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THESIS OUTLINE

A Study on Non-uniform Temperature Distribution Effect

in Viscosity Measurement of Vibrational Viscometer

Temperature is one of the most obvious factors that can have an effect on the viscosity behavior of a material. Some materials are quite sensitive to temperature and a relatively small variation will result in a significant change in viscosity. Consideration of the effect of temperature on viscosity is essential in the evaluation of materials that will be subjected to temperature variations in use or processing, such as motor oils, greases and hot melt adhesives.

Experimental viscosity temperature measurement data are often used as the basis for determining the quality of the selected fluids. Unfortunately not all data are equally qualified enough. Uncertainity analysis is the procedure used to quantify data validity and accuracy. Accuracy is the key point in enhancing viscometers and improving fluid quality. Therefore, measuring temperature values in high precision is vitally important for viscosity measurement.

A high precision temperature measurement can be achieved with capillary viscometers. However, this viscometer can only provide one-point viscosity measurement. In one point viscosity measurement, the results are more accurate but it takes days to obtain equivalent data of continuous viscosity measurement.

This research arises from the need of a swift, accurate and an economic viscometer which can carry out effective continuous viscosity measurement. Vibrational viscometers were selected to achieve this purpose because these viscometers are easy to use, their prices are economic and they have very high capability for continuos viscosity measurement. Unfortunately vibrational viscometers (and also rotational viscoemeters) are not as accurate as capillary viscometers. The main reason of this problem is the non uniform temperature distribution problem. This problem significantly degrades the accuracy of rotational and vibrational viscometers seriously.

Due to this reason, this work is focused on the temperature field in vibrational viscometers and rotational viscometers is primarily caused by three factors;

1) Heat Generation of Oscillators
2) Thermal Conduction
3) Thermal Convection

The purpose of this research is to reduce the viscosity measuremnt errors caused by non-uniform temperature field via these factors and provide viscosity measurement results with higher precision.

In industry and academia, the viscosity values that are determined by capillary viscometers are accepted as standart viscosity values. Only in that case, these measured viscosity values are universally accepted as faultless. However as it was mentioned, this process requires days and too much labor force.

By the help of this research, it is claimed that; in case a vibrational viscometer can obtain viscosity measurement results as accurate as a capillary viscometer, a methodology for continuous viscosity measurement which is qualifed enough to provide standart viscosity values may be proposed

By following the guidance of the results of this research, a vibrational viscometer with minimum non-uniform temperature distribution problem may be designed. This viscometer should be swift and very accurate in continuous viscosity measurement. Also, it should be easy to use and economic in price. A vibrational viscometer with minimum non-uniform temperature distribution problem is proposed in Chapter 6 Conclusion and Future works. Similar to vibrational viscometers, rotational viscometer with minimum non-uniform temperature distribution may be designed based onto this research.

As a conclusion, the objectives of this research can be listed as following;

1) Measure the effects of heat generation of oscillators, thermal conduction and thermal convection to the viscosity measurement.
2) Propose solutions to the problems of heat generation of oscillators, thermal conduction and thermal convection.
3) Propose a methodology for vibrational viscometers which can provide standart viscosity values as exact as a capillary viscometer can provide.
4) Propose a new design of vibrational viscometers that do not have non-uniform temperature distribution problem.

Chapter 1 “Introduction”

As a first step, defition of viscosity and the need for this research is clearly explained. Then, commercially available viscometers are investigated and their merits and demerits are compared with each other. In this chapter, capillary type viscometers, rotational type viscometers and vibrational type viscometers are investigated in depth. Their mathematical background and the concept of continuous and discrete viscosity measurement are clarified. The advantages of vibrational viscometers are explained. Finally, the main objectectives of the thesis are listed.

Chapter 2 “Heat Generation Problem of Oscillators”

This chapter introduces the non-uniform temperature distribution problem caused by the heat generation of oscillators during viscosity measurement. Due to the friction between the sample fluid and the oscillators, heat is generated from the oscillators and thus serious temperature deviation within the sample fluid occurs. In time, this may cause serious viscosity measurement errors. In this chapter the magnitude of this problem is analyzed. As a solution to this problem forced convection is proposed.

Chapter 3 "Thermal Conduction"

This chapter introduces the non-uniform temperature distribution problem by thermal conduction in vibrational viscometers. The study was conducted in two parts. In the first part of this chapter, the challenge of non-uniform temperature distribution caused by thermal conduction in vibrational viscometers is analyzed by several experiments. The experiments are repeated several times with various heating speeds in order to gain a better understanding about the effect of non-uniform temperature distribution problem on fluid viscosity.

The experimental findings have also been supported by mathematical calculations and simulations. In the second part of this chapter, to solve the non-uniform temperature distribution problem, forced convection which is used to mix up the fluid throughout the viscosity measurement with the aim of achieving a homogenous temperature distribution.

Chapter 4 "Thermal Convection"

This chapter introduces the non-uniform temperature distribution problem by thermal convection in vibrational viscometers. The study describes the experimental study of viscosity measurement error in the vibrational type viscometer, which measures viscous damping of the oscillating circular plate in a fluid in continuously increasing temperatures. The experiments are carried out to measure the non-uniformity of the temperature field in the test cup of the vibrational viscometer with continuously increasing temperatures, while changing the viscosity of the target fluids. Experimental outcomes show that non-uniformity of the temperature grows in the cup and results in viscosity measurement error, when the viscosity of the fluid increases. In order to understand this phenomenon, velocity measurement by particle image velocimetry is conducted in the test cup for fluids of varying viscosity. The results indicate that mixing is enhanced in the low-viscosity fluid by the occurrence of unsteady thermal convection, while weaker convection appears in the high-viscosity fluid.

Chapter 5 "Proposal of a non-dimensional parameter for heating speed"

As mentioned in Chapter 3; due to the thermal conduction, heat generated by a heater during continuous viscosity measurement disperses to every part of a sample fluid and influences the fluid's viscosity. This may create serious viscosity measurement errors in time. Since capillary viscometers do not have the non-uniform temperature distribution problem, they can acquire viscosity results in very high precision. In this chapter, a new concept called acceptable heating speed is proposed to solve the non-uniform temperature distribution problem in vibrational viscometers and its effects on viscosity measurement. This concept claims that there should be an acceptable speed to heat a fluid regarding to the heat flux that is applied, volume and thermal diffusivity of the fluid. By the help of this new concept, it is claimed that vibrational viscometers may also provide viscosity measurement results as accurate as a capillary viscometer can.

Chapter 6 "Conclusion and Future work"

This chapter summarizes the results of this study and proposes a new design for a vibrational viscoemeter with minimum non-uniform temperature distribution problem as future work.

During this research, the non-uniform temperature distribution problem of viscosity measurement and solution proposals are investigated in Chapter 2, Chapter 3 and Chapter 4. In Chapter 5, a non-dimensional parameter is proposed for vibrational viscometers. This parameter may provide us to obtain as accurate viscosity results as a capillary viscometer can do. Finally, in Chapter 6.2 Future Works, a new design of a vibrational viscometer with minimum temperature distribution problem is proposed based onto the results of Chapter 2, Chapter 3 , Chapter 4 and Chapter 5.

Therefore, the objectives are accomplished by these chapters.

References

[1] Brookfield Engineering Laboratory, (2014), Why measure viscosity?, Retrieved Feb 12, 2014 from http://www.brookfieldengineering.com/education/viscosity_whymeasure.asp
[2] Kenkel J, Analytical Chemistry for Technicians, Third Edition, 2002, pp. 419-420.
[3] Lane JL, Henderson KO, (June 2004), Viscosity measurement so easy, yet so difficult, Retrieved Feb 12, 2014 from ttp://www.astm.org/SNEWS/JUNE_2004/lanhen_jun04.html
[4] Senapati PK, Mishra BK, Parida A, Modeling of viscosity for power plant ash slurry at higher concentrations: Effect of solids volume fraction, particle size and hydrodynamic interactions, Powder Technology, 2010, 197 (1–2): 1-8.
[5] Ouriev B, Windhab E, Braun P, Zeng Y and Birkhofer B, Industrial application of ultrasound based in-line rheometry: Visualization of steady shear pipe flow of chocolate suspension in pre-crystallization process, Review of Scientific Instruments, 2003, 74 (12): 5255 - 5259.
[6] Hemmati-Sarapardeh A, Shokrollahi A, Tatar A, Gharagheizi F, Mohammadi AH, Naseri A, Reservoir oil viscosity determination using a rigorous approach, Fuel, 2014, 116: 39-48.
[7] Al-Balushi M, Mjalli FS, Al-Wahaibi T, Al-Wahaibi Y, Al-Hashmi AA, Parametric study to develop an empirical correlation for undersaturated crude oil viscosity based on the minimum measured input parameters, Fuel, 2014, 119: 111-119.
[8] Tao R, Tang H, Reducing viscosity of paraffin base crude oil with electric field for oil production and transportation, Fuel, 2014, 118: 69-72.
[9] Lee DH, Jung JM, Kim SY, Kim KT, Cho YI, Comparison tests for plasma viscosity measurements, International Communications in Heat and Mass Transfer, 2012, 39 (10): 1474-1477.
[10] Mayer GA, Blood Viscosity in Healthy Subjects and Patients with Coronary Heart Disease, Canadian Medical Association Journal, 1964, 91(18): 951–954.
[11] Kim H, Cho YI, Lee DH, Park CM, Moon HW, Hur M, Kim JQ, Yun YM, Analytical performance evaluation of the scanning capillary tube viscometer for measurement of whole blood viscosity, Clinical Biochemistry, 2013, 46 (1-2):139-142.
[12] Shin S, Keum DY, Viscosity measurement of non-newtonian fluid foods with a mass detecting capillary viscometer, Journal of Food Engineering, 2003, 58 (1): 5-10.
[13] Singh RP, Heldman DR, Chapter 2 - Fluid Flow in Food Processing, Introduction to Food Engineering (Fifth Edition), 2014: 65-209.
[14] Fabek H, Messerschmidt S, Brulport V, Goff HD, The effect of in vitro digestive processes on the viscosity of dietary fibres and their influence on glucose diffusion Food Hydrocolloids, 2014 35: 718-726.
[15] Yorgancioglu A, Bayramoglu EE, Production of cosmetic purpose collagen containing antimicrobial emulsion with certain essential oils, Industrial Crops and Products, 2013, 44: 378-382.
[16] Bono A, Mun HC, Rajin M, Effect of various formulation on viscosity and melting point of natural ingredient based lipstick, Studies in Surface Science and Catalysis, 2006 159: 693-696.
[17] A&D Company Limited, SV-A Series Sine-wave Vibro Viscometer Users` Handbook Ver. 1.13E, 2009: 3.
[18] (The Online Etymology Dictionary". Etymonline.com. Retrieved 2013-12-24)
[19] Walters K, Jones WM, Instrumentation Reference Book, Fourth edition, 2010: 69- 75.
[20] Fox R, McDonald AT, Pritchard PJ, Fluid Mechanics, John Wiley & Sons, Eighth edition, 2012: 31-33.
[21] Churchill SW, Chapter 7-Couette Flows, Viscous Flows, 1988: 107-130.
[22] Houghton EL, Carpenter PW, Collicott SH, Valentine DT, Chapter 2-Fundamental Equations of Fluid Mechanics, Aerodynamics for Engineering Students (Sixth Edition), 2013: 17-19.
[23] Chhabra RP, Richardson JF, Chapter 1-Non-Newtonian Fluid Behaviour, Non- Newtonian Flow and Applied Rheology (Second Edition), 2008: 1-55.
[24] Streeter VL, Wylie EB, Bedford KW, Fluid Mechanics, McGraw-Hill, 1998, ISBN 0-07-062537-9.
[25] Holman JP, Heat Transfer, McGraw-Hill, 2002 ISBN 0-07-122621-4.
[26] Incropera FP, DeWitt DP, Fundamentals of Heat and Mass Transfer, Wiley, 2007 ISBN 0-471-45728-0.
[27] Viswanath DS, Ghosh TK, Prasad DHL, Dutt NVK, Rani KY, Viscosity of Liquids: Theory, Estimation, Experiment, and Data, 2007:9.
[28] Maron SH, Krieger IM, Sisko AW, A Capillary Viscometer with Continuously Varying Pressure Head, Journal of Applied Physics, 1954, 25(8): 971-976.
[29] Gilinson Jr PJ, Dauwalter CR, Merrill EW, A Rotational Viscometer Using an A.C. Torque to Balance Loop and Air Bearing, Journal of Rheology, 1963, 7:319-331.

[30] Kestin J, Newell GF, Theory of Oscillation Type Viscometers: The Oscillating Cup, Zeitschrift für angewandte Mathematik und Physik, 1957, 8(6):433-449.
[31] Labstand, (2014), In range of kinematic viscosity measurements, Retrieved Feb 13, 2014 from http://labstand.com.pl/en/Wzorcowanie-kalibracja.html
[32] Webster JG, The Measurement, Instrumentation, and Sensors: Handbook, 1999, 30-12.
[33] Singh, Industrial Instrumentation & Control, second edition, 2003:437.
[34] Viswanath DS, Ghosh TK, Prasad DHL, Dutt NVK, Rani KY, Viscosity of Liquids: Theory, Estimation, Experiment, and Data, 2007:63.
[35] Viswanath DS, Ghosh TK, Prasad DHL, Dutt NVK, Rani KY, Viscosity of Liquids: Theory, Estimation, Experiment, and Data, 2007:61.
[36] Singh, Industrial Instrumentation & Control, second edition, 2003:439.
[37] A&D Company Limited, SV-A Series Sine-wave Vibro Viscometer Users` Handbook Ver. 1.13E, 2009: 9.
[38] Izumo N, Kowai A, Technological Background and Latest Market Requirements Concerning "Static Viscosity" Measurement with a Tuning-fork Vibration Viscometer, Proceedings of Asia-Pacific Symposium on Measurement of Mass, Force and Torque (APMF 2009), 2009: 51-57.
[39] The Portal of Industrial Product Finder (IPF online), 2014, Measuring Viscosity with Sine-Wave Vibro Viscometer, Retrieved Feb,13 2014 from http://www.ipfonline.com/IPFCONTENT/articles/technical-articles/measuring-viscosity-with-sine-wave-vibro-viscometer.php
[40] A&D Company Limited, SV-A Series Sine-wave Vibro Viscometer Users` Handbook Ver. 1.13E, 2009: 8
[41] A&D Company Limited, SV-A Series Sine-wave Vibro Viscometer Users` Handbook Ver. 1.13E, 2009: 18- 19.
[42] Bourne MC, Chapter 6-Viscosity Measurement, Food Texture and Viscosity (Second Edition), 2002: 235-256.
[43] Coleman HW, Steele WG, Experimentation, Validation and Uncertainty Analysis for Engineers (Third edition), 2009:3-5.
[44] Kline SJ, The Purpose of Uncertainty Analysis, Journal of Fluid Engineering, 1985, 107 (2):153-160.
[45] Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity), ASTM D445-12, 1970
[46] M. Thirumaleshwar, Chapter-9 Forced Convection, Fundamentals of Heat and Mass Transfer, 2009: 382.
[47] Standard Practice for Basic Calibration of Master Viscometers and Viscosity Oil Standards, ASTM D2162 – 06, May 2006
[48] Standard Test Method for Calibration of Thermocouples By Comparison Techniques, ASTM E220-07a, 2007
[49] Schetz JA, Fuhs AE, Fundamentals of Fluid Mechanics, 1999:702-703
[50] Schlischting H, Boundary Layer Theory, McGraw-Hill, Seventh Edition, 1979: 90-91.
[51] Cannon JR, The One-Dimensional Heat Equation, Cambridge University Press, 1984: 13-15
[52] Widder DV, The Heat Equation, Academic Press, 1976:205-215.
[53] Pletcher RH, Tannehill JC, Anderson D, Chapter-3 Basics of Discretization Methods, Computational Fluid Mechanics and Heat Transfer (Third Edition), 2012: 43-51.
[54] Baehr HD, Stephan K, Chapter-2 Heat conduction and mass diffusion, Heat and Mass Transfer, 2006: 109-111.
[55] Abu-Orf MM, Walker CA Dentel SK, Centrate Viscosity for Continuous Monitoring of Polymer Feed in Dewatering Applications, Advances In Environmental Research, 2003, 7:687-694.
[56] Fedorchenko A, Satchiv I, Wang A-B, The Optical Viscometer Based on the Vibrating Fiber Partially Sub-merged in Fluid, Sensors and Actuators B, 2009, 142:111-117.
[57] Fedorchenko A, Satchiv I, Wang W-C, Method of the Viscosity Measurement by Means of the Vibrating Micro-Nano-Mechanical Resonators, Flow Measurement and Instrumentation, 2013, 32:84-89.
[58] Adrian RJ, Ferreira RTDS, Boberg T, Turbulent Thermal Convection in Wide Horizontal Fluid Layer, Experiments in Fluids, 1986, 4:121-141.
[59] Koschmieder EL, Bernard Cells and Taylor Vortices, Cambridge University Press, 1993: 1-195.
[60] Fujisawa N, Adrian RJ, Three-dimensional Temperature Measurement in Turbulent Thermal Convection by Extended Range Scanning Liquid Crystal Thermometry, Journal of Visualization, 1999, 1: 355-364.
[61] Fujisawa N, Funatani S, Katoh N, Scanning Liquid-crystal Thermometry and stereo Velocimetry for Simultaneous Three-dimensional Measurement of Temperature and Velocity Field in a Turbulent Rayleigh-Bernard Convection, Experiments in Fluids, 2005, 38:291-303.
[62] Corvaro F, Paroncini M, An Experimental Study of Natural Convection in a Differentially Heated Cavity through a 2D-PIV System, Int. J. Heat Mass Transfer, 2009, 52 : 355-365.
[63] Kiuchi M, Fujisawa N, Tomimatsu S, Performance of PIV System for Combusting Flow and Its Application to Spray Combustor Model, J. Visualization, 2005, 8:269-276.
[64] Raffel M, Willert C, Kompenhans J, Particle Image Velocimetry, Practical Guide, Springer, 1998:1-146.
[65] Castaing B, Gunaratne G, Heslot F, Kadanoff L, Libchaber A, Thomae S, Wu X-Z, Zaleski S, Zanetti G, "Scaling of Hard Turbulence in Rayleigh-Bernard Convection", Journal of Fluid Mechanics, 1989, 204:1-30.
[66] Janna WS, Chapter 4-Unsteady state heat conduction, Engineering heat transfer (second edition), 1999: 195-196