proposed by the authors are included. Figure 1 shows an example of gas explosion simulation by the authors using one of the most advanced CFD analysis software called "FLACS".

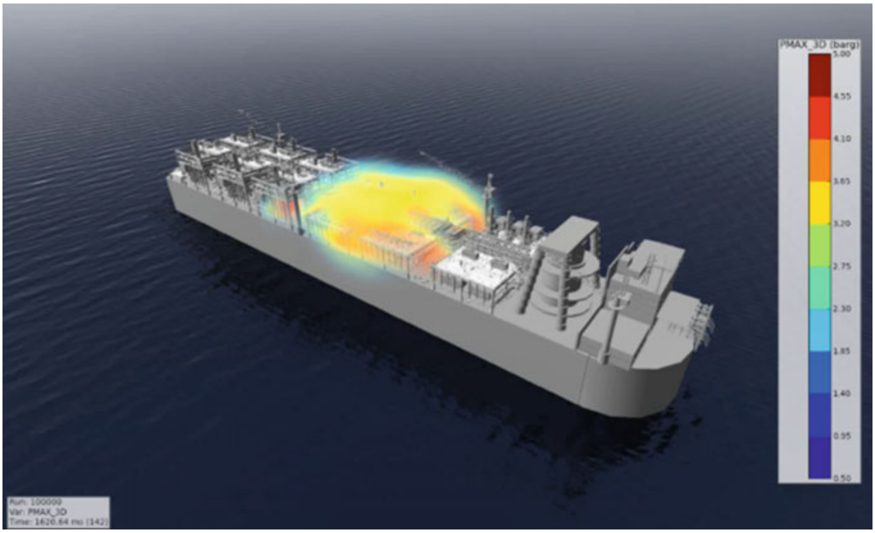

Fig. 1 FLACS simulation example of gas explosion

Chapter 2 illustrates three most prevailing empirical methods for load prediction, including the TNT equivalent model, the TNO Multi-Energy model and the Baker–Strehlow–Tang model. Case studies of all models by using DNV PHAST are given.

Chapter 3 presents the principles of the CFD-based overpressure calculation approach. The gas explosion mechanism regarding fluid flow equations, thermodynamic relationships, and turbulence and combustion modelling are described, and the numerical simulation procedure is introduced.

Chapter 4 demonstrates explosion load predictions for a single module based on the CFD simulations. A newly derived correlation, confinement specific correlation (CSC) and performance validation of CSC are presented and discussed.

Chapter 5 introduces explosion overpressure calculations of two separate modules with consideration of the gap effects. A data-dump guideline is then provided to improve the overpressure prediction accuracy prior to further investigation of safety gaps.

Chapter 6 evaluates blast effects for a super-large cylindrical floating liquefied natural gas (FLNG) vessel. Gas explosion simulations of different settings for safety gaps are covered.

The second half of this book, Chaps. 7–13, presents the most popular and generally applied explosion risk analysis methods from theoretical to standardized approaches. Trendy developments in explosion risk analysis methods, such as a confidence-level-based event tree analysis, a multi-level evaluation and a grid-based model, are introduced. Figure 2 depicts an example of a grid-based risk screening map of a living area with a VCE at the centre.

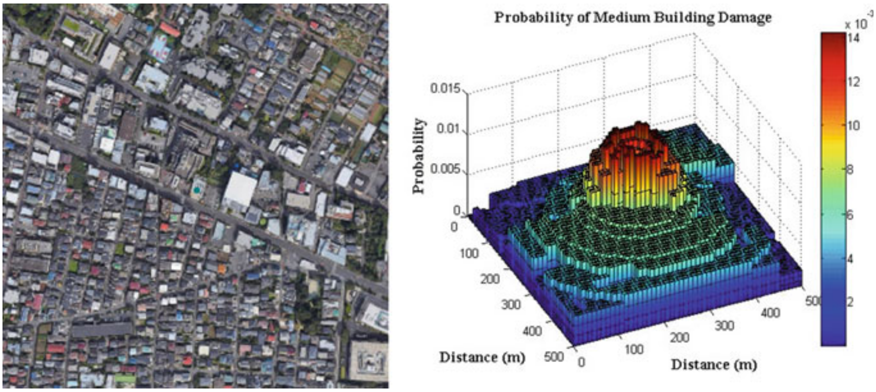

Fig. 2 Example of 3D grid-based risk screening method

Chapter 7 gives a broad literature review on the state-of-the-art explosion risk analysis methods including both qualitative and quantitative approaches, such as risk checklist, HAZOP, HAZIP, event tree, fault tree, and Bayesian network.

Chapter 8 describes an event-tree-based risk analysis of hydrocarbon release accidents, which is the source for the VCE formation. A fuzzy-theory-based confidence level method for reducing uncertainties is also described.

Chapter 9 is the description of a Bayesian-network-based quantitative risk analysis method for VCE accidents occurring at small oil and gas facilities, such as petrol stations. A case study using the proposed method to model the complete explosion process is presented.

Chapter 10 demonstrates a grid-based risk mapping method of explosion risk screening for large oil and gas facilities combined with the surrounding living areas. Exemplification is demonstrated with a refinery factory.

Chapter 11 illustrates a multi-level explosion risk analysis method for super-large oil and gas facilities, so as of the FLNG platform. The CFD method is applied for detailed risk quantification, and an as low as reasonably practical (ALARP) method is described as a calibration tool.

Chapter 12 demonstrates a detailed quantitative risk assessment method using CFD modelling and exceedance curves. The effect of blast wall on the cylindrical FLNG to reduce explosion risks is also investigated.

Chapter 13 outlines the prevailing explosion risk management methods based on worldwide industrial standards, wherein a lifecycle risk management process for explosion accidents based on structural integrity management (SIM) is introduced.

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