Journal of Hydraulic Research Vol. 41, No. 4 (2002), pp. 339–351

A model for simulating deepwater oil and gas blowouts – Part I: Theory and model formulation

Un modèle pour simuler les éruptions en eau profonde de pétrole et de gaz – Partie I: Formulation de la théorie et du modèle

LI ZHENG, *Research Associate, Department of Civil and Environmental Engineering, Clarkson University, Potsdam, NY 13699, USA (now at Quantitative Environmental Analysis, Montvale, NJ 07645, USA)*

POOJITHA D. YAPA, *Professor, Department of Civil and Environmental Engineering, Clarkson University, Potsdam, NY 13699, USA*

FANGHUI CHEN, *Graduate Research Assistant, Department of Civil and Environmental Engineering, Clarkson University, Potsdam, NY 13699, USA*

ABSTRACT
A model developed to simulate the behavior of oil and gas accidentally released from deep water is presented. This model presents major modifications to a three-dimensional model developed earlier (Yapa and Zheng, 1997) that simulate the behaviour of oil from under water accidents (shallow water). In deepwater, the ultra-high pressure and cold temperature causes phase changes in gases. These combined with relatively strong currents in some deepwater regions presents extraordinary challenges to modeling jets/plumes from deepwater oil and gas blowouts. The present model incorporates the phase changes of gas, associated changes in thermodynamics and its impact on the hydrodynamics of the jet/plume. Hydrate formation, hydrate decomposition, gas dissolution, non-ideal behavior of the gas, and possible gas separation from the main plume due to strong cross currents are integrated with the jet/plume hydrodynamics and thermodynamics.

This paper presents the complete model development and testing of various computational modules with available data. A companion paper presents the comparison of model results with three large-scale field experiments conducted in the Norwegian Sea.

RÉSUMÉ
On présente un modèle développé pour simuler le comportement de pétrole et de gaz accidentellement libérés en eau profonde. Ce modèle présente des modifications majeures par rapport à un modèle tridimensionnel développé précédemment (Yapa et Zheng, 1997) qui simulait le comportement de l'huile suite à des accidents sous-marins (en eau peu profonde). En eau profonde, les très fortes pressions et la température froide provoquent des changements de phase en gaz. Ceux-ci combinés avec les courants relativement forts dans certaines régions en eau profonde constituent un réel défi pour modéliser les jets et panaches des éruptions de pétrole et de gaz en eau profonde. Le modèle actuel incorpore les changements de phase en gaz, les changements associés de la thermodynamique et leur impact sur l'hydrodynamique du jet/panache. La formation et décomposition d'hydrate, la dissolution de gaz, le comportement non-parfait du gaz, et la séparation possible de gaz du panache principal dûe aux forts courants en travers, sont intégrés à l'hydrodynamique et la thermodynamique du jet/panache.

Cet article présente le développement complet du modèle et les tests de divers modules informatiques avec des données disponibles. Il est accompagné d'un autre article qui fait la comparaison des résultats du modèle avec trois expériences à grande échelle conduites sur le terrain en Mer de Norvège.

Keywords: Blowout models; deepwater spills; deepwater models; oil spills; oil and gas spills; gas hydrates; well head blow outs; underwater blowouts.

1 Introduction

Steadily increasing oil and gas exploration and production from deepwater locations (water depths in excess of 300 m) are found in several regions in the world: e.g. Gulf of Mexico, the North Sea, off shore West Africa, and off shore Brazil. According to Lane and Labelle (2000), the number of exploratory wells in the Gulf of Mexico (GOM) has increased by 70% from 1996 to 1998. They estimate the production from installations deeper than 800 m to be 69% of the total production by year 2007. The oil industry plans to extend the exploration and production from as deep as 3000 m water depth. As the production increases the potential for an oil/gas spill increases. Major concerns from a deepwater oil/gas spill are fire, toxic hazard to the people working on the surface installations, and loss of buoyancy of ships and any floating installations. Therefore, it is important to know when, where, and how much gas will surface. Another environmental concern is whether oil will surface and if so, where, when, and what the oil slick thickness be. To meet these new challenges, spill response plans need to be upgraded. An important component of such a plan would be a model to simulate the behavior of oil and gasses, if accidentally released, in deepwater.

Revision received March 20, 2002. Open for discussion till December 31, 2003.