#### Detecting and Characterizing Oil Agglomerates in Water Using Particle Imaging

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#### Outline

- What is Dynamic Imaging Particle Analysis?
- History of Particle Imaging So Far With Produced Water
- Limitations Found for Oil Agglomerates
- Proposed Methods
- Next Steps for the Technology

## What is Dynamic Imaging Particle Analysis?

- "Automated Microscopy"
- Sample is Moved Through Optical Path "Dynamically" & Imaged in Real-Time
- Large Number of Measurements Enables Differentiation by Shape
- "Shape Filters" Automatically "Bin" Particles Into Different Types
- High Quantity of Particles Measured Yields
  Higher Statistical Confidence

#### How It Works Flow Cell View



#### **FlowCAM** Overview

- Collects size, shape, and count data upwards of thousands of particles/second at 20 frames/second
- Allows query and examination of individual particle images and associated morphology
- Wide particle size range 2µm-2mm
- Low sample volume (~ 35 ul)
- Total Magnification from 20x to 200x

## **FlowCAM Models**





#### **Benchtop**

#### Portable



# PetroCAM



#### How It Works Imaging Mode



#### How It Works Size Distribution View



#### How It Works Filtered View by Particle Type



#### How It Works Particle Collage View

and the second second	-	-		Particle Properties	
				Particle ID	49064 🔦
000	6680	10 10		Aspect Ratio	0.85
809 5782	6275	7372	2453 16575	Average Blue	81.87
0802		9948	12687	Average Green	88.98
54 (MAR)		100		Average Red	93.31
· S			0 0 0	Circle Fit	0.84
		45511	48029 40407	Circularity	0.87
38480	40334 #	44617	40123 40127	Circularity (Hu)	0.98
38445			490	Compactness	1.15
	-	A 12 12	-	Convex Perimeter	114.19
090	T 10 1			Convexity	1.00
00400		04400	95500 00007	Date	2013-08-14
02422 # 005/8	# 6/246 69	572 81438 83198	000/2 8030/	Diameter (ABD)	32.34
	π		00	Diameter (ESD)	33.76
				Edge Gradient	132.76
				Elongation	1.00
				Feret Angle Max	85.00



#### **Round Dispersed Oil Droplets**



1.3

#### **Non-Oil Droplets**



#### **Early History Summary**

- Particle Imaging Can Easily Distinguish Oil Droplets From Other Particulates Merely by Shape
  - Oil Droplets Perfectly Round
  - Other Particulates Varying Degrees Less Round
- Fine for Cleanly Dispersed Single Droplets

## But What About Agglomerated Oil Droplets?

 Can Have Same Aspect Ratio As Other Particulates:



• Oil Droplets Can Also Adhere to Solids:





18

- In Some Produced Water Samples, the Volume of Oil Represented by Agglomerates May Be Very Significant
- So, HOW do we Measure Aggregated Oil Droplets in Those Samples?
  - Need to Isolate Droplets First
  - Then Count Them Individually
  - Add Count to Original Isolated Oil (Singlets)
  - Total Volume for ALL

#### Methodology Used:

- **1. Detect Full Particle Image**
- 2. Detect Edges on Image
- **3. Identify Circular Arcs**
- 4. Fit Circles to Arcs
- 5. Calculate Spherical Volume of Each Circle

# **Example of Method**

original image	edges separated	arcs identified	circles identified
0		$\rightarrow \bigcirc$	
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#### **Example of Method**



Sphere Count, Volumes as added particle properties

🙀 Particle Properties	×	
Particle ID	6578	*
Diameter (ESD)	71.48	
Edge Gradient	73.59	
Elongation	14.43	
Feret Angle Max	-10.00	
Feret Angle Min	-80.00	
Fiber Curl	0.92	
Fiber Straightness	0.52	
Filter Score	0.00	
Geodesic Aspect Ratio	0.07	
Geodesic Length	180.01	
Geodesic Thickness	12.47	
Image File	000009.tif	
Intensity	130.00	
Length	93.94	
Particles Per Chain	1	
Perimeter	384.97	
Roughness	2.33	
Sigma Intensity	33.91	
Source Image	2466	
Sphere Complement	0.00	
Sphere Count	15	
Sphere Volume	557.28	
Sum Intensity	1.04e+006	
Symmetry	0.64	
Time	10:13:49	
Transparency	0.30	
Volume (ABD)	65375	
Volume (ESD)	191216	
Width	37.40	Ŧ

### **Example: Single Droplet**



3849

Sphere Complement	0.00
Sphere Count	1
Sphere Volume	4200.11

### **Example: Oil Agglomerate**



5157

Sphere Complement	1196.47
Sphere Count	14
Sphere Volume	743.12

#### **Set Droplet & Solids Densities**

2
a
0.930
2.400
55.0%
Cancel

## **Agglomerate Droplet Analysis**

- Use droplet count, oil volume, solids volume
- Calculate average droplets per particle, average droplet size, and average solids size over the range of particle sizes
- See trends of particle size over time

## **Agglomerate Droplet Analysis**



#### **Limitations of Method**

- Look at droplets down to 4 um
- Works best on suspended oil droplets rather than on globs of free oil where sample is not so saturated that oil droplets are clearly visible
- Can be used for oil in water or water in oil

### **Questions?**

# Thank You!

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