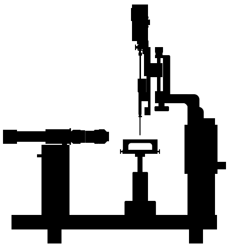
Application Note

Evaluating the interfacial tension between ink and different dampening solutions used in offset printing

Offset printing is a widely used technique in the production of printed products such as books, newspapers, and packaging. The process relies on the transfer of an image from an inked surface to the substrate. When used in combination with a lithographic process, it comprises the use of a dampening solution and an oil-based printing ink. The inked surface (plate) is divided into hydrophilic regions, which accept the dampening solution and repel the ink, and hydrophobic regions which repel the dampening solution and accept the ink. If the process is functioning optimally, it can be confirmed that the non-printing regions of the plate are devoid of ink. It is essential to ascertain the precise interfacial tension between the dampening solution and the printing ink at the interface to avert the possibility of their mixing. The OCA system, developed by DataPhysics Instruments, is a highly robust and reliable apparatus for measuring the optical contact angle and performing contour analysis. The system employs the pendant drop method to accurately determine interfacial tension between liquid/liquid interfaces. The following note will illustrate the pendent drop technique with ink and three different dampening solutions commonly utilised in offset printing.

Measurement device
Optical contact angle measuring and contour analysis systems of the OCA series



Measurement method
Optical contact angle and contour analysis systems

Measured quantities
Surface tension
Interfacial tension

Environmental conditions
25 °C

Samples
Three different dampening solutions and one ink

Industries
Ink
Offset printing

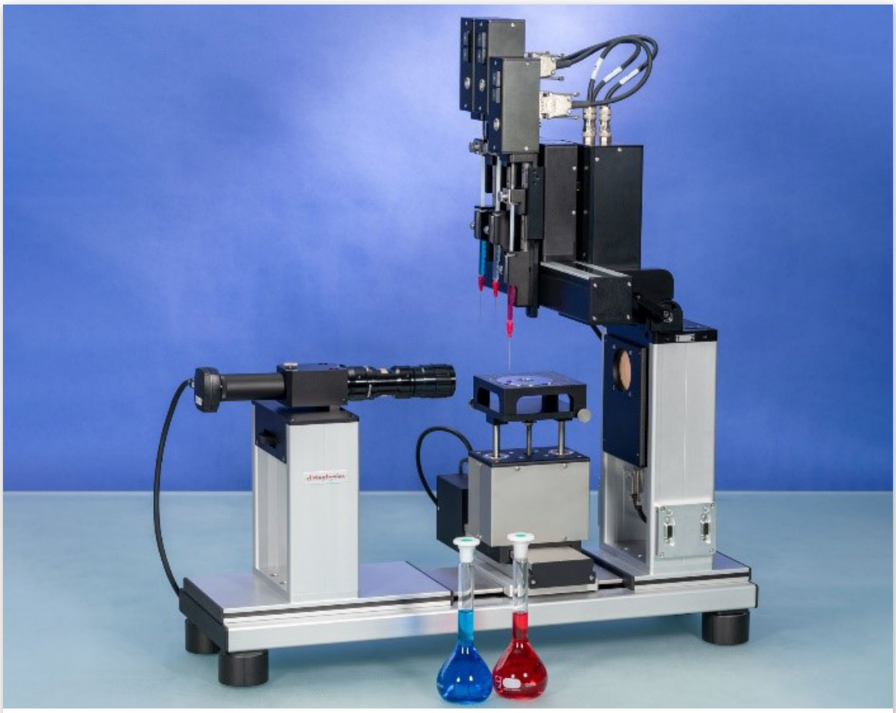


Fig. 1: The optical contact angle measuring and contour analysis systems of the OCA series from DataPhysics Instruments

Technique and Method

The surface tension of a liquid and the interfacial tension between two liquids can be easily determined with an optical contact angle measuring and contour analysis system of the OCA series from DataPhysics Instruments (Fig. 1) by analysing the shape of a pendant drop hanging or floating on a needle.[1] Depending on the density of the phases, the drop can be dosed downwards with a needle or upwards with a bent needle (Fig. 2b).

The polar part and the dispersive part of the surface tension of a liquid can be determined by measuring its total surface tension against air, and the interfacial tension against a non-polar liquid with the equation below[2][3][4]:

$$\sigma_{1/2} = \sigma_1 + \sigma_2 - 2\left(\sqrt{\sigma_1^d \cdot \sigma_2^d} + \sqrt{\sigma_1^p \cdot \sigma_2^p}\right)$$

In which, $\sigma_{1/2}$ is the interfacial tension between two liquids, σ_1 and σ_2 are the surface tension of test liquid and surrounding, σ_1^d and σ_1^p are the dispersive and polar parts of the test liquid, while σ_2^d and σ_2^p are the dispersive and polar parts of the surrounding medium.

Conversely, the interfacial tension between two opaque liquids can be calculated using the polar and dispersive parts of the surface tension of each liquid, as obtained. This is a crucial method in numerous technical applications, including the production and processing of paints and inks.

Experiment

In this study, the total surface tension was determined for three different dampening solutions and one ink, along with the polar and dispersive parts, using an OCA with the pendant drop method. Images or movie sequences of the pendant drops were recorded using the integrated USB 3.0 camera, thereby facilitating subsequent analysis of the drop contour. To ensure the accuracy and reproducibility of the results, three measurements were taken for each sample.

In order to utilise the pendant drop method with the greatest accuracy, it is essential that the drop shape exhibits a clear deviation from a spherical shape. Typically, a "pear-shaped" configuration is attained just before the drop detaches with a secondary reflection in proximity to the needle. Furthermore, the diameter of the needle is also a critical factor that affects the outcome. It is recommended by DataPhysics Instruments that a needle diameter of 1 mm or above should be used for the analysis of pendant droplets.

Table 1: The measured surface tension of n-dodecane and n-perfluorohexane

Liquid	Surface tension (mN/m)
n-dodecane	25.08 ± 0.15
n-perfluorohexane	11.91 ± 0.15

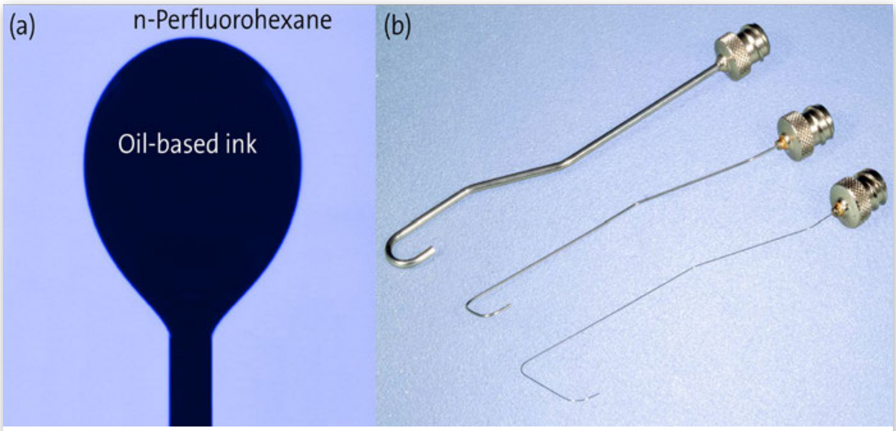


Fig. 2: (a) Measuring the interfacial tension of an oil-based ink against n-perfluorohexane using captive bubble equipment; (b) Specially curved needles for captive bubble measurements.

A preliminary test was conducted to ensure the purity of the liquids used as the surrounding medium, as well as the cleanliness of the syringe. It should be noted that the test liquids and surrounding phase employed in interfacial tension measurement must be immiscible. In this study, non-polar solvents, specifically n-dodecane and n-perfluorohexane, were employed. The surface tensions of these two liquids were therefore measured three times using the **pendant drop method** (Table 1).

Similarly, the total surface tensions of the dampening solutions and ink were also determined using the **pendant drop method**.

In order to determine the dispersive and polar parts of the samples, the interfacial tension between the dampening solutions and n-dodecane was measured. Since oil-based inks are alkane soluble, n-perfluorohexane was used as the surrounding phase. However, as the density of the oil-based ink is lower than that of n-perfluorohexane, the ink drop was dispensed 'upwards' (Fig. 2a). A special dosing needle was used for captive drop and bubble measurements (Fig. 2b).

With the polar and dispersive parts of the dampening solution and the ink surface tension, the interfacial tension between different dampening solutions and inks can be calculated automatically by the software.

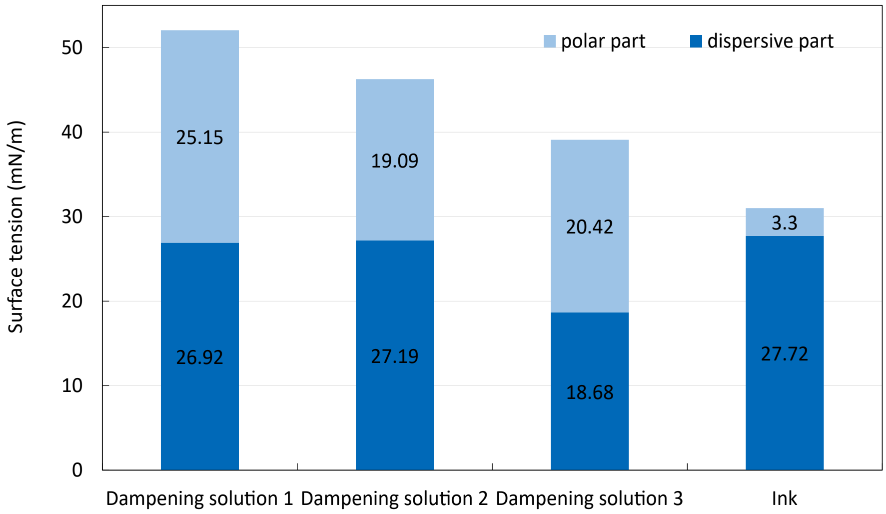


Fig. 3: Total surface tension of the dampening solutions and ink with the dispersive and polar parts

Results & Discussion

The total surface tension, along with its dispersive and polar parts, was determined for the dampening solutions and ink. Fig. 3 illustrates that the highest surface tension is exhibited by Dampening solution 1, with a value of 52.07 mN/m. In contrast, Dampening solutions 2 and 3 exhibit lower surface tensions, with values of 46.28 mN/m and 39.10 mN/m, respectively.

Furthermore, the ratio of polar to dispersive parts in Dampening solutions 1 and 3 is comparable, with a ratio of approximately 50:50, while Dampening solution 2 exhibits a ratio of approximately 40:60. This indicates that it contains a greater proportion of the dispersive part than the other two solutions. In comparison with the dampening solutions, the ink exhibits a lower surface tension, accompanied by a higher proportion of the dispersive part, at approximately 90:10.

Based on the total surface tension and the polar and dispersive parts, the interfacial tension of the ink in relation to the dampening solutions was evaluated. Fig. 4 illustrates that the interfacial tension between the ink and Dampening solution 2 is the lowest, with a value of 6.51 mN/m. These findings are consistent with the previous results, which indicated that Dampening solution 2 has the highest proportion of the dispersive part amongst all the dampening solutions and is therefore closer to the proportion of the dispersive part present in the ink. In contrast, the highest value of interfacial tension is observed between Dampening solution 1 and the ink, at 10.23 mN/m. It is widely accepted that the interfacial tension between the dampening solution and the ink should be maximised to ensure the formation of a distinct interface. Consequently, this result suggests that the Dampening solution 1 has the highest potential as a candidate for further development.

This study demonstrates that measuring the total surface tension of liquids alone is insufficient for obtaining comprehensive results. Consequently, it may lead to the inappropriate selection of liquid combinations for further application. The quantification of the polar and dispersive parts of the surface tension is of significant importance for formulation designers, as it enables the prediction of the degree of interaction between two liquids when brought into contact.

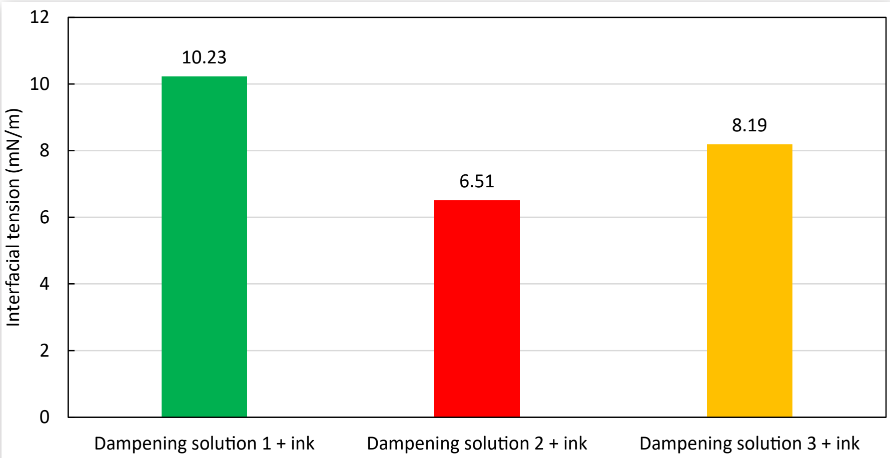


Fig. 4: Interfacial tension of the ink against different dampening solutions

Summary

The optical contact angle measuring and contour analysis system of the OCA series from DataPhysics Instruments are the reliable, straightforward solution for determining surface tensions with their polar and dispersive parts of dampening solutions and ink. Based on these measurements, the interfacial tension between liquids can be readily calculated. This study clearly shows that measuring the total surface tension of liquids alone is insufficient for obtaining comprehensive results. It is crucial for those engaged in the formulation process of dampening solutions and inks to gain a deep understanding of the polar and dispersive components of surface tension. This enables the appropriate selection of liquid combinations for further applications.

References

[1] https://www.dataphysics-instruments.com/products/oca/

[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.

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