

Behavior of Oil and Gas from Deepwater Blowouts

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Abstract: This paper presents a detailed analysis of different deepwater blowout scenarios using the Clarkson deepwater oil and gas model (CDOG). In CDOG, hydrate formation, hydrate decomposition, gas dissolution, nonideal behavior of gas, and possible gas separation from the main plume due to strong cross-currents, are integrated with the jet/plume hydrodynamics and thermodynamics. CDOG takes into account unsteady-state three-dimensional variation of ambient currents and density stratification. Detailed comparisons between CDOG simulations and deepspill field experiments have been published. The model is used to simulate 30 deepwater blowout scenarios based on realistic cases and the results are analyzed in this paper. The scenarios demonstrate the differences in plume behavior due to different ambient conditions, different types of gas, possible hydrate formation, and variations in gas-to-oil ratio. Some key findings of these analyses follow. Oil droplet sizes affect the oil surfacing time significantly. For oil-only blowouts, the ambient conditions do not affect the oil surfacing time significantly, but the location and the size of the slick are affected. For oil and gas mixes, the surfacing time is not sensitive to the type of gas in the mix, but is somewhat dependent on the ambient conditions. In none of the cases simulated here, did free gas reach the water surface. While changing the release temperature had only an insignificant effect on the model results, changing oil type or gas-to-oil ratio did affect the model results. The analyses are useful to engineers/scientists and administrators.

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Introduction

Deepwater oil and gas exploration and production are steadily increasing in several regions: e.g., Gulf of Mexico, the North Sea, off shore West Africa, and off shore Brazil. The number of exploratory and production wells in the Gulf of Mexico (GOM) has been increasing. The U.S. Minerals Management Service (MMS) estimates that in the GOM, 69% of the total production will be from wells deeper than 800 m by the year 2007 (Lane and Labelle 2000). As the production increases, the potential for an oil or gas spill increases. Response plans for oil or gas spills are designed to meet safety and environmental concerns that include fire and toxic hazards to the people working on surface installations; loss of buoyancy in floating installations; and the quantity and location of any oil or gas reaching the surface. To provide the critical information needed for such response plans a computer model with reasonable reliability is needed.

An oil and gas mixture released from a blowout initially rises as a jet or plume (jet/plume). Gas expands as it rises because of the pressure drop and thus increases the buoyancy of the jet/plume. However, the jet/plume as a whole gradually loses its momentum and buoyancy due to the entrainment of seawater. In deepwater, the high pressure and cold temperature causes phase changes in gases, i.e., possible formation and decomposition of

gas hydrates. Gas hydrate is a slush-like compound made of gas and water. The gases or hydrates formed move at a slightly different velocity from the rest of the jet/plume fluid. Under strong cross flow conditions, the gas/hydrate may separate from the main plume. In a stratified ocean environment, the jet/plume is likely to reach a neutral buoyancy level below the water surface, though this also depends on a number of factors such as ambient stratification, densities of oil and gas, depth of release, and the velocity of release. Under field conditions, oil and gas are known to move as individual droplets beyond the neutral buoyancy level (Rye et al. 1997; Yapa et al. 1999). Free gas dissolves into water. In high pressure, the gas behavior is better described by a nonideal gas state equation than an ideal one (Zheng and Yapa 2002).

Barbosa et al. (1996) and Topham (1984a,b) developed plume models to simulate deepwater blowout scenarios. These are two-dimensional and do not consider hydrate decomposition. Johansen (2000) developed a comprehensive deepwater spill model capable of simulating gas hydrate formation/decomposition, gas dissolution, and gas separation from the main plume. The simulations for hydrate formation/decomposition in Johansen's model were based on thermodynamics. Spaulding et al. (2000) reported a deepwater model which could simulate hydrate formation. No details were provided in Spaulding et al. (2000) regarding the hydrate formation calculation.

The formulation of Clarkson deepwater oil and gas model (CDOG) was given in Yapa et al. (2001a,b) and Zheng et al. (2003). The model components and assumptions are summarized in Appendix II. In CDOG, hydrate formation, hydrate decomposition, gas dissolution, nonideal 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. CDOG takes into account the unsteady-state, three-dimensional variation of ambient currents and density stratification.

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