Subsea dispersant injection as an oil spill response option on the Norwegian Continental Shelf

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Introduction

Mechanical recovery and surface dispersants application have traditionally been the preferred response options when performing an emergency preparedness analysis for an offshore subsea-blowout on the Norwegian Continental Shelf (NCS). Subsea dispersant injection (SSDI) capability is now available through Oil Spill Response Limited (OSRL) and Wild Well Control (WWC), and Statoil aims to include SSDI in emergency (and oil spill) response plans for NCS and our international operations where relevant. The local regulatory requirements differ around the globe.

The current understanding of the regulation regarding the use of subsea dispersant injection on NCS is two-fold; If SSDI is implemented, to protect human health and lives, there is no need for permission with legal basis in the Pollution Control Act, and the Norwegian Petroleum Safety Authority (PSA) will be the authority to give required permissions. In §86 of the "Regulation Related to Conducting Petroleum Activities" PSA calls for an action plan that describes how the loss of well control can be regained, with guideline reference to NORSOK D-010, calling for an outline plan for capping and containment. In other scenarios, for pre-approval of SSDI use or where capping is not feasible or desirable, and SSDI is to be used as an oil spill response tool mitigating environmental impacts, permission must be given with legal basis in the Pollution Control Act. The Norwegian Environment Agency (NEA) is the regulator for the pollution preparedness requirements. The pollution regulation concerning dispersants, however, does not specifically include injection of dispersants subsea.

A gap analysis with focus on using SSDI as an oil spill response tool on NCS and the Norwegian regulatory regime was performed by the Norwegian Oil and Gas Association, suggesting areas where more research or documentation was recommended before implementing SSDI on the NCS (**Daling et al., 2016**).

As a result of the gap analysis research has been conducted to further optimize and qualify SSDI technology and to improve the OSCAR oil spill trajectory model for subsea plume modelling including subsea injection of dispersants. Improvement of the oil spill trajectory model has focused on the algorithms describing the distribution between oil on the surface and in the water column, and the persistence of the surfacing oil after SSDI is implemented. The improved model has been used for different NCS specific scenarios. Developing the required tools and input data to perform a Spill Impact Mitigation Analysis (SIMA) is necessary for comparing benefits and limitations of SSDI compared to other oil spill response options (e.g. surface dispersant, mechanical recovery, in situ burning). A quantitative approach using a novel Environmental Risk Assessment methodology and accompanying software tool (ERA Acute) has been tested in a first attempt including SSDI. The more operational aspects regarding SSDI have been approached through a project focusing on optimising injection techniques, dosage control and online operational monitoring of efficiency of the dispersant. Regulatory issues have been addressed by developing a screening test for approval of dispersant use.

Main Results

Oil trajectory modelling

Proving efficient use of SSDI on the NCS is challenging, due to the relatively shallow water depths in many areas compared to, for instance, the Gulf of Mexico. Wide variety of sea depth of the oil fields made it crucial to better understand which locations and scenarios that SSDI can be used efficiently. Efficient SSDI is characterized by reducing the amount of oil on the sea surface, increase offset of surfacing oil (horizontal distance from release point) and decreased persistence of the oil film on the surface.

The introduction of OSCAR 7.0 and an improved algorithm (modified Weber scaling) for initial oil droplet formation (**Johansen et al., 2013**), introduced challenges when applied to a subsea release including SSDI. The oil viscosity, oil rheology and the release temperature is becoming more important, and using viscosity data that are dedicated for characterizing the viscosity of the oil on the sea surface could significantly overestimate droplet sizes in some scenarios. Viscosity-temperature curves at different shear rates for selected NCS oil qualities were generated. A model describing oil temperature and viscosity during droplet formation was developed and implemented into OSCAR (**Skancke, 2016**). This gave lower and more realistic oil viscosity and reduced the median droplet size for most subsea scenarios.

Case study NCS

The main parameters determining the oil droplet size distribution and fate of the oil in a blow-out scenario are; water depth, release rate, gas-to-oil ratio (GOR), release diameter, oil temperature, oil properties (IFT, viscosity and density), dispersant dosage and metocean data.

Typical water depths at the NCS varies from 80 to 120 meters (North Sea), more intermediate depth (300 to 450 meters in the Barents Sea), and some, less abundant deeper water areas (greater than 1000 meters depth in parts of Norwegian Sea). The objective was to express efficiency of subsea dispersant injection with respect to areas with different water depth. Performing a screening of the potential for dispersant application, varying the above parameters in large number (several thousands of simulations) proved to be challenging. Due to this, the screening was focused on a limited number of the most important parameters; release velocity of oil and gas, reduction of oil droplet size and trapping or not of the plume. Based on the screening study a limited number of full OSCAR oil trajectory simulations were performed to illustrate typical parameters for scenarios with high, moderate and low effect of SSDI. Possible future work aiming to develop a screening tool to assess SSDI feasibility based on the above parameters is currently being evaluated.

It is clear from the results that a fraction of shallow water scenarios will end up with a moderate efficiency of subsea dispersant injection, with a surfacing plume or a plume trapped close to the surface. SSDI could change the properties of the resulting surface film and possibly influence the persistency and the feasibility and efficiency of surface spill response. Recent efforts initiated laboratory work to assess the effect of remaining dispersants on the surfaced oil.

Regulations for dispersant use on NCS

Dispersant testing protocols for acute toxicity and effectiveness for surface application of dispersants are described in the Pollution Control Act within the Norwegian regulations. There is no official list of approved dispersants, or specific effectiveness threshold for approval. For dispersant application on the sea surface, dispersant efficiency at varying degrees of oil weathering (for the relevant oil) should be tested to estimate the "window of opportunity". However, the present regulations do not reference relevant test criteria regarding efficiency for SSDI or documentation needed to perform SIMA assessment including SSDI as a response option.

The Norwegian Coastal Administration (NCA) is the supervising authority related to dispersant approval when an incident occurs. However, until test criteria for SSDI is implemented in the regulation (Pollution Control Act), NEA (Norwegian Environmental Agency) will be the supervising authority when SSDI is used as an oil spill response tool. NEA has requested a test methodology for documentation of SSDI efficiency. SINTEF has developed a new bench-scale (MiniTower) test where SSDI efficiency has been documented for a selection of oil types and dispersants as a function of temperature and DOR (dispersant-oil-ratio). This matrix of results will be used for documentation of efficiency for new oil qualities unless the oil properties are very different from the oils already described (**Brandvik et al., 2016**).

SIMA (Spill Impact Mitigation Analysis)

ERA Acute is a newly developed tool for environmental impact and risk assessment of acute oil spills. ERA Acute methodology is a quantitative environmental risk methodology which can facilitate screening of environmental risk, detailed environmental risk assessments, and SIMA of oil spill response options in four compartments: Sea surface, shoreline, water column and sea floor. The ERA Acute methodology is now enrolled as the new industry standard (best practice) environmental risk assessment method on the NCS. The methodology has been used in a NCS scenario where SSDI was included as one of the response options. Further case studies to gain experience with ERA Acute have been initiated.

Operation, optimization and monitoring

A project to develop and test a prototype automated system for regulating subsea dispersant volume rate injected into the oil plume is nearly finalized. The project was led by Oceaneering with SINTEF as a project partner, funded by NCS oil operators and the Norwegian Research Council (NRC). The system for adjustment of the dosage of dispersant is based on oil droplet size output (measured by SilCam), and has been documented by down-scaled testing in the SINTEF Tower basin, and with full-scale function testing in the Oceaneering seawater basin. The details of this project will be given in a separate Interspill 2018 oral presentation. The next step is to develop an implementation plan for the automated system.

Conclusion

Including SSDI as an oil spill response on the NCS requires development of several issues related to SSDI efficiency, regulatory requirements and operational considerations. The oil spill trajectory model (OSCAR) has been updated by including an improved estimation of temperature and viscosity during droplet formation, resulting in a more realistic median droplet size. A case study for the NCS has shed light on the regions and conditions for which SSDI will be an effective response technology. Shallow water, with a combined oil and gas release, will challenge SSDI efficiency for some fields on NCS, and further work aims to develop a screening tool for SSDI feasibility. SSDI could change the properties of the resulting surface film and laboratory work has been recently initiated to assess the effect of remaining dispersants on the surfaced oil. A bench-scale screening test of SSDI efficiency for different combinations of oil and dispersants has been developed. A selection of oil types and dispersants has been tested. A first test case using the ERA Acute methodology for SIMA analysis with SSDI as a response option has been performed. Further case studies to gain experience with ERA Acute is initiated. The bench-scale screening test and ERA Acute SIMA assessment is planned used for pre-approval of dispersant use. A prototype automated system for regulating and optimizing subsea dispersant injection flow rate has been successfully tested, and the next step is to develop an implementation plan to advance the technology.

References

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