Modeling Underwater Oil/Gas Jets and Plumes: Comparison with Field Data

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Abstract: A jet and plume model previously developed to simulate underwater blowouts of liquid/gas mixtures is used here to simulate five field experiments. The field experiment data that became available only after the previous paper was published are unique. In this technical note, the variation of jet/plume diameter with depth for all five field experiments is compared with model simulations. The model simulations were carried out without changing any coefficients from one simulation to another. The comparisons between the observed data and model results of two surface oil slicks are also included.

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Introduction

Recent increase in oil and gas exploration and production off shore has brought new challenges to response plans (Lane and LaBelle 2000). Computer models to simulate the behavior of oil and gas accidents released from underwater locations are needed as an essential component of these plans.

The paper by Yapa et al. (1999), “Modeling underwater oil/gas jets and plumes,” described the development of a comprehensive model to simulate the behavior of oil and gas when released underwater. They also compared the model results with two field experiments (Rye et al. 1996; Rye and Brandvik 1997). The first experiment was an oil release at a water depth of 107 m in the North Sea. The second experiment was a release of oil and gas at a water depth of 106 m in the North Sea with a gas to oil ratio (GOR) of 67. At the time the paper by Yapa et al. (1999) was published, only a limited amount of data related to the second experiment was available. Since then the Norwegian researchers not only released more detailed data related to the second experiment, but also detailed data from four other field experiments conducted at the same time as the second experiment (Rye et al. 1997/1998).

Field data that can be used to compare the results of numerical models for underwater blowouts are very difficult to obtain. The new data provide five unique and previously unavailable data sets. In this technical note, we will use a previously developed model COMBOS3D (Yapa et al. 1999) to simulate the five field experiments. The simulations will be done with no adjustments of coefficients or formulations from one case to another. The comparisons provided here are useful in understanding the level of prediction capability of models.

Data from Field Experiments

Rye et al. (1997/1998) reported details of five field experiments in which liquid/gas mixtures were released at a depth of 106 m in seawater. The release location was slightly east of the Frigg field in the North Sea (close to Lat/Lon 60°02′N and 2°30′E). The water temperature and the salinity at the field location during the period of experiments as reported by Rye et al. (1997/1998) were plotted in Fig. 1. The water velocity varied somewhat during the experimental period. The water velocity was measured at three different depths: 3, 10, and 60 m. The water current magnitude and direction as functions of time are plotted in Figs. 2 and 3, respectively.

Because of the environmental concerns relating to the release of oil, only one of these experiments was oil and the other four consisted of colored water. Compressed air represented the gas component. In the industry, a key parameter in an oil/gas release is the GOR. Since these experiments included gas/oil and air/water, we will introduce a new term to refer to the equivalent of GOR as gas to liquid ratio (GLR). The GLR ratios for the experiments varied from 7.25 to 67. The units of GLR in metric are $N\ m^3/s^{-1}/m^3/s^{-1}$. In the above unit, $N$ stands for normalized. Since the gas volume changes with pressure and temperature, $N\ m^3$ is used to express the equivalent gas volume at standard pressure and temperature. For GOR and GLR, the U.S. industry commonly uses the unit scfd/bopd, which stands for standard cubic feet per day divided by barrels of oil per day. The range of GLR used in the experiments in scfd/bopd is from 41 to 376. Case 3 was a release of gas and oil and had a GLR (GOR) of 67. All relevant data from the field experiments that are used as input to the model are shown in Table 1. The variables that remained the same for all experiments are shown in Table 2.

The main data for the plume phase are the plume width. SINTEF scientists obtained the plume width based on data from a