Enhanced Oil Recovery

a report by
Sigmund Stokka
Research Director, Improved Oil Recovery, International Research Institute of Stavanger (IRIS)

Enhanced oil recovery (EOR) has regained focus in the oil industry as the price of oil has remained high for a long time and is forecast to maintain its high level, since petroleum reserves are declining. EOR research was high during the 1980s and early 1990s in many oil-producing areas, but dropped to a very low level as the oil price dropped to around US$10 per barrel. Now a number of oilfields could be candidates for economic EOR application. Field applications are being evaluated worldwide and research and development efforts will follow.

In offshore areas, such as the Norwegian continental shelf (NCS), water injection and water-altering gas (WAG) injection is often utilised as a secondary recovery technique. It is then easier to use an EOR technique based on water additives, rather than considering injection of nitrogen, carbon dioxide (CO_2) or air. Surface active chemicals and polymers can be added to the injection water in low concentrations to mobilise additional oil. For the NCS, it is a challenge to find chemicals that are approved by the environmental authorities and are also cost-efficient, a main problem being controlling retention at the rock surface in the reservoir. Chemical suppliers are working on developing next-generation chemicals in dialogue with EOR researchers. The qualification process is complicated by the lack of attractive field pilot candidates, long well distance and long timescale for planning and execution of the offshore operations.

Microbial EOR (MEOR) has potential for cost-efficient application, but more research into the MEOR mechanism is needed before it can be applied to a specific oil field. So far, documented field applications are limited to near-wellbore applications.

For a lot of offshore applications, EOR techniques have to compete with continued water injection or WAG, accompanied by drilling of more wells and sidetracks, and the EOR potential is substantially reduced after additional oil has been produced by the secondary recovery technique. This is the main reason why several European field evaluations for the application of CO_2 injection have resulted in negative conclusions recently. The US experience for onshore CO_2 EOR applications is 7–15% additional recovery of the original oil in place, while estimates at the NCS are in the range of 3–7%. Also, for offshore CO_2 EOR applications, the cost associated with CO_2 separation at the producers – as is required to avoid polluting the hydrocarbon sales gas and for geological storage of CO_2 – is substantial.

A CO_2 value chain is being considered in Norway, including producing electric power from a gas-fired power plant, separating out the CO_2 from the exhaust gas, sending the CO_2 offshore in a pipeline, using it for EOR at several oil fields and, finally, storing it in the produced oil reservoirs or another geological storage site. A combined plan could also involve bringing in CO_2 from northern Europe to make available sufficient CO_2 volumes for CO_2 injection into the large Norwegian oil fields.

In Norway, it is estimated that 46% of the original oil in place will be recovered under existing development plans, a number that has been growing substantially in recent years as a result of implementation of significant technological improvements, such as field optimisation, better reservoir characterisation, gas and WAG injection and improved drilling and well technology. This is considerably higher than the global average of 32%, one of the reasons being that the Norwegian authorities require that the field operators target high hydrocarbon recovery. They even request that operators improve their knowledge and technology through research and development to enable them to produce as much from the resources as is economically feasible. EOR is likely to increase recovery further, and a number of oil fields are potential candidates for EOR applications and are motivation for increased EOR research. These are Ekofisk, Valhall, Snorre, Heidrun, Oseberg, Gullfaks, Njord,

> Enhanced oil recovery has regained focus in the oil industry as the price of oil has remained high for a long time.

Sigmund Stokka is Research Director for Improved Oil Recovery at the International Research Institute of Stavanger (IRIS). He is also Manager of the Centre for Oil Recovery (COREC), which was established in 2002 jointly between ConocoPhillips, the University of Stavanger and IRIS. Dr Stokka has been working for 25 years in petroleum research and technology development and engineering services for IRIS, Rogaland Research and the service industry. He has broad experience as a project leader and research manager within both improved oil recovery and drilling and well technology. He holds a PhD in Applied Physics from the Norwegian University of Science and Technology.

Brage, Grane, Aasgard, Visund, Ula, Norne, Veslefrikk, Vigdis, Kristin, Gyda, Tordis, Draugen and Volve. It is estimated that an average 5% increase in the oil recovery factor for the 20 largest fields will add some 375 million Sm^3 of oil reserves to the NCS.

In Norway there was high emphasis on EOR research from the early 1980s to the late 1990s through the national research programmes SROR, RUTH and RESERVE, the main goal being to bring results from research and development to field pilots, which was, to some extent, successful. Today, EOR is one of eight technology target areas within the Petromaks national research programme for oil and gas. CO_2 injection and CO_2 WAG injection has also been emphasised, including improved macroscopic sweep efficiency by gas mobility control with, for example, foam. Today, water-based techniques using water additives in connection with ongoing water injection programmes or WAG are given high attention, including use of surfactants, polymers, alkaline agents, low-salinity water, polymer gels and MEOR. They are being evaluated for improving the microscopic or macroscopic sweep efficiency, or changing the rock wettability.

Improved process understanding is important, especially for some of the chemical processes and MEOR, and relating to various rock wettability conditions – i.e. whether the rock prefers to be in contact with the water or the oil, or has a mixed wettability. For most of the EOR technologies, moving from laboratory results to field predictions is a challenge, e.g. for CO_2 flooding, CO_2 WAG, surfactant flooding or MEOR. Uncertain predictions will lead to increased risk in the application phase and lower economic rating of the EOR technique. Improved simulation tools should be developed.

Well-planned pilots could be essential for qualification of EOR technologies, and will experience a series of challenges in offshore applications – e.g. related to logistics in operations, production monitoring, measurement of residual oil saturation, corrosion and reservoir souring, high offshore costs, long time lag from injection starts until results are obtained, reservoir uncertainty as related to large well spacing offshore and economic evaluation.

> Today, enhanced oil recovery is one of eight technology target areas within the Petromaks national research programme for oil and gas.

The Norwegian EOR efforts are in line with the international focus on reducing the amount of oil left in reservoirs. Could a combination of a set of EOR technologies lead to leaving only one-third of oil behind, as is experienced in the most successful Norwegian field cases? Do we need to take on board brand new ideas and develop radically new technologies? ■