SINTEF FACTS

Electrocoalescence

April 2012

- for water separation from heavy crude oils

By activating electric fields in oil-water mixtures small water droplets will be attracted to others and form larger drops. This makes the oil-water separation process more effective as larger drops settle faster than smaller droplets. The process is called electrocoalescence.

Traditionally gravity separation without an electric field is used for oil-water separation. This takes place in large tanks and it takes a long time for the oil and water to separate and the sand to settle on the bottom. The typical dimensions of such tanks are 30 m long and 5 m in diameter.

Electrical field

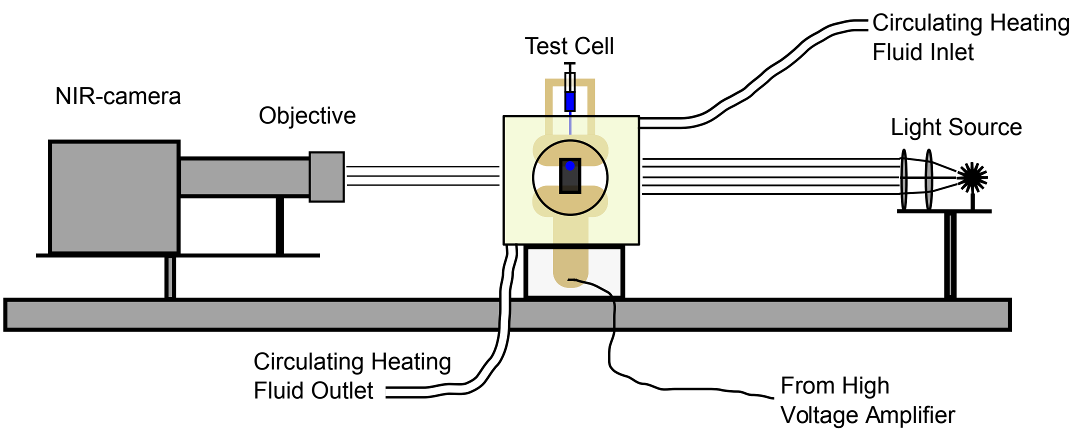
One way to make the separation process more efficient is activating an electric field in sections of these large tanks with a relatively stagnant emulsion. Newer more compact coalescers can further be achieved by combining a turbulent fluid flow with an electric field. The turbulent fluid flow produces more frequent collisions between droplets and the electric field helps nearby waterdrops to coalesce. Hence, both the production of a field can be increased and the size of the separation tanks can be reduced.

Experience has proven that this technique works. However the details about what will happen when two drops coalesce were previously unknown. Thus it was difficult to understand how the process or equipment could be optimized in terms of the degree of turbulence and the size and frequency of the electric voltage. This was partly due to large variation in crude oil quality and partly due to the fact that visual studies of wter drops in dark crude oil is impossible with ordinary high-speed cameras.

High-speed NIR-camera can see through crude oil

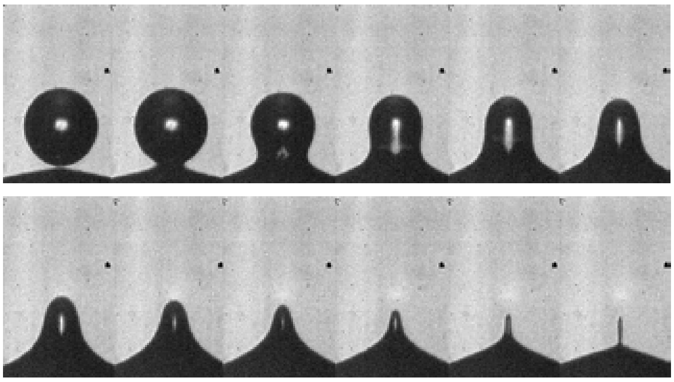
In order to study the fundamental effects in this process, high-technology equipment is required. In this case a high-speed camera that can find out what happens when two waterdrops collide and coalesce in a dark heavy oil is used. The equipment is an NIR (near infrared) camera that has been purchased especially for such experiments. The resulting images reveal effects that previously were impossible to study in such detail.

This set-up (below) requires a lot of computing power to process the images that are obtained. A typical image shows the waterdrop in black and the surrounding light grey-white medium is the darj heavy oil.



Experimental set-up using the NIR camera

Such images clearly show the interface between waterdrops and therefore we can see how the drops react when activating an electric field. The figure below shows a sequence of pictures where one drop coalesce with a larger drop. This time from the first to last image is less than 0.04 seconds; the surface of the larger drop below is pulled upwards to the upper drop and results in contact between the water phases in the two drops. The surface tension ensures that they merge. This shows how fast the process is and the demand placed on the camera and experimental set up. Previously there have been studies in transparent model oil which is unsatisfactory as the real problem is crude oil in general.

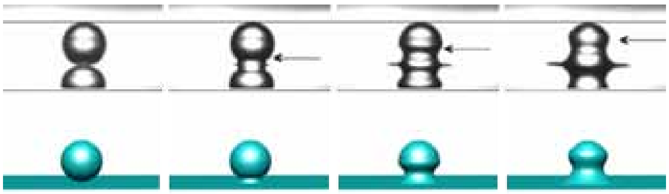


Images of waterdrops that coalesce with larger waterdrops in a vertical electric field (Svein Magne Hellesø)

Having such clear images, researchers are now able to compare experimental results in different qualities of heavy oil under a variety of temperatures with mathematical model calculations of equivalent effects. Just as in the experiments, an intensive degree of detail is required to model the effects we see when two drops coalesce and how the process is influenced by electric forces and the interface characteristics of the oil-water emulsions.

Calculation model

A detailed calculation model has been developed that can calculate an individual drop and how it is influenced by an electric field that is either constant or variable. The coalescence process between two drops is also modelled. Some challenging aspects of comparing experiments and calculations have become apparent in the project as it is demanding to see such effects one studies both experimentally and in the calculation model. The comparisons are affected by uncertainties in the experimental set up. The ambient temperature will influence the fluid characteristics or characteristics such as viscosity and surface characteristics in the water/oil mixture. The model that is used in the calculation tool will also have some uncertainty and limitations as only models are being used.



Comparison of experiments and modelling falling drops on a water surface, and the coalescence process itself between a drop and the water surface. Figure from Knut Erik Teigen, NTNU. The upper part is published with permission from Xiaopeng Chen, Physics of Fluids, 18, 051705 (2006). Copyright 2006, American Institute of Physics

Need for separation

Irrespective of whether it is on the Norwegian continental shelf, in Brazil or in Saudi Arabia, what is produced from an oil reservoir will be a mixture of oil, gas, water and sand. For some heavy oils and in tar sands, steam is used in the recovery process to reduce the viscosity. This results in oil/water mixtures and processing is required before the oil can be sold to a customer, either as natural gas for use in residential units or gaspower plants or as oil for the production of petrol or diesel.

The density differences between oil, gas, water and sand are used in order to separate these four main components:

- gas can easily be separated because of the large density difference
- oil and water have a smaller density difference and will need more time for separation
- sand can precipitate and become a sediment

Norwegian research with international collaboration

- A new project on electrocoalescence have been initiated. In 2010 this project was granted funding from the Research Council of Norway for the period 2011-2015.
- Our research within this field started in 2001, when SINTEF Energy Research got a research contract from the RCN on a project directed towards a 4 year study of fundamental aspects of electrocoalescence. This was continued in a new research contract with RCN established in 2006, on a 5 year study with emphasis on electrocoalescence in crude oils.
- The previous project was supported by international energy companies and manufacturers; Aker Solutions AS, BP Exploration Operating Company Ltd, Hamworthy Technology and Products AS, Shell Technology Norway AS, Petrobras, Saudi Aramco and Statoil ASA

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