A new response option - Subsea Mechanical Dispersion (SSMD)
A summary of an industry funded R&D program

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Extended Abstract

The size distribution of oil droplets formed in subsea oil and gas blowouts is known to have a strong impact on their subsequent fate in the environment. Small droplets have low rise velocities, are more influenced by oceanographic turbulence and have a larger potential for natural biodegradation. Subsea Dispersant Injection (SSDI) is an established method for achieving this goal. However, despite its many advantages, the use of SSDI can be limited both by logistical constraints and legislative restrictions. An alternative approach for subsea dispersion, without the use of chemicals, would therefore enhance our response capability. This option is called Subsea Mechanical Dispersion (SSMD).

An extensive research and development program on SSMD has been performed and the main findings are reported in this presentation. The work was initiated by BP post-Macondo in 2015 and later followed up by a consortium of Equinor, AkerBP, Total Norge and Lundin Norge (2015-2020). Initially, multiple principles for generating subsea dispersions (ultrasonic, mechanical shear forces and water jetting) were studied both by laboratory experiments and modelling. These studies clearly indicate that SSMD has an operational potential to significantly reduce oil droplet sizes from a subsea release and influence the fate and behaviour of the released oil volume.

The feasibility study of multiple technologies for subsea mechanical dispersion showed that using a high velocity water jet was both very effective and easier to implement since, for example, large subsea pumps already were available. This presentation will for this reason focus on SSMD performed by water jetting. Recent work (Phase-IV, 2019-20) has focused on operationalisation, upscaling, and large-scale testing. This R&D program has been performed by SINTEF in close cooperation with Exponent in USA (computational fluid dynamics and shear stress modelling) and Oceaneering in Norway (subsea operations and operationalisation).

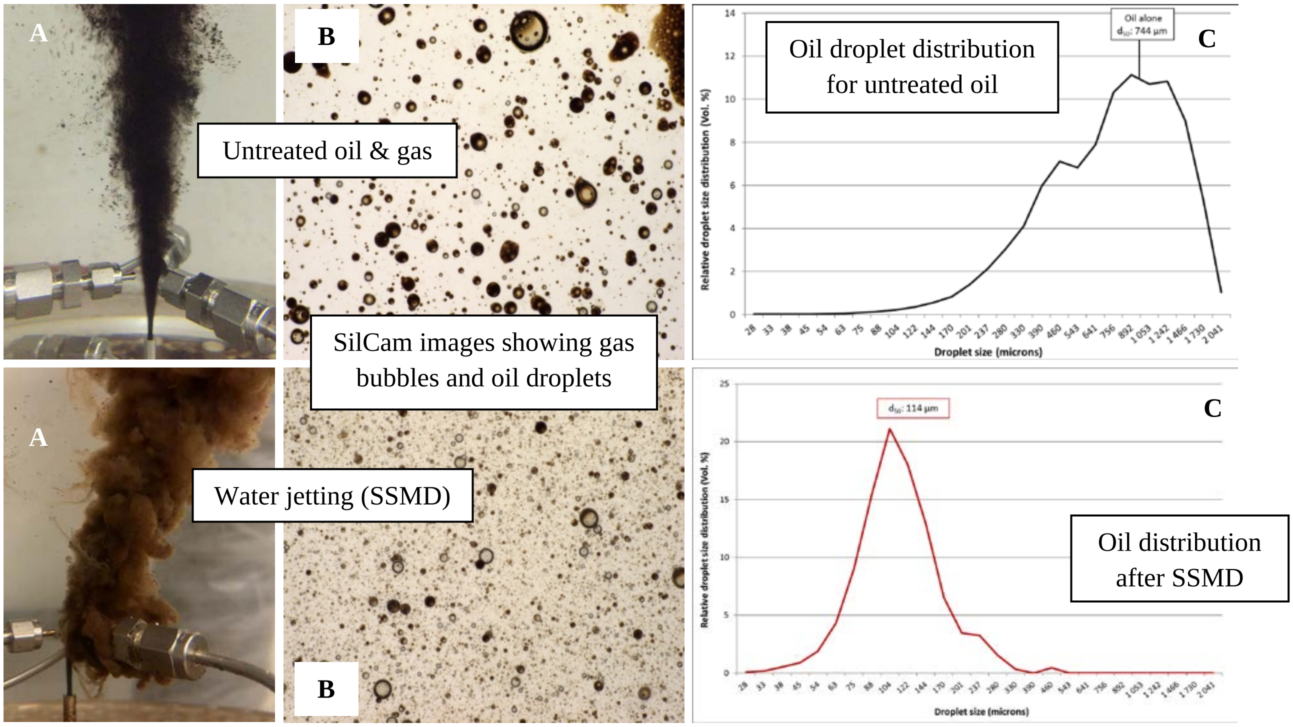

Figure 1: Water jetting experiments performed with oil & gas in SINTEFs Mini Tower. A: Oil & gas plumes, B: SilCam images used to identify and quantify oil droplets and gas bubbles. C: Resulting oil droplet size distribution. Upper part: Experiments with untreated oil. Lower part: Experiments with treated oil (water jetting).

Traditionally, light scattering instrumentation has been used to measure particle sizes in an aqueous solution. However, the experiments described in this study include gas (air) and since light scattering is not capable of distinguishing between oil droplets & gas bubbles it was not used in this study. The SINTEF Silhouette Camera (SilCam) has been successfully used for quantifying oil droplets and gas bubbles in multiple projects over a wide range of particle sizes and was also used for this study. Figure 1 above shows untreated and treated oil plumes, SilCam images and the resulting size distributions based on a large number of images/particles.

Large-scale testing was performed at the Ohmsett facility located in New Jersey, US, in 2019. The facility has proven to be very well suited for oil spill response technology testing, especially for large-scale validation of research findings from earlier small-scale laboratory experiments, due to its large outdoor test tank and ability to handle experiments with real oil. Assistance from the highly experienced staff operating the basin is also a valuable asset with the Ohmsett facility. The 200 meter long basin has two movable bridges. The first of these were used to tow a release system for oil and gas, while a particle size monitoring system (SilCam) was mounted on the second towable bridge. A high resolution video system was used for additional documentation of the reduction in oil droplet sizes obtained by SSMD (see Figure 2).

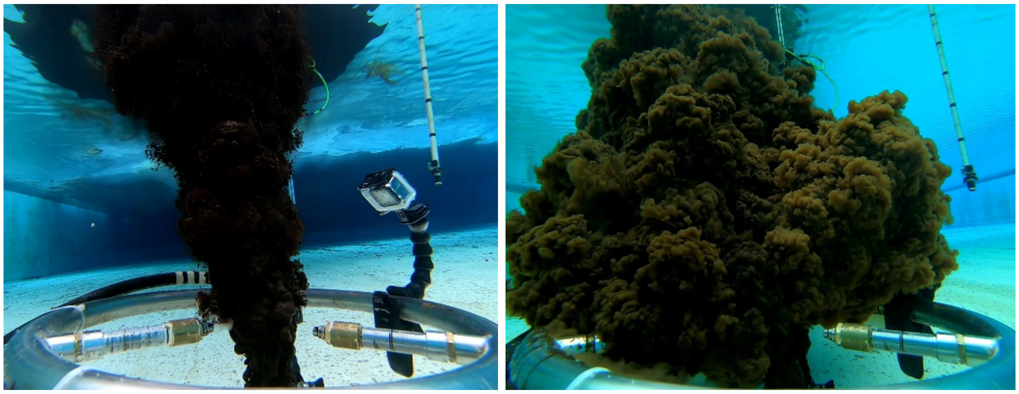

Figure 2: Release of untreated oil with a d_{50} of multiple millimetres (left) from a 25 mm nozzle (80 l/min) and the same release after water jetting with the star configuration creating significantly smaller droplets (right).

The main objective for the large-scale testing at Ohmsett was to verify the SSMD effectiveness measured at smaller scale in the laboratories and seen in the results from CFD modelling. Two possible nozzle configurations were tested at different oil and gas rates and different rates/velocities for water jetting. One example is shown in Figure 2 above, where both large untreated droplets are shown (left) and smaller droplets after SSMD treatment (right).

We have earlier performed comparable large-scale testing of subsea dispersant injection (SSDI) at Ohmsett, both in 2015 and 2017. Similar oil release nozzles, oil flowrates and detection techniques (SilCam) were used during the SSMD work in 2019. The results from the two types of experiments (reduction in d_{50}) are directly comparable and are shown in Figure 3 below (example from 32 mm nozzle). Figure 3 shows that SSDI and SSMD have comparable effectiveness.

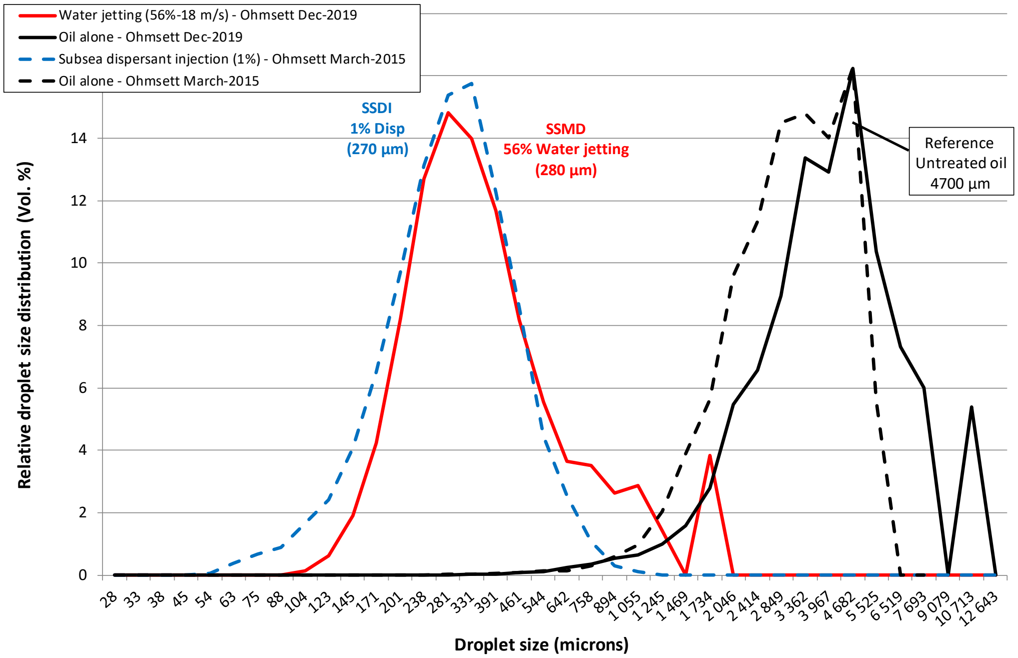

Figure 3: Comparison of SSMD and SSDI effectiveness (reduction in d_{50}) from the Ohmsett experiments in 2015 and 2019 both with 32 mm oil release nozzle and 80 L/min.

Initially in this study CFD was used to describe (1) the initial droplet splitting created by the release conditions and (2) the secondary droplet splitting caused by SSMD. This work was initially performed by BP in UK and later followed up by Exponent in USA. This modelling approach was feasible for the initial small-scale lab experiments, but the computer resources required for CFD modelling of full-scale scenarios is too resource and cost intensive to be practical.

Exponent later used CFD to model the turbulence dissipation rate (TDR) metrics for a large number of tracer particles and correlated this to the experimental results from SINTEF. This approach has been used to support optimisation of nozzle designs and design of a full-scale prototype. Figure 4 below illustrates the impact of water jetting by tracking the TDR metric for a full-scale blow out.

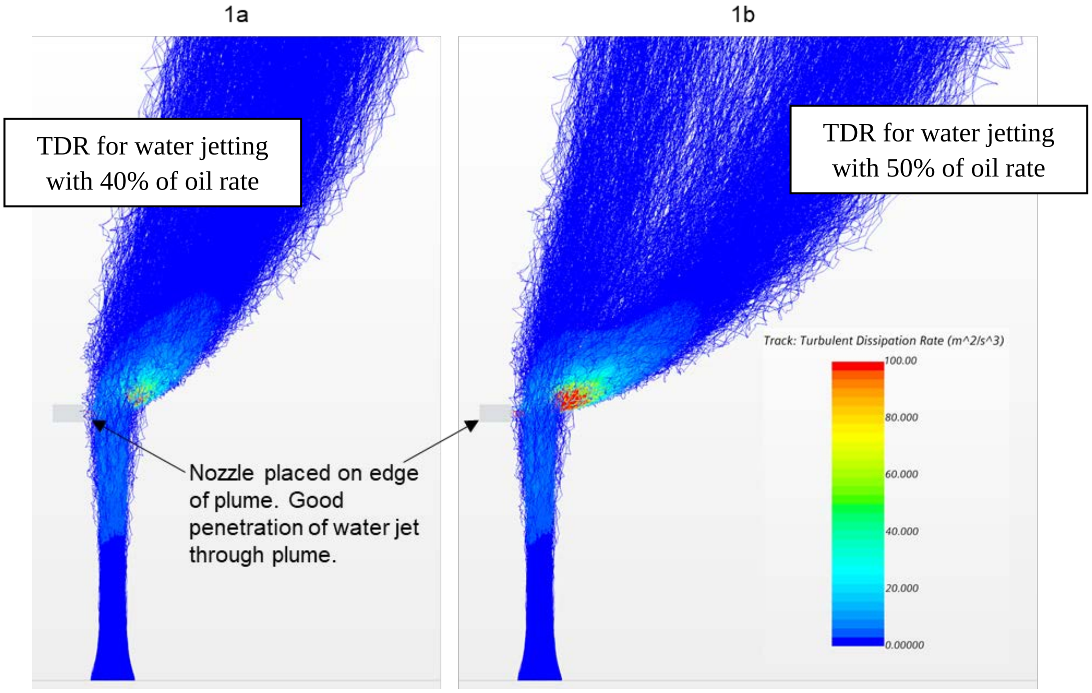

Figure 4: Turbulent Dissipation Rate (m^2/s^3) modelled with CFD for a full-scale blow out (11 500 m3/day, GOR: 50%, release diameter: 500 mm). Water jetting was performed 6 release diameters above the release with 40% (1a) and 50% (1b) of the oil rate.

The presentation at INTERSPILL will focus on how modelling- and small-scale studies have been verified by large-scale testing at Ohmsett and updates on our strategy for developing SSMD to an operational oil spill response option.

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