Droplet Lab

The Practical Guide to Surface Science for the Oil & Gas Industry

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INTRODUCTION

Surface property measurement is an essential aspect of the oil and gas industry. Measuring surface properties such as surface tension, sliding angle, surface energy, and contact angle is important for various applications, including:

Oil Recovery

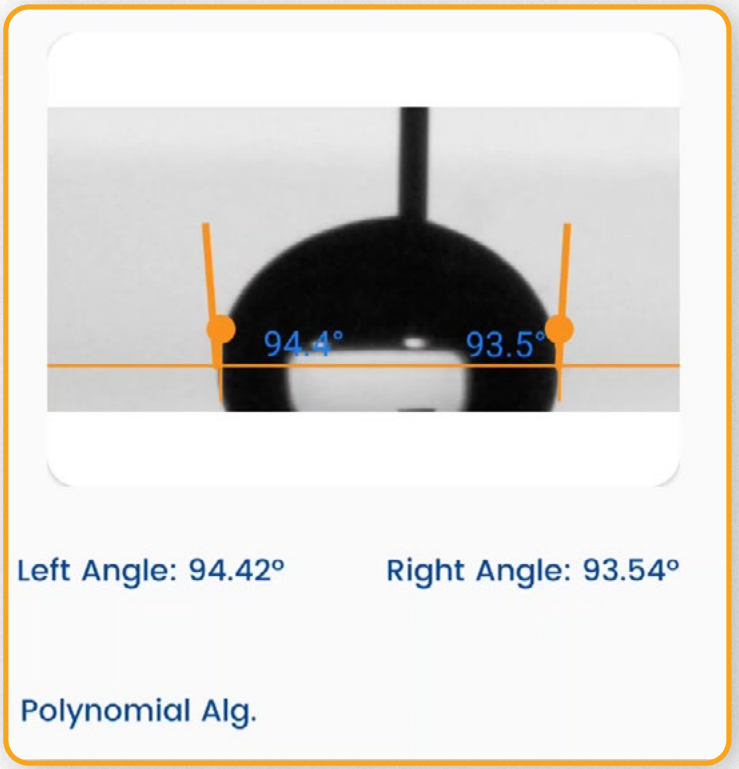
Wettability Alteration Evaluation

Materials Failure Analysis.

Some of the important surface properties that are used to understand the behavior & characteristics of petroleum products are:

Contact Angle Measurement

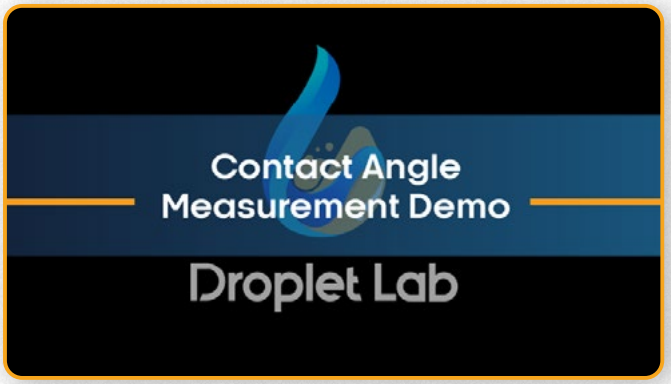
Contact angle quantifies the wettability of a surface, representing the angle between the surface of a liquid and a solid surface. For example, It is used to determine the wettability of the surface by the liquid to improve oil recovery. [1]



Sample Image taken from Droplet Lab Tensiometer

Droplet Lab offers both Young-laplace and Polynomial methods in our Tensiometer.

Young - Laplace Method	Polynomial Method
Uses the whole drop profile to calculate the contact angle value	Uses only a certain percentage of the drop profile to calculate the contact angle value.
Only compatible with an axisymmetric drop. This is not always seen in practice, as a needle is typically inserted into the drop to increase/decrease the drop volume.	Compatible with both axisymmetric and non-axisymmetric drops.
Measurement results are more consistent compared to the polynomial fitting method.	Measurement results are less consistent, as they are affected by local surface imperfections.



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Learn how Contact Angle measurement is done on our Tensiometer

Dynamic Contact Angle

Ideally, when a drop is placed on a solid surface, a unique angle exists between the liquid and the solid surface. The value of this ideal contact angle (the so-called Young's contact angle) can be calculated using Young's equation.

In practice, due to the surface geometry, roughness, heterogeneity, contamination, and deformation, the value of the contact angle on a surface is not necessarily a unique value but falls in a range. The upper and lower limits of this range are called the advancing contact angle and the receding contact angle, respectively.

The value of Advancing and receding for a solid surface is also very sensitive and can be affected by many parameters, e.g., temperature, humidity, homogeneity, and minute contamination of the surface and liquid. For example, the advancing and receding contact angles of a surface at different locations can be different.

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Dynamic Contact Angle versus Static Contact Angle

Practical surfaces and coatings naturally show contact angle hysteresis, indicating a range of equilibrium values. Measuring static contact angles provides a single value within this range. Solely relying on static measurements poses problems, like poor repeatability and incomplete surface assessment regarding adhesion, cleanliness, roughness, and homogeneity.

Practical applications require understanding a surface's liquid spreading ease (advancing angle) and removal ease (receding angle), such as in painting and cleaning. Measuring advancing and receding angles offers a holistic view of liquid-solid interaction, unlike static measurements, which yield an arbitrary value within the range.

This insight is crucial for real-world surfaces with variations, roughness, and dynamics, aiding industries like oil & gas, materials science, and biotechnology in designing effective surfaces and optimizing processes.

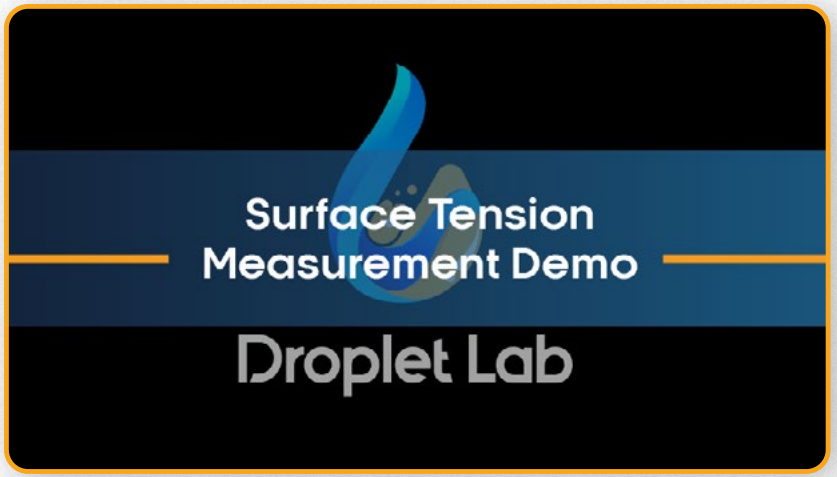
To improve the data quality of your contact angle measurements we recommend you read up on the best practices in the below referenced paper.

Guidelines to measurements of reproducible contact angles using a sessile-drop technique

Surface Tension Measurement

This property measures the force acting on the surface of a liquid, aiming to minimize its surface area. For example, it is an important property for understanding the spreading behaviour of oil spills and the effectiveness of oil spill response techniques.

Sample Image taken from Droplet Lab Tensiometer



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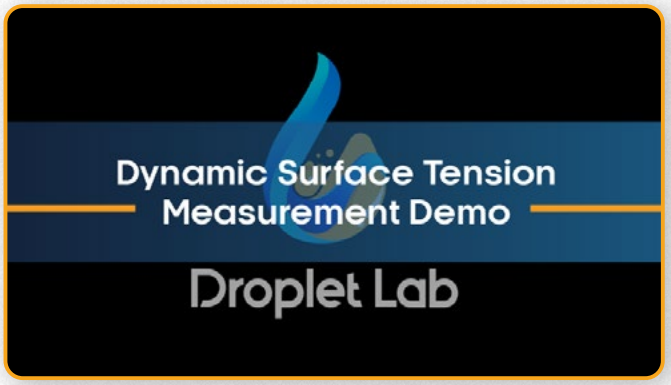
Learn How Surface Tension measurement is done on our Tensiometer

Dynamic Surface Tension

Dynamic surface tension is different from static surface tension, which refers to the surface energy per unit area (or force acting per unit length along the edge of a liquid surface). Static surface tension characterizes the equilibrium state of the liquid interface, while dynamic surface tension considers the kinetics of changes at the interface. These changes could be the presence of surfactants, additives, or temperature, pressure, and/or compositional changes at the interface.

These measurements are used to understand the behaviour of oil-water or oil-gas interfaces, which is important for processes such as enhanced oil recovery.



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Learn how dynamic surface tension measurement is done on our Tensiometer

When to use Dynamic Surface Tension Measurement

Dynamic surface tension is particularly important when dealing with processes that involve rapid changes at the liquid-gas or liquid-liquid interface, such as droplet and bubble formation or coalescence (change of surface area), behavior of foams, and drying of paints (change of composition, e.g. evaporation of solvent). It is measured by analyzing the shape of a hanging droplet over time.

Dynamic surface tension has applications in various industries, including oil & gas, coating, pharmaceuticals, cosmetics, food and beverage, and industrial processes where understanding and controlling the behavior of liquid interfaces is essential for product quality and process efficiency.

Scientific Validation of our Instrument:

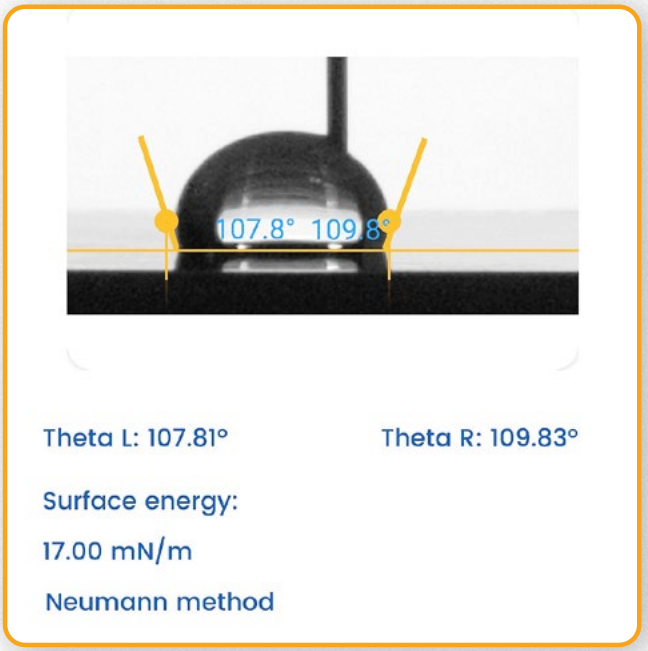
Accuracy and reliability are the cornerstones of any scientific instrument, and concerns regarding the precision of our setup are both understood and acknowledged. While our state-of-the-art tech lays the foundation, it's our unwavering commitment to validation that sets us apart.

This promise of transparency and scientific rigor is supported by two peer-reviewed papers that thoroughly detail and validate the performance of our instrument:

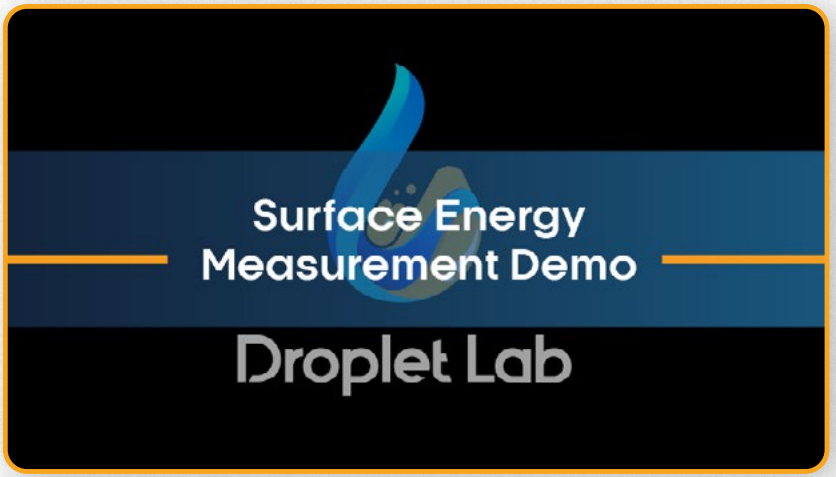
1. Review of Scientific Instruments
2. Colloids & Surfaces A

Surface Energy Measurement

Surface energy is a significant factor in the adhesion and deposition of mineral scale on surfaces within the oil and gas industry. Understanding surface energy and its influence on fluid behaviour and surface deposition is crucial for the effective management of oil and gas production while also reducing the adverse environmental consequences of spills and other incidents.



Sample Image taken from Droplet Lab Tensiometer



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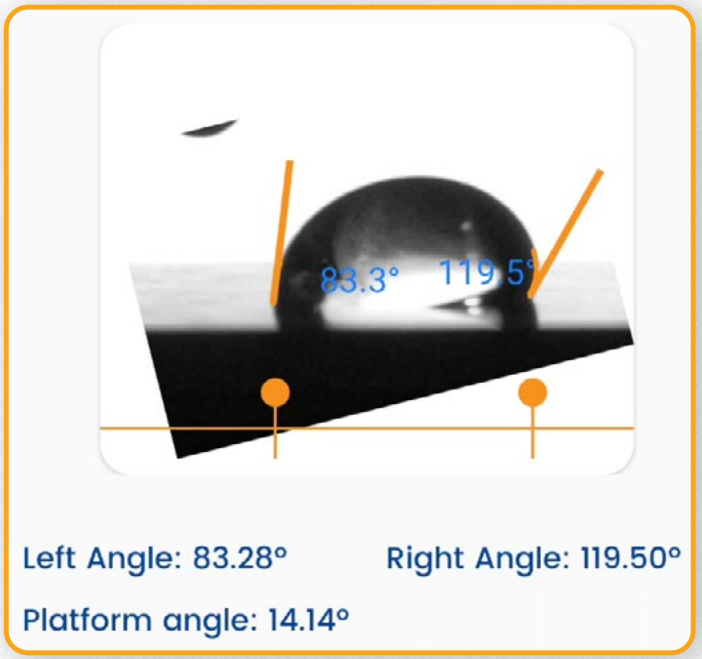
Learn how Surface Energy measurement is done on our Tensiometer

Sliding Angle Measurement

The sliding angle measures the angle at which a liquid film slides over a solid surface. It is commonly employed to assess the slip resistance of a surface. By measuring the sliding angle, researchers can evaluate the wetting properties of surfaces and to determine the effectiveness of wettability alteration techniques in oil reservoir management, for example. [2]



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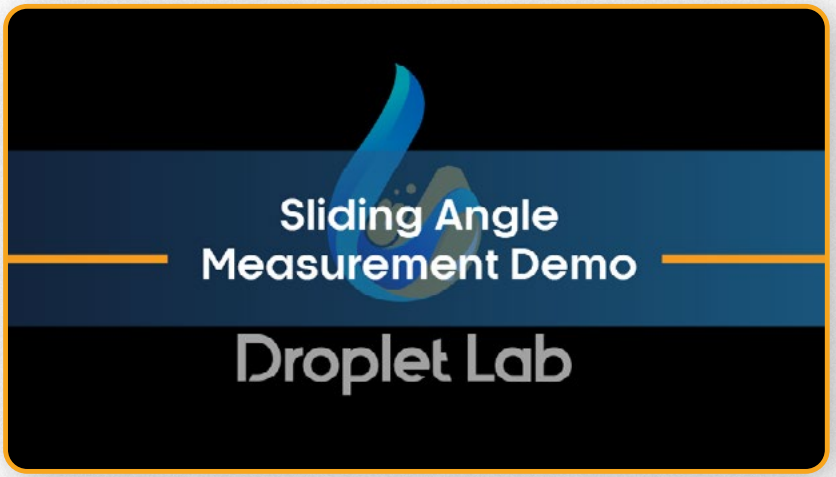

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[Learn How Sliding Angle Measurement is done on our Tensiometer]

By carefully considering and measuring these surface properties, researchers in Oil & Gas industry can continually improve their products' quality and meet the evolving needs of their customers.

Real-World Implications
Case Studies

Within the Oil & Gas industry, several case studies exemplify the advantages derived from conducting surface property measurements.

Presented below are a few illustrative instances:

1 Enhanced Water-Oil Separation [3]

Scenario: In an offshore oil production platform, the production stream includes a significant amount of water, which forms an emulsion with the crude oil due to high surface tension.

Application: By lowering surface tension using appropriate surfactants, contact angle and surface energy measurements can guide the selection of the most effective chemicals. This optimization improves emulsion destabilization, allowing for more efficient water-oil separation and reduced energy consumption during processing.

2 Polymer Flooding [4]

Scenario: Enhanced oil recovery (EOR) methods are employed in a mature oil reservoir to recover more oil. Contact angle measurements are used to assess the wettability of the reservoir rock. Researchers discovered that the rock has mixed wettability characteristics.

Application: By altering the contact angle using specific surfactants or polymers, surface energy measurements help design a more effective EOR strategy. This increases oil recovery by modifying the interaction between the reservoir rock and injected fluids.

3 Offshore Pipeline Protection [5]

Scenario: Offshore pipelines are exposed to harsh seawater conditions, leading to corrosion and reduced lifespan. Engineers apply hydrophobic coatings to the pipeline surfaces. Sliding angle measurements help evaluate the performance of these coatings.

Application: By achieving a low sliding angle, the coatings effectively repel water and reduce the risk of corrosion, extending the life of the pipeline and reducing maintenance costs.

4 Exploration and Production [6]

Scenario: It helps to determine the properties of the reservoir rock and the fluids contained within it. This information is used to determine the best drilling and production techniques to use.

Application: Surface property measurement is also used to determine the properties of the drilling mud and the cement used to seal the wellbore.

5 Enhanced Oil Recovery [7]

Scenario: It is used in enhanced oil recovery techniques such as surfactant flooding. Surfactants are used to reduce the surface tension between the oil and water, allowing the oil to be more easily recovered.

Application: Surface property measurement is used to determine the optimal surfactant concentration and to monitor the effectiveness of surfactant flooding.

6 Corrosion Control [8]

Scenario: To determine the corrosion rate of the metal surfaces in contact with the oil and gas. This information is used to select the appropriate corrosion inhibitors and to monitor their effectiveness.

Application: Conduct surface property measurements are key activities in ensuring asset integrity and control of corrosion.

7 Pipeline Transport [9]

Scenario: Conduct surface property measurements can be used to determine the properties of the oil and gas being transported through pipelines.

Application: This information is used to optimize the pipeline design and to monitor the pipeline for leaks and other problems.

8 Environmental Impact Assessment [10]

Scenario: Surface property measurement is used in environmental impact assessments of oil and gas exploration and production activities.

Application: It helps determine the potential impact of spills and leaks on the environment and develop appropriate response plans.

9 Material Selection [11]

Scenario: Advances in surface coating technologies are enabling material scientists and engineers to choose light metals such as aluminium, magnesium, titanium, and valve metals that have unique properties but were previously unfeasible in certain situations. High-performance polymers are also used in the industry for their excellent balance of properties.

Scenario: Measuring surface properties can also help select materials for the oil and gas industry.

These case studies demonstrate the importance of surface property measurements in the oil and gas industry. They provide insights into the behavior of petroleum products and help optimize oil and gas production while minimizing the environmental impact of these activities.

We are your partners all the way in solving your Business & Technological challenges

If you are interested in implementing these or any other applications you can send an email to us at abhandankar@dropletlab.com

We would also be interested to hear from you if you face any sample related difficulties. Book a call with our engineer to discuss the same with the below link https://calendly.com/gsaini-ob4

Standards and Guidelines

Several organizations have developed standards and guidelines for surface property measurement in the oil and gas industry. These standards provide a framework for accurate and consistent measurement of surface properties, ensuring the quality and safety of petroleum products. **Some of the organizations and their standards are listed below:**

The main objective of a thesis published in NTNU Open was to experimentally measure surface tension with the pendant drop technique for oil, gas, and glycol.

https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/257859/746608_FULLTEXT01.pdf? sequence=1

The Surface Operating Standards and Guidelines for Oil and Gas Development (Gold Book) provides information on the surface operating standards and guidelines for oil and gas exploration and development, which may include guidelines for surface property measurement.

https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5173043.pdf

A study published in the Journal of Petroleum Exploration and Production Technology describes an automated method for determining interfacial tension and contact angle using computer vision for oil field applications.

https://link.springer.com/article/10.1007/s13202-021-01398-6

A study published in ACS Omega discusses the estimation of water sliding angles for hydrophobic surfaces. Although this study focuses on commercial face masks, the method described for estimating sliding angles based on image brightness monitoring may be applicable to other surfaces, including those in the oil and gas industry.

https://pubs.acs.org/doi/10.1021/acsomega.2c00628
.

- **ASTM D5946-** Paints and varnishes — Wettability — Part 1: Terminology and general principles. General terms, definitions and general principles for

Sources

[1] https://glossary.slb.com/en/terms/c/contact_angle

[2] Mohamadreza Beitollahpoor, Melika Farzam, and Noshir S. Pesika, Determination of the Sliding Angle of Water Drops on Surfaces from Friction Force Measurements, Langmuir 2022 38 (6), 2132-2136, DOI: 10.1021/acs.langmuir.1c03206

[3] Tian, Ying, Jingjing Zhou, Changqing He, Lin He, Xingang Li, and Hong Sui. 2022. "The Formation, Stabilization and Separation of Oil–Water Emulsions: A Review" Processes 10, no. 4: 738. https:// doi.org/10.3390/pr10040738

[4] http://large.stanford.edu/courses/2015/ph240/zerkalov1/

[5] Bai, Yuxing, Haiping Zhang, Yuanyuan Shao, Hui Zhang, and Jesse Zhu. 2021. "Recent Progresses of Superhydrophobic Coatings in Different Application Fields: An Overview" Coatings 11, no. 2:116. https://doi.org/10.3390/coatings11020116

[6] Ganat, Tarek. (2020). Fundamentals of Reservoir Rock Properties.

[7] Weidong Chen, David S. Schechter, Surfactant selection for enhanced oil recovery based on surfactant molecular structure in unconventional liquid reservoirs, Journal of Petroleum Science and Engineering, Volume 196, 2021, 107702, ISSN 0920-4105, https://doi.org/10.1016/j.petrol.2020.107702.

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[8] https://www.astm.org/products-services/standards-and-publications/standards/petroleumstandards.html