JORIN

Title

"Produced Water, Process Problem or Process Control"

Authors

Nick Roth, Technical Director, Jorin Ltd.
Rick Gaskin, Marketing Director , Jorin Ltd.

Abstract

This paper discusses the potential uses of on-line image analysis techniques to provide information on the particle size distributions and relative concentrations of both oil and solids in produced water.

This technology could be installed at a number of points within the oily water separation process, to provide enhanced process control and compliance monitoring information and here we will discuss the potential benefits from three of the possible installation points.

Having true oil droplet size distribution information (a size distribution without solids) after the first stage separator could allow accurate control of the dosing level of demulsifier chemicals, minimising their usage, environmental impact and cost. This information would allow the confident specification of coalescors where required and give genuine information on the efficiency of separators.

Continuously monitoring oil concentration in overboard discharge water would allow operators to improve their discharge control by providing information on the trend in discharge level, allowing action to be taken to maintain a process within specification. Information on droplet sizes at this point in combination with concentration provides a diagnostic tool to identify areas in the separation train that may be experiencing problems. For example, if oil concentration in discharge water is increasing then it is evident that there may be a problem, but if it also known that oil drop size is increasing, there is strong evidence that the reject orifices in the deoiling cyclones are blocking.

Where produced water is re-injected, knowing the size and concentration of both oil droplets and solids is the only means to reduce injectivity losses, as different size and concentrations of different materials affect the formation's porosity differently. Where the formation is soft and injection has to be maintained at less than fracture pressure this becomes increasingly important.

Jorin Limited, 4 c b & a Vulcan Close, Sandhurst, Berkshire. GU47 9DD. England
Tel 01252 861 221 Fax 01252 861 551 email: info@jorin.co.uk web site www.jorin.co.uk

Introduction

The full characterisation of the oil and solids content of produced water between the first stage separator and the deoiling cyclones provides the opportunity to control the separation process. Downstream of the deoiling cyclones the same information can offer compliance monitoring as well as process monitoring and is absolutely necessary where produced water is re-injected.

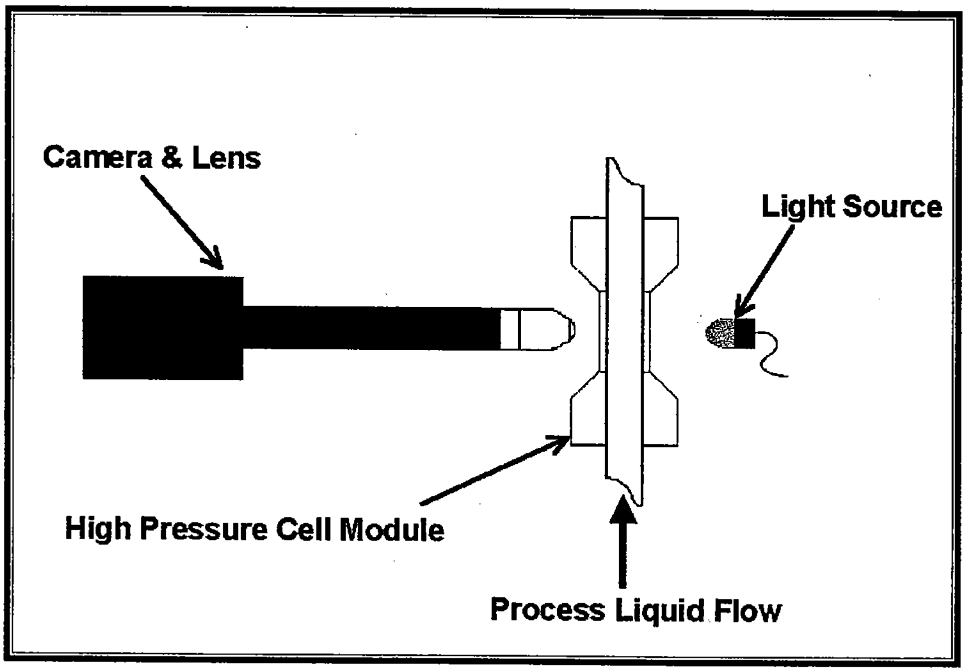
Having access to information on oil droplet size and concentration is critical to the effective design and operation of any produced water clean up process. This information can be devalued if solids are included within the size distributions. Without being confident that a size distribution is a distribution of the sizes of oil droplets alone, it is not possible to accurately dose demulsifier chemicals, assess where coalescors offer benefits or determine the efficiency of any oily water treatment. Alternately, if produced water is to be re-injected, the size distributions of oil droplets and solids each may have a different impact on the formation and only by measuring both can formation damage/injectivity losses be minimised.

The ViPA analyser is an on-line particulates and droplet analyser, providing information on the size distributions of both oil and solids and their relative concentrations. Potential benefits of the information from the ViPA system are discussed in this document in relation to potential installation/application areas.

ViPA analyser

The **ViPA**, **V**isual **P**rocess **A**nalyser, is an on-line instrument for the monitoring of particle and droplet sizes and concentrations. The ViPA can operate continuously on-line at high pressure and elevated temperatures.

The ViPA package consists of the ViPA software set and a compact and robust measuring head (with a built-in cleaning mechanism) that can be located up to 1100 yards from the control computer (6.25 miles with upgraded unit). The compact measuring head (approximately 17 x 8 x 6 inches) is installed on bypass line very close (typically a few inches) to a quill type sampler, this ensures the most representative possible sample is used.

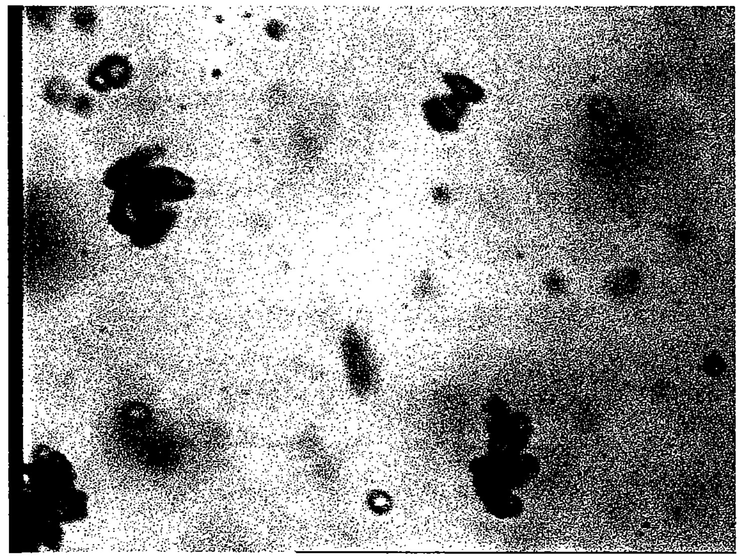


Using image analysis techniques to differentiate between particles and droplets in real time, the ViPA monitors up to seventeen parameters about each particle and droplet continuously including size and concentration.

The ViPA software includes a set of trend algorithms that use statistical tests to determine if a process will exceed pre-determined specifications during a set period. This provides the opportunity to pre-empt process upsets by taking action before an impending problem occurs.

4 – 20 mA outputs further allow control signals to be tied to measured parameters, for example, the d_{50} mean size of oil droplet could be mapped to a control signal for a demulsifier dosing pump.

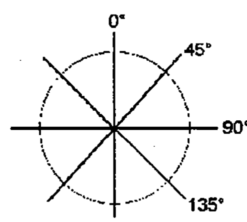
The ViPA uses a video microscope in a ruggedised assembly consisting of a video camera and lens and a light source to examine the contents of a liquid. Produced water flows through the ViPA's cell module, which has a pair of transparent windows, and the camera looks through the water at the light source. This allows the video microscope a backlit view of the objects in the water flow, whether these are solid particles, liquid droplets or gas bubbles. The ViPA operates by freezing a single frame of the video image and analysing the objects present. A database of information is built by rapidly acquiring and analysing sequences of these frozen images.



Above is a typical image from the ViPA, the image is of ground garnet mixed with a light lubricating oil. The individual garnet crystals are approximately 35µm in size.

Typically, using three parameters for each object seen; size, shape factor and concentration allows information on the size and concentration for oil droplets and solids to be calculated.

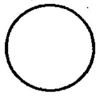
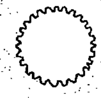
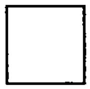
Size.



The ViPA measures four diameters for every object. These Diameters are measured at fixed angular intervals. These diameters are called Feret Diameters and the ViPA reports size as average Feret Diameter.

Shape Factor.

Shape Factor is mathematically described as: **4.Π.Area / Perimeter^2.**
The shape factor for a perfect circle (sphere) is always 1. As the length of perimeter increases compared to the area enclosed, shape factors decrease very rapidly.

Shape	Shape Factor	Shape	Shape Factor
	1.0		0.19
	0.75		0.0000061

Shape factor is one of the tools that the ViPA can use to distinguish between different types of particles.

For example:

- The non-continuous phase of a liquid-liquid emulsion, such as oil in water, exists as perfectly spherical droplets.
- Most solids are irregular in shape.

Therefore, in a liquid flow system containing both of the above, shape factor can be used to distinguish and discriminate between the two types of particles or particle populations, i.e. the oil droplets and the solids.

The ViPA can use sets of user defined values for parameters such as shape factor to determine the limit values of a population. Then, in real-time, the ViPA can determine which population an object belongs to and record it's statistical information into a separate database for each population.

Concentration.

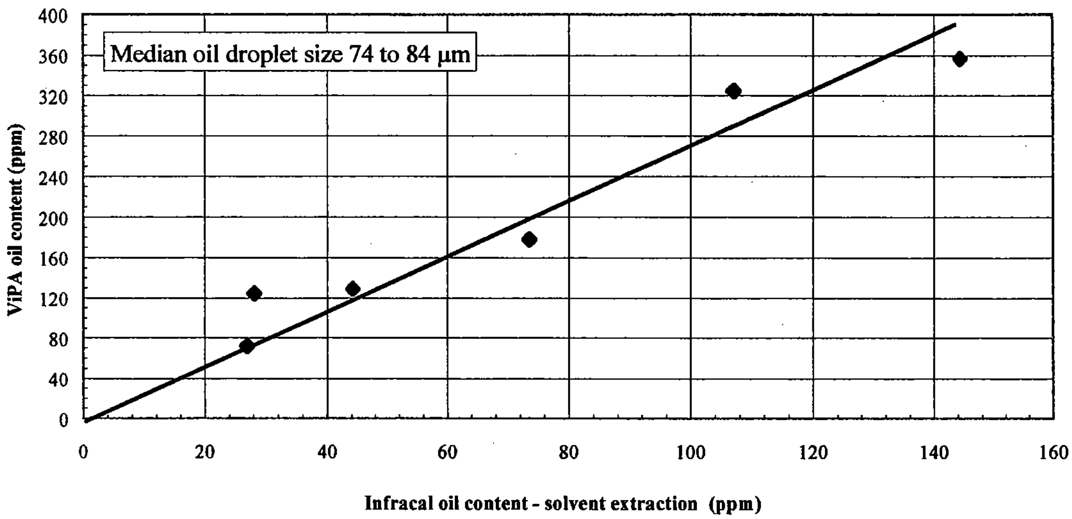
The ViPA reports concentration as visible parts per million (ppmv). There is a known volume of liquid for each frame that the ViPA analyses. This volume is calculated as:
(the width of the analysed image) x (the height of the analysed image) x (the depth of focus of the image). In each frame the ViPA calculates the volume of the objects for each particle or droplet population/class. At the end of each analysis the ViPA software sums up the volume of all the objects in a population/class and the volume of all the frames, which then allows ViPA to report a volume/volume concentration for each run.

The measured concentration is reported as visible ppm, because only those objects seen are measured and included in the calculation. In other words, materials passing through the cell between frames and objects that are not in focus are not seen and hence not measured.

However, while the concentration figures are not absolute, they are repeatable and indicate how the concentration of a material is changing relative to previous or later measurements. Work has been done demonstrating the strong correlation between the concentration reported by the ViPA and those reported by other industry accepted methods such as the Rivertrace system and the Infracal solvent extraction method.[1]

[1] "On-line determination of particle size and concentration (solids and oil) using ViPA Analyser - A way forward to control sub sea separators" presented at the IBC Production Separation Systems Conference. May 2000.

ViPA Oil conc calibration
Forties crude in fresh water - tests at temperatures 21-30° C
Median oil droplet size based on volume distribution



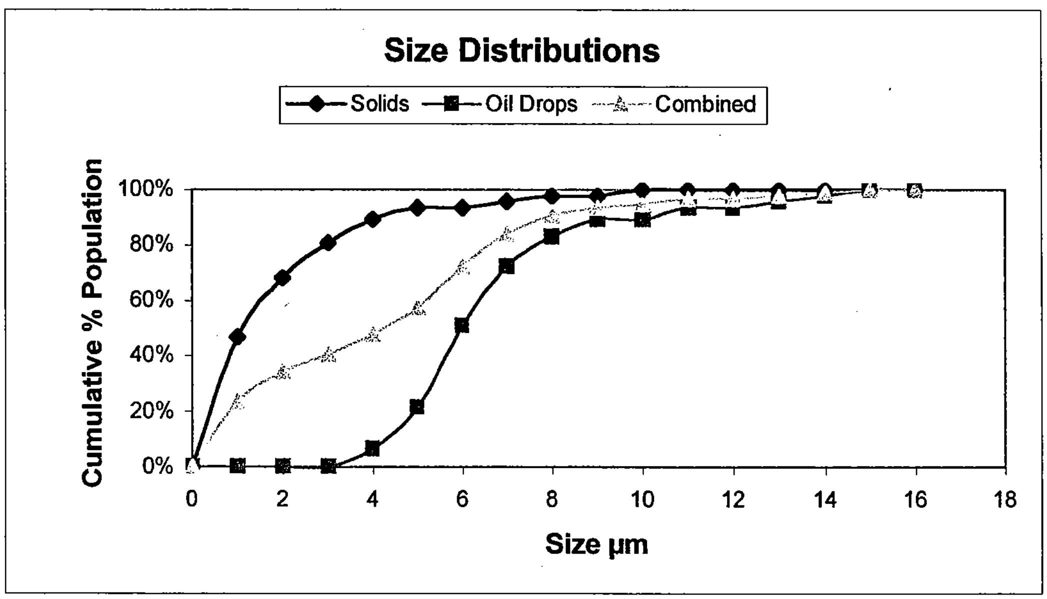
Installation Points & Potential Benefits.

1. Downstream of first stage separator.

Historically, grab samples have been taken at this point and size distributions generated by laboratory analysis. These analyses assume that all particulate materials are oil droplets and are generally carried out off-line at atmospheric pressure.

This can lead to errors in the particle size distribution. Most water based system have naturally occurring solids present. These particles are small, usually in the range 0 – 10 µm. If oil droplets in the inlet to a deoiling cyclone are in the range 4 – 15 µm and the naturally present solids loading is added to this the distribution will be skewed.

The Example below shows separate solids and droplet size distribution and a combined distribution, this combined distribution shows the effective downshift in apparent size caused by incorporating small solids.



Treatment regimes that are based on the assumption made by this combined distribution will tend to over compensate and attempt to treat untreatable particles.

In the above example, a chemical demulsifier dosing rate could be calculated to increase d_{50} mean size from 4µm to 10µm. This dose would be far in excess of the dose required because the d_{50} mean size of the oil droplets is 6.5µm and no amount of demulsifier will increase the d_{50} mean size of the solids.

In 1998 in excess of 20 tonnes of production chemicals where discharged to the sea from 126 installations in the North Sea[2]. Monitoring the size distributions of both oil and solids would allow the injection of minimum effective dose of demulsifier to ensure that optimum droplet size for the deoiling cyclones where achieved, while minimising the discharge of these usually highly toxic chemicals to the environment and minimising the cost of treatment.

This information also allows the efficiency and requirement for tertiary treatment equipment such as centrifuges and coalescors.

Take, for example, an extreme case with a very high loading of small solids and oil droplets in the region of 8 – 12µm. A combined particle size distribution may show mean size of 3µm and indicate an coalescor may be effective, where as, in fact a coalescor would have no effect on the combined distribution and may not be necessary at all.

However, taking a similar system with a very high loading of small particles and oil droplets in the range 3 – 6 µm, trial data may show that the combined particulates on both the inlet and the outlet of the coalescor have a mean size of 2 µm, so there is no apparent effect from the coalescor. In reality the coalescor may be increasing the mean size of the oil droplets from 4µm to 10µm, but this is hidden by the large number of small solids present.

Ideally, in an unchanging system, identifying the size distribution of oil droplets alone is the only required information to properly achieve process control. In reality, the outlet from the first stage separator is rarely constant and the continuous monitoring of oil droplet size and solids size would allow for continuous control of dosing pumps etc. Combining drop size information with oil concentration information may also indicate the interface level within the first stage separator and allow further control of this.

2. Overboard Discharge

Compliance monitoring is clearly currently the sole reason for the analysis of discharge waters. The grab samples usually taken to ensure compliance with discharge regulations, either legal requirements or corporate policy, do not provide an 'insightful' description of the separation process, or even a helpful means of avoiding a breach of compliance between samples.

A continuous monitor reporting oil concentration offers obvious benefits in terms of both compliance and process control, with trend information allowing action to be taken before the event rather than after it.

Such a continuous monitor can still only indicate that there may be a problem within a separation process, concentration data alone can not provide any insight as to where the problem may lie. Typically, where oil concentration levels are increasing to a point where discharge limits may be breached, a number of samples must be taken from different points in the separation train to determine where the problem is arising.

If oil droplet size is also monitored continuously at the discharge point, a combination of the information on concentration and size distribution can be taken together to provide an instant diagnostic tool for the problems occurring.

---

[2] UKOOA 1999 Environmental Report

The following table gives some indication of how the combination of droplet size and concentration information might be interpreted, with more specific information on a particular separation process, this information can be better related to the process:

	Oil Concentration Decreasing	Oil Concentration Increasing
Drop Size Decreasing	Process at less than capacity	Chemical Dosing/Coalescor Problem
Drop Size Stable	Water Cut Increasing	Process at Capacity
Drop Size Increasing	Process at less than capacity	Separator Reject Orifices Blocking

The monitoring of solids at this point appears to be only beneficial to ensure that the oil droplet size distributions are 'clean', however, monitoring the size distribution and concentrations of solids on discharge may provide evidence of the rate of erosion caused within the process by solids.

3. Produced Water Injection

Where produced water is re-injected, in order to minimise formation damage it is essential to have information on solids size and concentration and oil droplet size and concentration. (In fact there may more than one type of solids material of importance and it is possible in some systems to use the ViPA to differentiate between different solid particle populations). Each type of material has a different impact on the formation and while solids in one particular size range may have no impact on injectivity, a similar loading of larger solids may cause rapid injectivity loss.

'It is evident that the phenomenon of the plugging of porous media by particles generally involves complex mechanisms that depend on a great many factors. It has been amply demonstrated that the particle concentration, the particle-size to pore size ratio and the flow rate must be considered as important parameters in these mechanisms'.[3]

' It was found in this study that the effect of the concentrations of oil droplets on permeability damage was not the same as that of solid particles…It was observed that permeability decline was not directly linked with oil concentration. In core flooding test within the range 100 ppm to 500 ppm oil concentrations and with similar droplets, the dispersions with greater mean oil droplet size diameter caused greater damage'.[4]

Core flooding studies may provide some data on the type of water treatment plant that is most appropriate, but it then has to be assumed that there will be no change during the life of the field.

The solids loading and even solids types change during the life span of a well. Oil droplet sizes and concentrations change from day to day, as different risers are brought on-line, as process plant ages, and the only effective insurance against formation damage is continuous monitoring coupled with predictive trend analysis to provide the opportunity to change treatment regimes before damage occurs.

Summation

- It is possible to use on-line image analysis techniques to provide data on size distributions of oil and solids and their respective concentrations.

- Downstream of the first stage separator, Oil droplet size distributions can be used to
    - Control chemical dosing

[3] 'Mechanisms of Formation Damage by Retention of Particles Suspended in Injection Water.' C Roque et al. Institut Francais du Petrole & Elf Acquitaine. 1995 SPE.
[4] 'An Experimental Investigation of the Formation Damage Caused by Oily Water Injection' NS Zhang, JM Somerville, AC Todd. Herriot Watt University. 1993 SPE.

- Assess coalescor requirement
- Monitor coalescor efficiency
- Ensure optimum conditions for deoiling cyclones
- In combination with oil concentration, indicate the interface level within the separator.

- In overboard discharge waters, oil droplet size and concentration data can be used to enhance compliance control and provide diagnostic information for the separation process

- In overboard discharge waters, solids size and concentration data might be used to asses and monitor sand erosion within the process

- Oil droplet and solids size and concentration data is essential to protect injectivity. Continuous monitoring with predictive trend analysis provides an opportunity for injectivity loss avoidance