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Research Article

Validation of Low Cost Solid Liquid Contact Angle Instrument Using Drop Shape Image Processing Suitable For Surface Property Measurement

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Abstract

Solid liquid contact angle measurement Instrument is investigated that will measured contact angle as per the ASTM standard D7334 using liquid drop shape analysis profile. This research work involved extensive use of LabVIEW (Laboratory Virtual Instrument Engineering Workbench) software by National Instrument which provide cost effective and reliable solution for the system. In addition, it also include hardware design using fire wire monochrome camera – 60 fps(frame per second) with lance. Entire software is prepared using LabVIEW vision module and fundamental tools of LabVIEW. In this paper systematic approach is presented for designing of CA Instrument. High end features likes selection of frame, single frame and multi frame selection, report generation in Microsoft excel, user logging information were developed to make professional application software. Manual 1000 µL gas tight piston syringe from Hamilton is used to place drop on substrate. Sample stage is placed between camera and high intensity blue LED light. When drop is released from tip of syringe needle, camera is grabbing frames as per user command in software. After acquiring frame user has to select single frame or multi frame and accordingly based on circle profile algorithm software calculate contact angle and generate report. This Instrument will be very useful for research center, industrial R & D and academic Institution.

Keywords: *Contact angle, wettability, LabVIEW vision, Drop Shape analysis, ASTMD7334*

1. Introduction

The wettability of a solid surface by a liquid is very important in many industrial processes such as paints, pigment dispersions, inks, water-proofing of concrete, fabric, food items or powders, lubrication, enhance oil recovery, printing (Russell Stacey, 2009 etc). Wetting studies usually involve measurement of contact angles as primary data. Contact angles indicate the degree of wetting when a solid and liquid interact. The lower the contact angle the greater the wetting. Contact angles near zero degree indicate that the liquid wets the solid spontaneously (in a thermodynamic rather than kinetic sense). There are several methods have been developed to measure contact angle from the shape of sessile drop. Complete wetting is occurs when the contact angle is 0°, as the droplet turns flat. For super hydrophobic surfaces, water contact angles are usually great than 150° showing almost no contact between the liquid drop and the surface, which can rationalize the lotus effectors self-cleaning surfaces (Fuerstenau, M. C,1988) .Intermolecular force to contract the surface, is called the surface tension and it is responsible for the shape of liquid droplets. Thomas young described first the contact angle of liquid drop on ideal solid surface is defined by the mechanical equilibrium of the drop under the action of three interfacial tension (Van Oss, 1987)

$$\gamma lv \cos\theta y = \gamma sv - \gamma sl \quad (1)$$

Where γsv, γsl and γlv represent the solid- vapor, solid-liquid and liquid -vapor interfacial tensions respectively and θy is the contact angle.

Surface tension tends to minimize the surface area by making the drop spherical, while the gravity deforms the drop in two ways(1) by elongating a pendant drop and (2)flattening a sensible drop (Good, R. J., 1992). The sessile drop method has been developed by Neumann (J. M. Alvarez et al, 1999) based on the model of asymmetric drop shape analysis profile. The parameters of this method are identified by analysis of drop meniscus shape. In the Laplace method, balance between surface tension and external forces reflects a thematically which will be

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useful to determine surface tension of liquid with shape analysis.

Before digital computer image processing people are using Bashforth and Adams tables to calculate surface tension. They were the first to use Laplace equation to analyze the shape of droplet profile and manually generated the tables. There are two popular methods to find contact angle using image analysis one is sessile drop and other is drop shape analysis. In the sessile drop enable the determination of drop air surface tension and wetting angles by solving ordinary differential equation versus boundary parameter (Goclawski, J et al, 2007) where as in drop shape analysis it gives value of contact angle. In that liquid droplet curvature is assumed part of circle and using circle diameter and height, it calculate contact angle as per equation.2. This method shows good results when liquid drop is extremely small, however spherical shape assumption cannot be applied if the drop shape is large enough to be affected by gravity (Woodward)

The propose Instrument works on calculation of contact angle on drop shape analysis. In this method liquid drop is assumed to be part of the sphere. Geometrically, the contact angle can be calculated by measuring the drop diameter and the height.

$$\theta/2 = \tan^{-1}(h/d) \qquad (2)$$

2. Experimental

Instrument for sessile drop imaging and measurement consist of hardware model and software module. The schematic of Instrument is shown in Fig. 1.

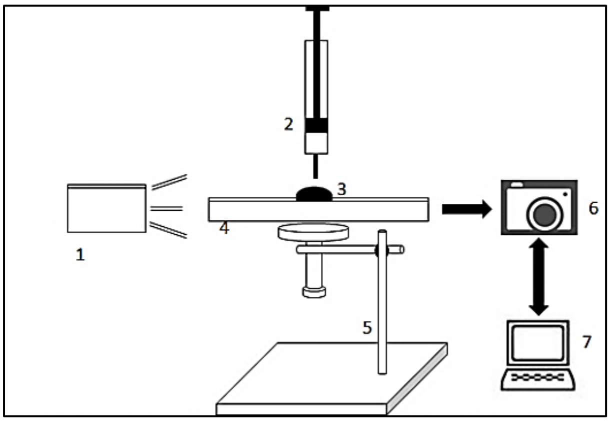


Figure 1 Functional block diagram of Instrument

Hardware details: 1-High Intensity LED Source, 2- Micro syringe with piston pump, 3- sample drop 4- substrate platform, 5 –manual precision stand, 6 - Fire wire camera (60fps), 7- computer with camera interfacing card and software.

Camera communicates with the computer using IEEE 1394 b cable which capable of high speed data transfer. If the IEEE port is not available with the computer, IEEE to USB converter can be used.

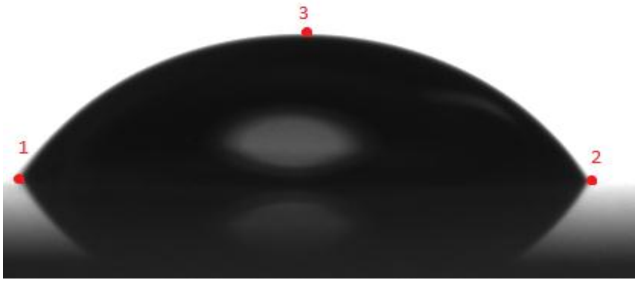
The liquid drop of 1µl volume injected from the piston type gas tight syringe on a surface. The drop is illuminated by the source of visible blue light LED (Woodward,). USB port of computer is used to supply 5V to the LED. The droplet image is acquired by CCD monochrome camera which is having 60 frames per second with lance, image from the camera is transmitted to PC via frame grabber card. The camera is purchased from Imaging source, Germany, model number DMK21AU04. Once the image is acquired in the PC, CAM (contact angle measurement application) is created in LabVIEW vision which is used to calculate contact angle according to drop shape algorithm (Bryon, 2001). The major function of CAM application is user data login, single mode or multimode image selection, calculation of CA using drop shape analysis and report generation.

Various approaches for the drop shape measurement

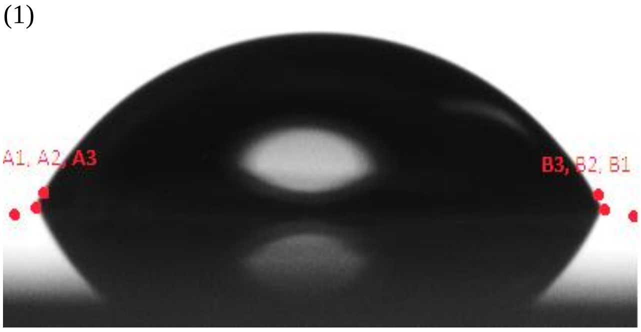
2.1 Approach 1

Using basic programming in LabVIEW, points 1, 2 and 3 are determined as shown in the figure -2(1). Difference between X co-ordinate of 1 and 2 gives the diameter of the drop and difference between Y co-ordinate of 1 and 3 gives the height of the drop from the surface. Diameter and height of drop can be found as per equation (2).

This approach for finding angle gives more accuracy and reliability then approach 2.



(1)



(2)

Figure 2 Image processing approach (1- Three point calculation, 2-Two Point calculation)

2.2 Approach 2

With fundamental programming in LabVIEW, points A1, A2 and A3 as shown in the figure-2(2), can be obtained. These points can be input for IMAQ Get Angle.vi.

Similarly, find B1, B2 and B3 points and obtain the contact angle on the other side of the drop.

To find accurate contact angle it is necessary to select frame at point one, if frame selection is not proper then it gives error in the results. If the surface containing the drop is not at the same level from the ground there would be variation in left and right angle. If uniform level is maintained, both the angles are almost same due to uniform gravitational force acting on it.

The level of accuracy was not obtained in this method as A3 and B3 points were not obtained as desired. If drop is little deformed up to few micrometers near the surface,

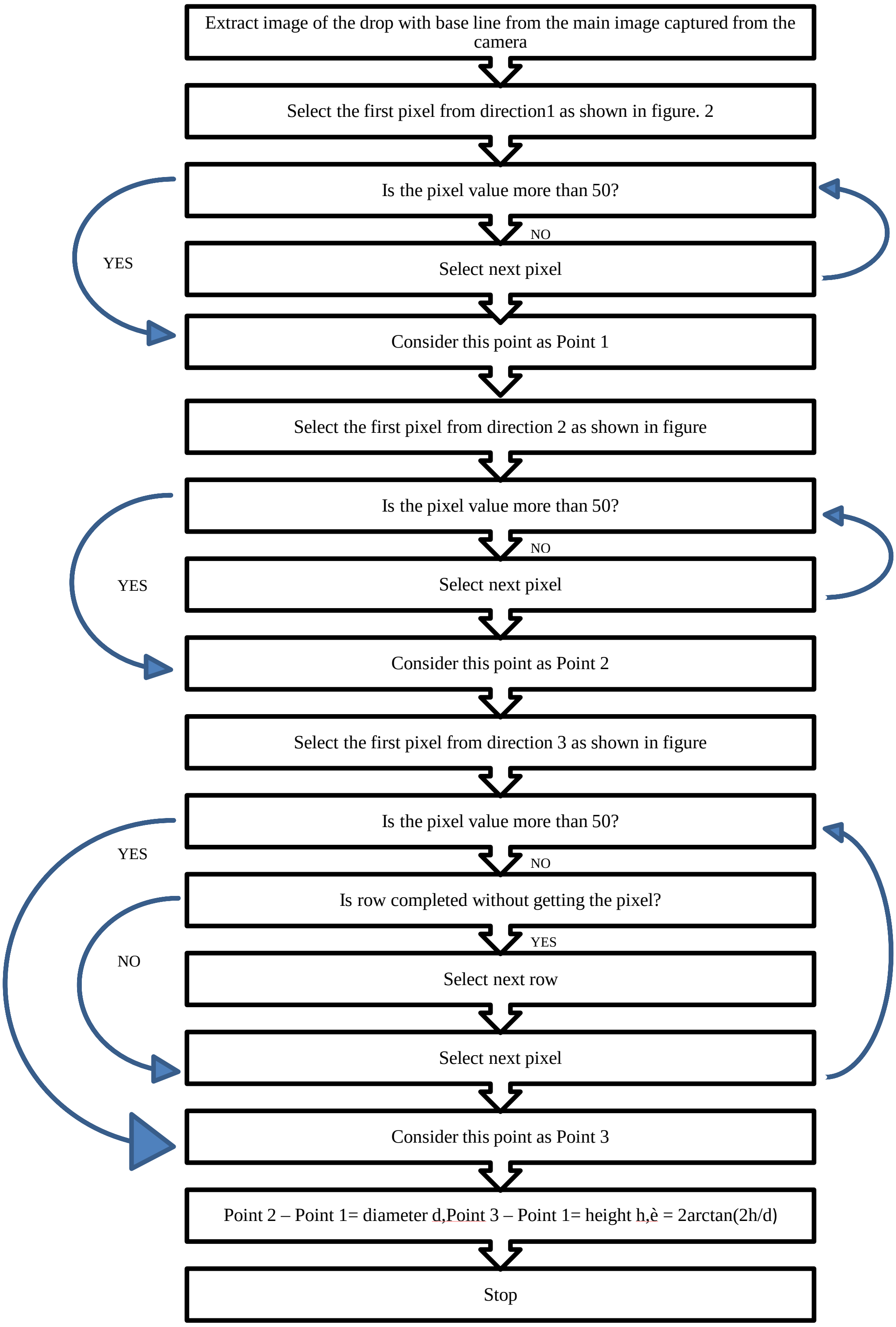


Figure 3 Flow chart of the system

angle is not obtained correctly. Thus another approach for finding angle is used.

2.3 Image processing algorithm using LabVIEW vision

In this software majority of image processing features provided by NI Vision, It is very powerful software in image processing. Use of NI-Vision eliminates the need of various traditional sensors and measurement tools because of its unique ability for providing accuracy and reproducibility. Acquired image can be processed in various ways. NI-IMAQ driver software is for NI 17x smart cameras, as well as analog, parallel digital, and Camera Link image acquisition devices. NI-IMAQdx driver software is for FireWire (IEEE-1394), Gigabit Ethernet (GigE), DirectShow-compatible USB and IP cameras. Further NI Vision provides facilities image manipulation, pixel manipulation, filtering, morphing, and many more.

2.4 VI and SubVI designed for this software

An attempt to make the user friendly software following subVIs developed. A modular programming approach is used to design the software. It is divided in various sections (in different sub Vis) for providing professional features.

2.4.1User and experiment details

Before starting the experiment, user and experiment details are entered which includes, details about the fluid and the substrate used in the experiment. Number of frames to be captured on receiving the command from the user is can also be controlled. This information is stored in a report created at the end of the experiment.

2.4.2Image Acquisition window

The online video is available to the user for capturing the drop image. Synchronization between fall of the drop on the substrate and capturing the image is done by the user himself. Specified number of frames is stored in the CPU memory after 'TAKE IMAGE' button is pressed.

2.4.3 Operating modes

After the drop images are captured, two options are available for processing it. Single frame option can be used when CA for only one frame is calculated. In Multi frame option, CA and for 10 consecutive frames from the selected frame is calculated. This option can be used to find gradual change in CA with time.

2.4.4 CA measurement

After capturing specified number of images, camera is closed and post processing of the image is done. It is observed that after the drop touches the surface, it becomes stable only after few milliseconds. Thus the user selects the frame when the shape of the drops seems to be almost stable.

After selecting the frame, only the drop pixels are extracted from the main image. This reduces the processing area of the image and time. While selecting the drop area, interference of the surroundings should not be selected. The selected section of the image is displayed below the main image.

After selecting the image precisely, CA is calculated on pressing CALCULATE button. For measuring CA of the given fluid, the image is converted into an array of unsigned integers and the borders of the drop are identified. For such image all the values lie between 0 to 255 where 0 indicated black and 255 indicated white. Threshold technique is applied to identify the required points. Here the threshold value is 50. Using a while loop and examining the value of each pixel in sequence gives the diameter and height of the drop as shown in approach 1. These values are used in equation 2 and CA theta is measured.

In Single frame mode, user can measure CA for different drop images more than one time. As the user and experiment details remain the same, CA for all the drop images are saved in an excel sheet

In Multiple frame mode, CA for 10 consecutive frame is stored in an excel sheet.

LabVIEW Report Generation Toolkit is used to create and MS Excel sheet after every experiment along with the date and time. Option for printing the report is provide to the user. This option remains valid only if a printer is connected to the system.

3. Results and Discussion

The image processing algorithm has been applied to calculate contact angle of water(Millipore water ,S.T. =72 mN/M) on the Teflon Surface. From the various images, selected image is selected as per snap shot is shown in Fig.4 and after extracting image it calculate CA as per the eq.(2). CA was measured on following material with room temperature 25°C, RH=32%.

For comparing results of LabVIEW based software standard KSV software is used and results is shown in table-1.

Table- 1 Comparison of developed software with standard software

Sample Image Description	Contact angle By standard software	Contact angle by designed Software	Error
Water on Teflon surface	109.52°	109.10°	+0.42°
Water on Starch powder surface	31.50°	32.20°	-0.70°
Water on Gypsum sheet	22.50°	22.20°	+0.30°
Water on glass	33.00°	32.50°	0.50°
Glass treated with hydrophobic material	83.25°	83.00°	0.25°

Once the images of drops are captured it is important to select appropriate image which should not have shadow around the image. This image is considered as an ideal image of the drop and used for image processing. To avoid measurement error Extract the image is such a way that the complete drop remains above the reference line. Reflection of the drop may result in confusion for the user, but can be avoided by magnifying the image. Results also depend on selection of image profile.

The proposed method is very user friendly and relatively fast measurement compared with manual method of contact angle measurement. This approach provides results with +/- 1° error compared to standard software.

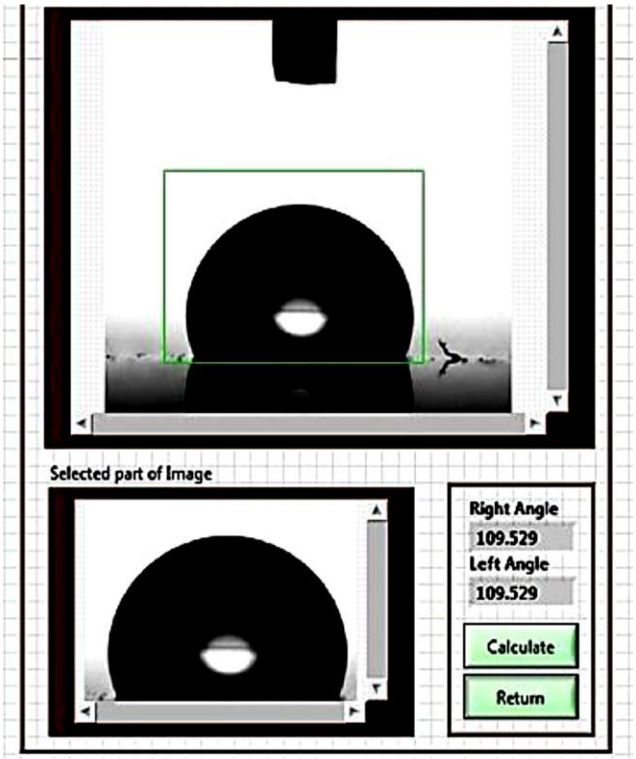


Figure 4 Screen shoot of software

Conclusions

In this paper, we proposed and designed a system for measurement of contact angle as per the standard ASTM D7334 of liquid on solid surface using drop shape image analysis with virtual Instrument LabVIEW software. Its flexibility and efficiency was demonstrated with its high end features like report generation, image acquisition and analysis at higher frame rate. Experimental results are comparable with standard software. Future work involved to add more features like surface free energy determination and to find surface tension with sessile drop method. This Instrument will be very useful in Industry like paints, Pharmaceuticals, coating, ceramics etc. The design is cost effective solution for academic and research Institute.

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References

Good, R. J., and van Oss.(1992), Modern Approaches to Wettability: Theory and Applications, Eds: M. E. Schrader, and G. Loeb, *Plenum Press, New York*, pp. 1- 27,.

Janczuk, B, Wojcik, W., Zdziennicka.(1993), *A. J. of Colloid and Interface Science*, 157, 384-393.

Paddy, J. F., (Ed).(1978), Wetting, Spreading, and Adhesion, *Academic Press*, New York.

Zisman, W. A.(1977), Handbook of Adhesives, Skeist, I., *Ed: van Nostrand, NewYork*, Chapter 3.

Chander, S., Wie, J. M. and Fuerstenau, D. W.(1975), Advances in Interfacial Phenomena, Ed: P. Somasundaran, *AIChE Series No. 150, New York*, pp.183-188.

Russell Stacey. (2009), Contact angle measurement technique for rough surfaces. Master's thesis, *Michigan Technological University*.

Fuerstenau, M. C., Lopez-Valdiviezo, A., and Fuerstenau. (1988), *Int. J. of Mineral Proc*., 23, 161-170.

Rayner, J. H., and Brown, G.(1973) Clays and Clay Minerals, Vol. 21, 103-114,

Ciullo, P. A.(1996) Industrial Minerals and Their Uses-A Handbook and Formulary, Ed: P. A. Cuillo, *Noyes Publications, New Jersey.*

Pukansky, B.(1995) Polypropylene: Structure, Blends and Composites, Ed: J. Karger- Kocsis, Vol. 3, pp. 1, *Chapman and Hall, London.*

Van Oss, C. J., Chaudhury, M. K., and Good. (1987) ,Separation Sci. and Technology, 22, 1.

S. Lahooti, O. I. del Rio, A. W. Neumann, P. Cheng.(1996), Axisymetric drop shape analysis (ADSA), A. W. Neumann, J.K.Spelt(Eds.) Applied SurfaceThermodynamics , *Marcel Dekker, New York*, p. 379.

J. M. Alvarez, A. Amirfazli, A. W. Neumann.(1999) Automation of the axisymetric drop shape analysis- diameter for contact angle measurements, *Colloids and Surfaces, A: Physicochem. and Eng. Aspects* 156, pp.167-176.

Goclawski, J., & Urbaniak-domagala, W. (2007), The method of solid-liquid contact angle measurement using the images of sessile drops with shadows on substratum, 135-140.

Woodward, B. R. P., & Ph, D. (n.d.). Contact Angle Measurements Using the Drop Shape Method, (Lvl), 1-8.

M.Thakker, D.O.Shah,(2011) An application of Instrumentation and Control Engineering for measurement of surface properties of liquids, in *Surface modification Technology journal volume – XXIV, Varaldoc Publication* (ISBN: 978-81-910978-81-906377-5-6).

Assembly, H. (2010). Contact Angle Measurements Using a Simplified Experimental Setup, 87(12), 1403-1407.

Wells, L. K. and Travis, J. (1997)LabVIEW for Everyone Graphical Programming Made Even Easier, *Prentice Hall, Inc., Upper Saddle River, New Jersey.*

Essik, J.,(1999). Advanced LabVIEW Labs, *Prentice Hall, Inc., Upper Saddle River, New Jersey*.

Bryon, J. Y. (2001), Hands-On Exercise Manual for LabVIEW Programming, Data Acquisition and Analysis, *Prentice Hall, Inc., Upper Saddle River, New Jersey.*