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Gas dispersion and deflagration above sea from subsea release and its impact on offshore platform

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ABSTRACT

Flammable gas dispersion and deflagration above sea resulting from subsea release have the possibility to cause an adverse impact on the operation safety of surface vessels. This paper presents a systematic simulation of gas dispersion and deflagration above sea from a subsea release using CFD-based approach, aiming to study the evolution process of accident scenario and assess its impact on surface vessels. A jack-up drilling platform is used as a case to discuss the impact of gas dispersion and deflagration. The uniqueness of this study is the integration of release, dispersion, and deflagration scenarios. The simulation includes the modelling of wind flow, gas dispersion and subsequent deflagration due to accidental ignition. The wind flow above sea surface is given using wind speed profile equation to generate steady wind field around offshore platform. Simulation of gas dispersion is conducted based on the generated wind field. The development of flammable gas cloud is predicted, and the dangerous area on offshore platform is assessed. Considering the appearance of ignition source, a deflagration simulation based on dispersion results is performed to predict the consequences including overpressure, high temperature, and heat radiation. Eventually, the damage criterion is utilized to evaluate their impact on offshore platform.

1. Introduction

Accidental subsea gas release, e.g. leakage of subsea pipelines or blowout, poses a threat to human life, assets integrity and corporate reputation (Skjetne and Olsen, 2012). Once a subsea gas release happens, gas will move into atmosphere and disperse above sea under wind (Hissong et al., 2014). The flammable gas cloud above sea may escalate into the fire or explosion accident due to the possible appearance of ignition source. The improved knowledge of gas dispersion and deflagration above sea from a subsea release is important for risk assessment, mitigation and prevention.

At present, considerable attentions were paid on the subsea gas release and dispersion induced by the leakage of subsea pipelines or other subsea installations, as well as blowout. A series of integral models, e.g. DEEPBLOW, CDOG and MEGADEEP (Johansen, 2000; Zheng et al., 2003; Chen and Yapa, 2003; Yapa et al., 2010; Premathilake et al., 2016; Wimalaratne et al., 2015) were developed for the transport and fate of subsea gas release. Furthermore, some computer models based on Eulerian-Lagrangian method were also developed for the underwater gas plume and free surface behavior resulting from a subsea gas release (Cloete et al., 2009; Olsen and Skjetne, 2016; Olsen et al., 2017a, 2017b). Underwater gas plumes, dissolution and hydrate formation, gas fate and transport, and physicochemical process that underwater gas undergoes were well studied based on these developed models.

For a subsea gas release, the whole dispersion process encompasses underwater and above-water movement. However, the studies about gas dispersion above sea surface from a subsea release can only be found sporadically in literature. Huser et al. (2015) estimated the range of flammable gas cloud above sea caused by a subsea gas release, and a look-up table for maximum plume dimensions was developed. However, the detailed development of flammable gas cloud, subsequent deflagration scenario and the corresponding impact on surface vessels are not mentioned in their studies.

Detailed safety analysis of gas dispersion and deflagration is useful for risk assessment and inherent safety design in oil and gas sector, and a number of researches contribute to this field. Hazardous gas dispersion in enclosed or open area such as complex terrains, chemical plant, offshore platform, FPSO and engine room spaces of LNG gas-fueled ships, was studied in previous years to analyze gas behavior and predict consequence (Zhu and Chen, 2010; Liu et al., 2015; Zhang and Chen, 2010; Dadashzadeh et al., 2016; Wilkening and Baraldi, 2007; Li et al.,

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2016; Shi et al., 2018). Furthermore, a series of efforts were made on safety assessment of gas deflagration due to ignition, which focused on deflagration development process and consequence assessment (Dadashzadeh et al., 2013; Wei et al., 2014; Bao et al., 2016; Shi et al., 2017). Modelling of hazardous gas release, dispersion and deflagration are essential for such a proper safety analysis. In these works, CFD simulation with the advantages of low cost, high efficiency, and powerful modelling capabilities, has been widely adopted. CFD can model required physics of a certain accident and are also capable of presenting the fully detailed geometry involved in the area of concern, which plays an important role in consequence analysis studies.

The objective of this paper is to present a systematic simulation of gas dispersion and deflagration above sea from a subsea gas release, which is used to predict accident evolution process and assess its impact on offshore platform. For this purpose, a generic methodology for simulation and assessment is proposed, and an integrated 3D CFD model is built. The wind flow above sea, gas dispersion and subsequent deflagration are simulated based on the developed model. The simulations could provide some useful and safety-related results, including wind field around offshore platform, the spatial distribution of flammable gas cloud, dangerous area on offshore platform, as well as influencing area of deflagration consequences. Based on simulation results, the impact of gas dispersion and deflagration on offshore platform is assessed, and the corresponding risk prevention and mitigation measures are discussed.

The rest of paper is organized as follows: Section 2 presents the proposed methodology for modelling and assessment of gas dispersion and deflagration above sea from a subsea release; The CFD theoretical model for gas dispersion and deflagration is shown in Section 3, while the CFD modelling and calculation process is presented in Section 4; The case simulations for a specific accident scenario is conducted in Section 5. Section 6 gives the summary and conclusions of this paper.

2. Simulation and assessment methodology

A comprehensive diagram of subsea gas release and dispersion is shown in Fig. 1, which is adapted from Cloete et al. (2009) and Takagi et al. (2012). When a subsea gas pipeline leaks, gas releases into seawater, and rises from seafloor to sea surface under the action of ocean current. A circular gas pool on sea surface is generated when gas reaches sea surface. Then, gas releases from the surface gas pool and disperses in atmosphere under the action of wind. Due to continuous release of gas, a flammable gas cloud with certain length and height is formed above sea surface, which has an adverse impact on the operation safety of offshore platform locating in downwind direction of surface gas pool.

This paper focuses on safety analysis of such a specific accident scenario, and the present study is planned to analyze the simulation results and assess the accident consequences. Fig. 2 outlines the procedures of the proposed methodology for simulation and assessment of gas dispersion and deflagration above sea from a subsea gas release, which includes geometric modelling, mesh generation, parameters

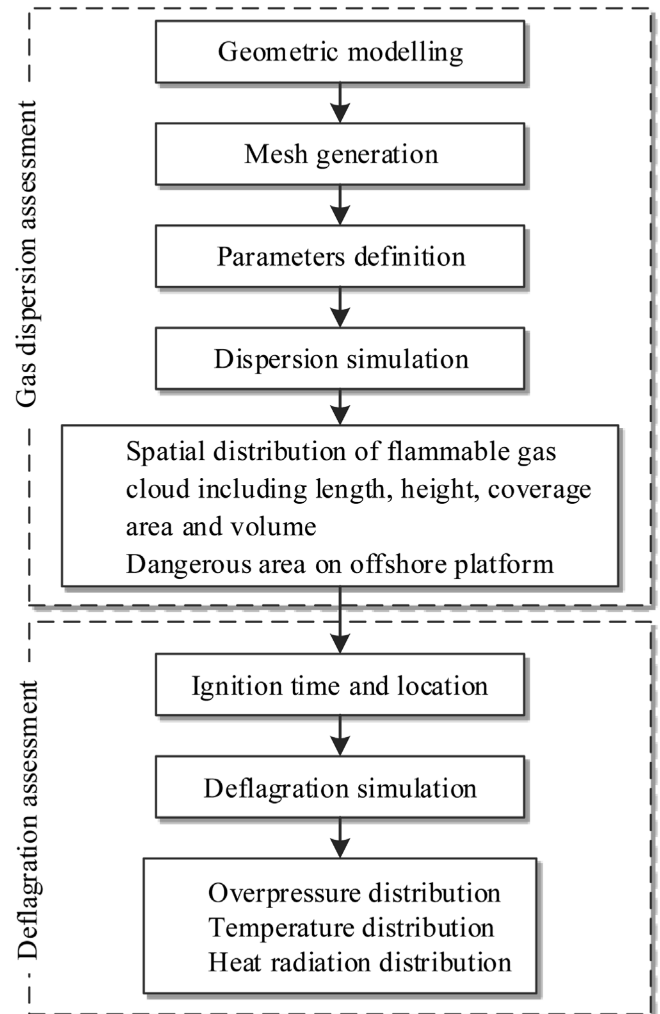

Fig. 2. Methodology for simulation and assessment of gas dispersion and deflagration above sea.

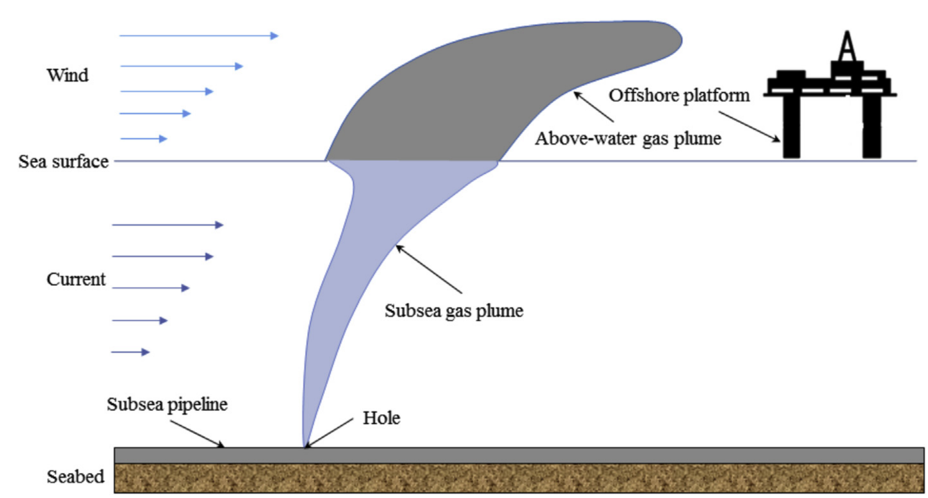

Fig. 1. Diagram of subsea gas release and dispersion (adapted from Cloete et al. (2009) and Takagi et al. (2012)).