Oil dispersion from blowouts in the presence of gas
Limited scavenging of dispersant due to gas bubbles

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Introduction

The droplet size distribution (DSD) of oil from blowouts such as the Deepwater horizon has been the focus of numerous studies (Gros et al., 2017; Zhao et al., 2015; Zhao et al., 2017a). While major advances have been achieved in predicting the DSD when oil only is present, little is known about the impact of the gas on the formation of droplets. Gas bubbles impart energy to the blowout because they rise faster than droplets, and they could potentially alter the effectiveness of dispersant by physically minimizing contact between dispersant and oil and/or scavenging the dispersant. Collaboration between national labs in the US and Canada created complementary projects to address the role of bubbles and dispersant. We focus herein on two aspects through numerical and experimental studies.

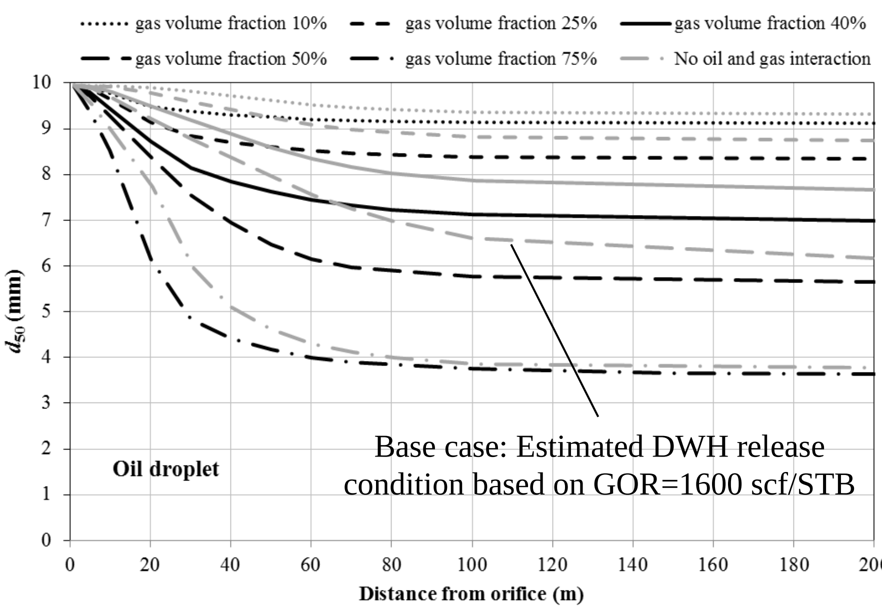

Figure 1: Evolution of the median droplet size d_{50} along the plume height for the cases without and with oil and gas interaction. The gas volume fraction 40% is the base-case with the GOR=1600 scf/STB.

The impact of gas bubbles on the oil droplets in blowouts was considered numerically using the oil droplet model VDROP-J, which is a model that uses the oil and gas discharges to predict the droplet size distribution (DSD) at various distances from the orifice (Zhao et al., 2017a). The model was used in application to scenarios of the Deepwater Horizon spill, where the various gas to oil ratios (GOR) spanning from 10% to 90% were considered. Although the model VDROP-J produces the full droplets size distribution (DSD), we focus herein on the volume median diameter, d_{50}, for brevity. Figure 1 shows d_{50} as function of distance from the source. It shows that, in the absence of dispersant, the d_{50} reaches equilibrium within 80 m from the orifice. One also notes that the GOR plays a major role with d_{50} varying from 3.0 mm for GOR=90% to 9.0 mm at GOR=10%. Therefore, it is essential to consider the energy of bubbles when predicting the size of oil droplets.

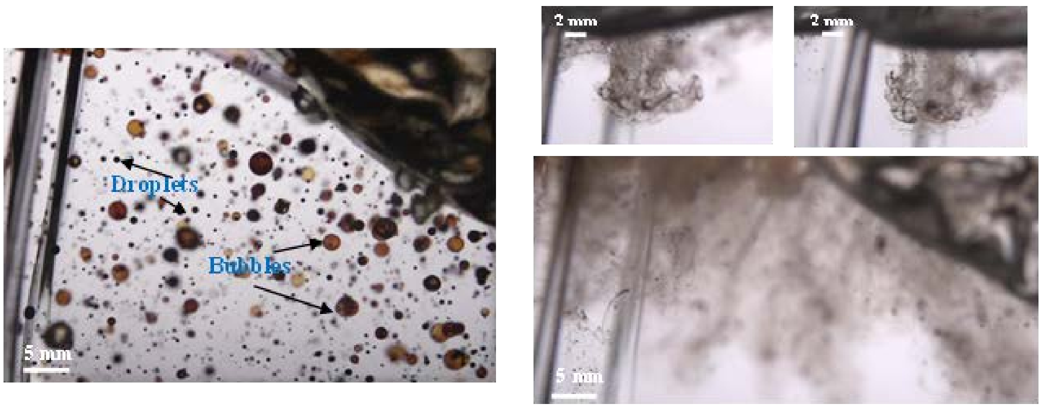

Figure 2: Oil behavior in turbulent flows: (left) oil alone without the addition of dispersants; (right) oil with dispersants, the DOR was 1:25. Experiments were conducted in baffled flask under rotational speed of 175 rpm.

The droplet size distribution decreases when chemical dispersants are added to the oil, and in particular through a process known as tip-streaming, whereby oil slough off of the oil droplets, and produces droplets that are around 2 to 3 microns. This is illustrated in Figure 2, which shows oil droplets without dispersants and droplets when the dispersant to oil ratio (DOR) was made 1:25. The experiments were conducted using moderate oil viscosity in the EPA's baffled flask placed on an orbital shaker that rotated at 175 rpm. This generated mixing energy comparable to breaking waves. The left panel shows the case without dispersants, where the droplets are spherical and they ranged in size from a few hundred microns to 1 mm. The turbulent mixing also caused air bubbles to be trapped in the water column, and certain amount of oil was also carried by the bubbles. The right panels show the case where the dispersants were added on the top of oil (similar behavior was also observed for the premixed oil and dispersant mixture). Mists of oil with tiny droplets were dispersed into the water. The droplets were elongated, and the tip-streaming phenomenon was observed. Thus, the effectiveness of dispersant might be underestimated by looking only at the median diameter of the droplets.

The high percentage of micron-sized droplets in the presence of dispersant has resulted in multimodal distributions, as reported in studies by the Department of Fisheries and Oceans (Canada) (e.g. Li et al., 2007; Li et al., 2008) and various academic institutions in the USA (e.g. Murphy et al., 2016). This indicates that models that produce only a unimodal distribution might not account for this considerable mass explicitly. It is worth noting that the amount oil sloughing through tip-streaming decreases with the DOR, and while some studies at DOR of 1:100 and below have not observed it, there is no theoretical reason to expect that tip streaming vanishes completely at lower DORs. For this reason, our group improved the capabilities of the model VDROP-J to include such a module (Zhao et al., 2017b), which accounts explicitly for the impact of dispersant, oil and water properties, and the mixing intensity around the oil droplet. Figure 3 shows the comparison of VDROP-J predictions without and with the tip-streaming module for an experimental investigation of underwater oil jet conducted in Bedford Institute of Oceanography (BIO), Canada (Zhao et al., 2017b). Very good agreement is noted.

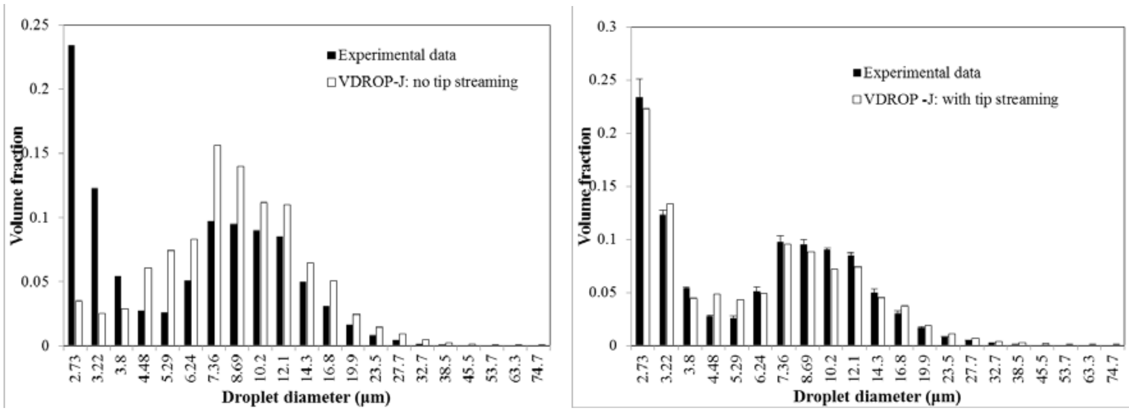

Figure 3: Comparison of the droplet size distribution predicted by VDROP-J (a) without and (b) with the tip streaming module with the experimental data.

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