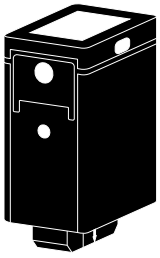
Application Note

Rapid assessment of cleaning agent performance after cooling lubricant application using the PCA 200

–In cooperation with BECHEM–

The effective removal of cooling lubricants is essential for ensuring high surface quality and reliable downstream processing. Contact angle measurements and free surface energy (SFE) analysis offer a fast, efficient, and non-destructive method for evaluating the performance of cleaning agents after cooling lubricant application. By characterising surface wettability, residual contamination and cleaning effectiveness can be quantitatively assessed, enabling informed decisions to optimize processes and conserve resources. This application note presents a rapid assessment approach using the PCA 200 portable contact angle goniometer from DataPhysics Instruments. Precise SFE values are obtained within seconds using a single-click measurement on a compact, stand-alone device, making it well suited for in-line quality control and incoming goods inspection. Measurements on two different material surfaces under various processing conditions demonstrate that contact angle and SFE analysis provide a reliable and efficient tool for comparing cleaning effectiveness and supporting resource-efficient manufacturing processes.

Measurement device
Portable Contact Angle Goniometer – PCA 200



Measurement method
Optical contact angle and contour analysis systems

Measured quantities
Contact angle
Surface energy

Environmental conditions
25 °C

Samples
Aluminium plate
Steel plate

Industries
Coatings
Pre-treatment or cleaning process on a solid surface

dataphysics
Understanding Interfaces

Theory

The PCA 200 Portable Contact Angle Goniometer (Fig. 1), manufactured by DataPhysics Instruments,[1] is the ideal **hand-held** device for **mobile** measurements of the surface energy of solid surfaces.

It is well established that the surface energy (SFE) of a solid can be determined by contact angle (CA) measurements with at least two different test liquids, for which surface tensions as well as their dispersive and polar parts must be known. The measured CAs as well as the known surface tensions with dispersive and polar parts are then employed in the calculation of the SFE, based on an appropriate theoretical model.[2][3][4] A frequently employed approach is the Owens, Wendt, Rabel, and Kaelble (OWRK) model, which considers the geometric mean of the dispersive and polar parts of the liquid surface tension, and the solid's SFE.

This approach allows to determine the polar and dispersive parts of the solid's SFE from the regression line in a suitable plot (Fig. 2).

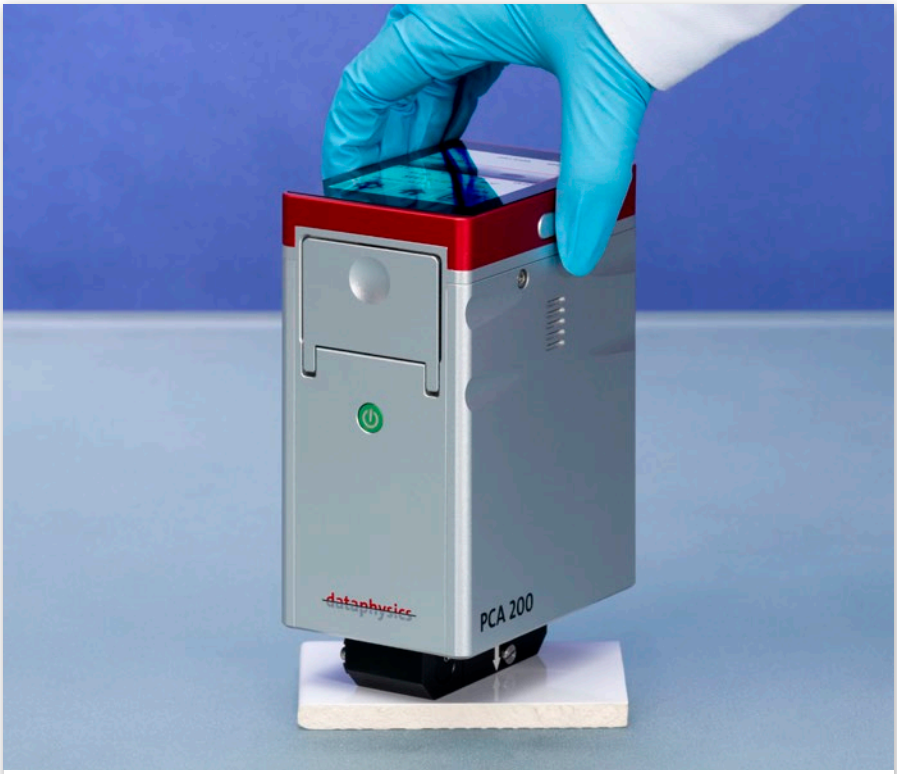


Fig. 1: The PCA 200 Portable Contact Angle Goniometer manufactured by DataPhysics Instruments

Main Features

The PCA 200 Portable Contact Angle Goniometer is the perfect instrument for analysing surfaces in production and quality control processes. By jetting up to two different testing liquids onto the surface to be analysed, it ***determines the CAs and SFE within seconds***. In addition to its lightweight design and intuitive user interface, the PCA 200 offers the following key features:

- ***On-Site Companion***

The PCA 200 is a **cable-free, independent system** with a mini-computer and built-in lithium-ion battery. It has an impressive battery runtime of 6 hours, numerous measurement capabilities, and a **highly portable design and low weight (820 g)**.

- ***Quick and Easy***

The PCA 200 can be one-hand controlled and accurately positioned even on small samples. The **live display** clearly shows the test site. By **simply touching** the screen or the measuring button, **the CAs, SFE with dispersive and polar parts, and the image will be displayed in just a few seconds.** The surface quality of the sample can be highlighted by colour (red/green). An integrated barcode scanner can be used to identify the sample.

- ***Reliable***

The PCA 200 is a 'lab-on-the-go' and provides **excellent measurement quality**. It performs optical drop shape analysis and **accurately** determines the surface free energy according to the selected models. It has an **easy-to-use** touch interface and a **web browser interface** for further functionality. It can be connected to a computer to adjust settings, set quality limits, review and organise the measurement data.

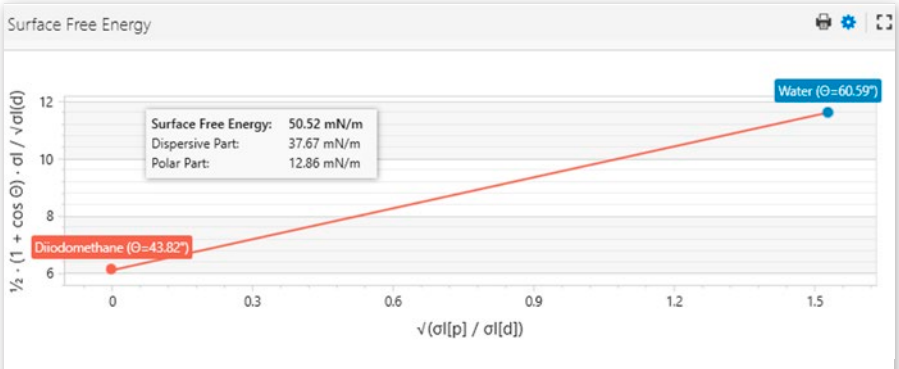


Fig. 2: The polar and the dispersive parts of the solid's surface energy is determined from the contact angles according to the selected model (e.g. OWRK or Wu model).

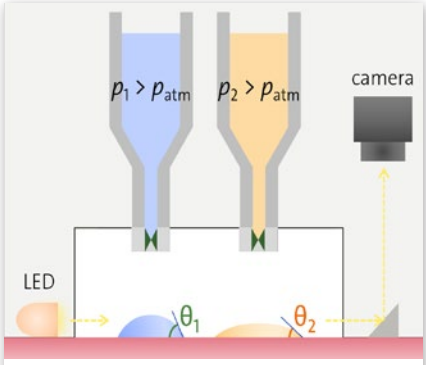


Fig. 3: The measuring principle of the PCA 200

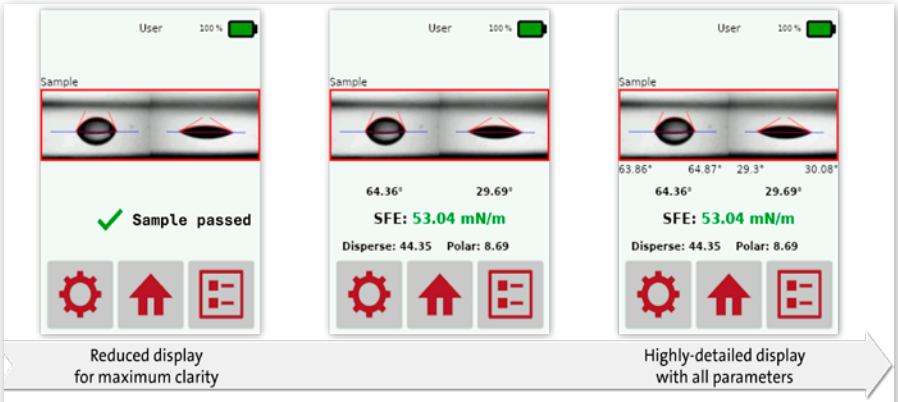


Fig. 4: Users can adjust displayed result detail via the web interface.

Experiment

In this study, the free surface energy (SFE) of aluminium and steel was analysed using the PCA 200. Each surface was evaluated step by step under the following conditions: (1) as received, (2) cleaned with water, (3) cleaned with isopropanol (IPA), (4) treated with a cooling lubricant, either (5a) cleaned with cleaner 1 [5] or (5b) cleaned with cleaner 2 [5], and finally (6) rinsed with water. To ensure reliable and reproducible results, five contact angle measurements were performed at each step by two independent users.

The PCA 200 initiates and performs a **fully automatic** measurement protocol, as illustrated in the diagram below, **without requiring any manual inputs**.

Step 1: Liquid dosing

The device employs a pressure-based dosing system, whereby both test liquids are simultaneously dosed onto the sample (Fig. 3).

Step 2: Recording the drop image

This is achieved by utilising an optical system incorporating a prism, which enables the camera to capture a profile image of both drops situated upon the sample surface (Fig. 3).

Step 3: Contact angle evaluation

In the image of the drop profile, the software identifies the contours of the drop and the line representing the substrate, and fits the contours with a suitable model. Subsequently, the CAs are determined based on the aforementioned fits.

Step 4: Calculation of surface energy

Following the measurement of the contact angles, the SFE is calculated in accordance with the selected model (OWRK or Wu model).

Step 5: Display of result output

The results are displayed on the device display just within a few seconds, with the desired level of detail (Fig. 4).

Results & Discussion

As shown in Fig. 5 and Fig. 6, surface free energy (SFE) measurements on aluminium and steel clearly demonstrate the influence of lubrication, cleaning and post-treatment steps on surface chemistry. For both materials, changes in total SFE and in the relative contributions of the dispersive and polar components provide a sensitive and quantitative indicator of surface contamination and cleaning efficiency.

Fig. 5 shows that the as-received, water-cleaned and IPA-cleaned aluminium surfaces exhibit similar SFE values (approximately 38–42 mN/m), which are dominated by the dispersive part with only a minor polar contribution. Among these states, IPA cleaning results in the highest SFE, indicating improved surface cleanliness.

After lubrication, the total SFE increases sharply to around 75 mN/m, primarily due to a pronounced increase in the polar part (33.31 mN/m). This clearly indicates significant surface modification by the cooling lubricant.

Cleaning with cleaner 1 (5a) effectively removes lubricant residues, restoring the SFE (~41 mN/m) and polar contribution to values close to those observed before lubrication. A subsequent water rinse further reduces the polar part to near-baseline levels.

In contrast, cleaner 2 (5b) results in a higher total SFE (~47 mN/m) accompanied by a noticeably increased polar part (~10.31 mN/m), suggesting the presence of remaining polar residues or a modified surface chemistry. A final water rinse after cleaner 2 significantly reduces both the total SFE and the polar contribution, returning the aluminium surface to a condition comparable with the as-received state.

Fig. 6 shows that the as-received, water-cleaned and IPA-cleaned steel surfaces exhibit similar SFE values (approximately 42–49 mN/m), again dominated by the dispersive part with only a minor polar contribution. As observed for aluminium, IPA clean-

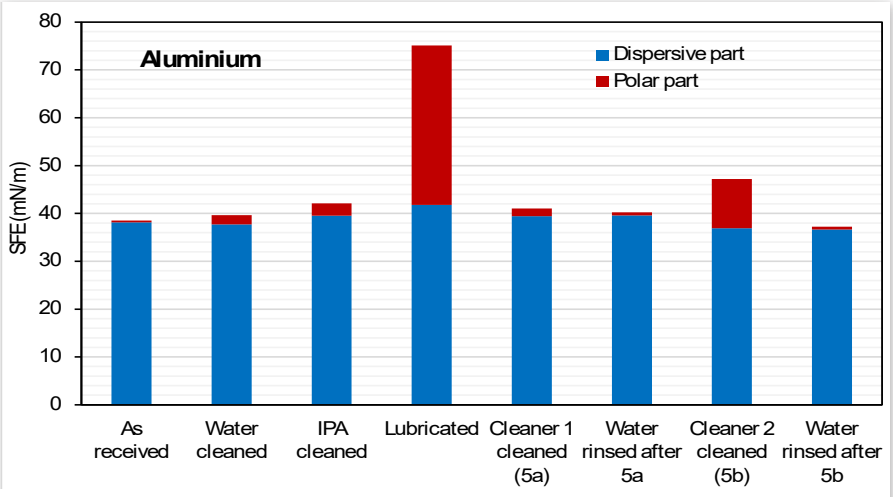


Fig. 5: The surface energy of the sample aluminium determined with PCA 200 technique

ing yields the highest SFE, indicating improved surface cleanliness.

Following lubrication, the total SFE of the steel surface increases to approximately 75.5 mN/m. In this case, the increase is mainly driven by a strong rise in the polar part (43.3 mN/m), indicating significant surface modification by the cooling lubricant.

Cleaning with cleaner 1 (5a) efficiently restores the steel surface to near pre-lubrication conditions, with SFE values (~48 mN/m) and a polar–dispersive balance similar to that of the IPA-cleaned surface. An additional water rinse provides a slight further reduction in residual surface polarity.

By contrast, cleaner 2 (5b) leaves a substantially elevated SFE (~62.6 mN/m) and a high polar contribution (~21.26 mN/m), indicating incomplete removal of lubricant-related residues. A final water rinse significantly reduces these effects and returns the steel surface close to its original condition.

Summary

Surface energy measurements with the PCA 200 clearly reveal the impact of cooling lubricants and cleaning processes on aluminium and steel surfaces. The system reliably differentiates cleaning performance, demonstrating effective lubricant removal with cleaner 1 and highlighting residual effects after cleaner 2 treatment. **These results confirm the PCA 200 as a fast, non-destructive tool for optimising cleaning processes and ensuring consistent surface quality in production.**

Reference

[1] www.dataphysics-instruments.com/

[2] Kaelble, H., J. Dispersion-Polar Surface Tension Properties of Organic Solids. *Adhesion*, **1970,** *2*, 66-81.

[3] Owens, D., Wendt, R.Estimation of the Surface Free Energy of Polymers. *J. Appl. Polym. Sci.*, **1969**, *13*, 1741-1747.

[4] Rabel, W. Einige Aspekte der Benetzungstheorie und ihre Anwendung auf die Untersuchung und Veränderung der Oberflächeneigenschaften von Polymeren. *Farbe und Lack*, **1971**, *77*, 10.

[5] BECHEM -www.bechem.com
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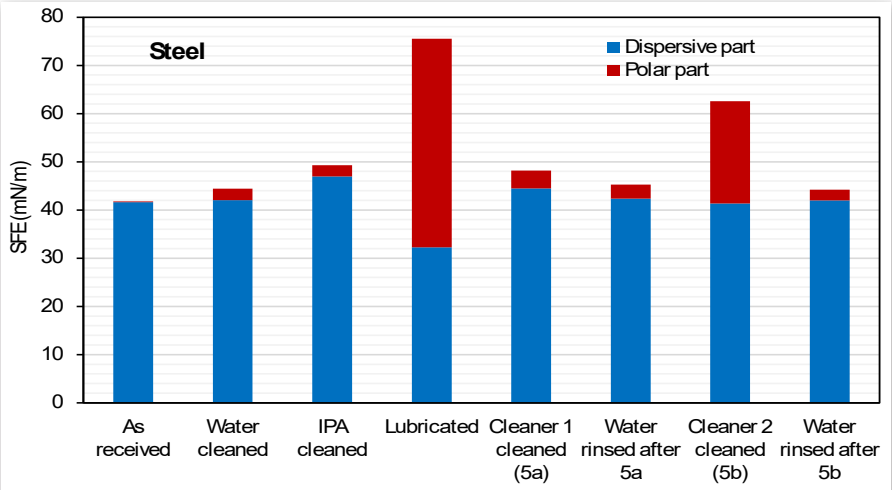

Fig. 6: The surface energy of the sample steel determined with PCA 200 technique

We will find a tailor-made solution for your surface science use case and will be pleased to provide you with an obligation-free quotation for the system that fits your needs.
For more information please contact us.

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