Journal University of Kerbala , Vol. 15 No.4 Scientific . 2017

THEORETICAL AND EXPERIMENTAL ANALYSIS OF FLUID FLOW VISCOMETERS IN LIQUIDS (OIL, WATER AND ETHANOL) REGION BASED IN FLUENT SOFTWARE

تحليل جريان المائع نظرياً وعملياً في مقياس اللزوجة في السوائل(النفط،الماء،والايثانول) باستخدام برنامج الفلونت

Dr.Haider Nadhom Azziz
University of Kerbala ,College of Engineering, Department of Petroleum Engineering
hyder078@yahoo.com

Abstract

This paper describes the fluid flow simulation results in the working space of fixed flow capillary viscometers of different configurations that are obtained on the basis of numerical solution of the Navier-Stokes equations for laminar flow using the experimental method. The influence of the capillary tube length and shape of the cylinder at the bottom the metrological characteristics of the viscometer. Given received during mathematical experiment conducted, the results developed functional diagram of the device measuring the viscosity.

The aim of this paper is to model a few script using Fluent. The purpose of doing so was to see how exact the program at modeling fluid flow viscometers in liquids in order to see if computational fluid dynamics has preceding enough to do away with the classical methods.
Keywords: capillary viscometer, flow, fluent. modeling, viscosity,

الخلاصة :

في البحث الحالي تم وصف لنتائج محاكاة التدفق للسوائل (الزيت ،ماء ،الايثانول) وعند استخدام مقياس اللزوجة في حالة الجريان الثابت وحل معادلات الجريان حلا عدديا ، ومن خلال الحل العددي لمعادلات نافير-ستوكس في حالة الجريان الطباقي وباستخدام طريقة تجريبية تتأثر بطول الأنبوب الشعري وشكل الاسطوانة في الجزء السفلي لمقياس اللزوجة. بينت نتائج البحث التي تم الحصول عليها خلال التجربة الرياضية التي أجريت والتي قد وضعت مخططا وظيفيا لجهاز قياس اللزوجة. يهدف البحث الحالي الى حل النموذج رياضيا بواسطة محاكاة حالة الجريان للموائع الثلاثة لمقياس اللزوجة بواسطة برنامج التحليل الرياضي فلونت. وكان الغرض من ذلك هو معرفة حالة النمذجة للموائع في مقياس اللزوجة ومدى تدفق جريان السوائل في مقياس اللزوجة من أجل معرفة الحالة الديناميكية للسوائل وحسابها للتخلص من الطرق الكلاسيكية في اجراء التجارب بواسطة برنامج فلونت ومدى مطابقتها مع النتائج الحقيقية من خلال حسابها عمليا.

1. Introduction

At the present time in various industries there is a substantial intensification of technological processes. For are used control and monitoring of these processes modern automated systems, including a variety of technical means. The greatest proportion of measurement errors in these systems is field-level technical facilities, which include automatic and capillary viscometers. For complete elimination of the error hardware first level of automation is not possible, but it can be reduced. Improving the accuracy of measurement is currently an urgent task. For this purpose it is necessary to study more deeply the hydrodynamic processes within the workspace capillary viscometers. To solve this problem with high accuracy one have to enable modern methods of computational fluid dynamics (CFD) and Compressible Navier-Stokes (N-S) equations that lead to the equation for the total specific energy which can be splitted into two separate equations for the one internal energy and the other kinetic energy[1] .

Experimental investigation of flows in the various studied when the experimental and theoretical viscosity rate were known search the scope of a process on how the spare viscosity of a liquid can be fixed without the learning of it spaper value is calculated in a large numbering of papers (Dikko A. B., et al., 2014)[2].

These works term results for various A three-phase of axisymmetric numerical paternal based on dimension of Fluid–Continuum flat Force (VOF–CSF) model was advanced to proceed parametric test of component droplet output in three-phase glazier glass capillary devices that take in co-flow and countercurrent flow focusing (Seyed Ali Nabavi et al., 2015)[3].

The modern methods of viscosity measurement in most widely capillary. Its main advantages are the relative ease of implementation and the possibility of a sufficiently accurate simulation of the measuring procedure. However, in any case, based on capillary measurement method for different methods of its implementation is the law of Poiseuille, which operates under the condition of existence of fully formed parabolic flow velocity profile, and the condition of constant pressure gradient along the entire length of the capillary tube.

The velocity distribution across the intermediate fluid layers:

$u_x = u_0 \frac{y}{Y}$……..……..(1)

This ratio is referred to shear stress:

$\frac{\text{Force}}{area} = shear\ stress\ \alpha \frac{u_0}{Y} = \mu \frac{U_0}{Y}$……..…..(2)

Which can be expressed in differential form:

Shear stress $\tau_{x,y} = -\mu \frac{du_x}{dy}$

$\tau_{x,y} = \frac{-\mu}{\rho}\left[\frac{\rho dux}{dy}\right] = -v[\frac{\rho dux}{dy}]$ ……..…..(3)

For incompressible flow

$\tau_{x,y} = -v \frac{d(\rho u_x)}{dy}$……..…..(4)

Figure (1). Schematic diagram of an exemplary device implementing this method includes three main elements - the storage and collection tanks and connecting them capillary tube.

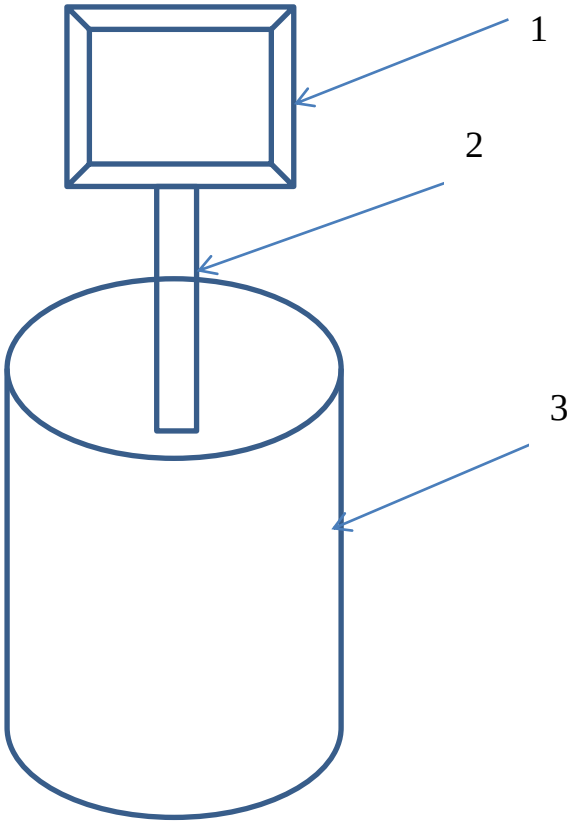


Figure (1) Schematic diagram of the capillary viscometer.
1-storage tank,2- the capillary tube, 3-receptacle

The classic version of the capillary method of determining the viscosity is realized by follows . (V)a fixed volume sample liquid is passed by gravity through a capillary with a precisely known geometric dimensions (d_c) and (L_c) measured time expiration of (ti).

$$\mu = \frac{\pi \Delta p_k d_c^4 \, ti}{128 v l_c} \quad \text{.....(5)}$$

Where in Table (1)

Symbol	Means	Units
M	Dynamic viscosity.	[Pa • s]
ΔPk	Pressure drop across the capillary tube.	[Pa]
Dc	Capillary diameter.	[m]
Lc	Length of the capillary.	[m]
V	Volume of liquid.	[m^3]
Ti	time fluid flowing out.	[s]

The desired parameter is calculated. The main source of error in determining the use of such procedures is considered inaccurate reference time has elapsed The viscometer due to different temperatures at which the viscometer was calibrated and used for measurement of viscosity of a liquid[4].

2. Theoretical and mathematical model

The remaining quantities in the equation (5) are considered constant and are entered in the so-called "device constant." The value and constancy of the most "constant" is defined and checked periodically by spilling through the instrument calibration fluid. However, in fact, with the free fluid outflow through the capillary viscometer any of the known configuration cannot remain constant, and decreases continuously in the course of the measurement procedure. For this reason, the flow rate (Q) through a measuring capillary decreases continuously. This means that due to violation of conditions (Q) equals a constant absolute value of the coefficient. This method of determining it cannot be accurate. The latter circumstance is one of the significant shortcomings of the classic embodiment of a method for determining capillary viscosity. To eliminate the measurement procedure it is suitable to implement the scheme with the constancy of flow rate, in this case, the dynamic viscosity is a function of pressure drop across the capillary ΔP_k. The condition of constant (Q) can be achieved using a device with a positive movement of liquid through the capillary at a predetermined speed. Hydrodynamic characteristics of the processes occurring in his workspace, such as the formation of the flow at the initial section of flow in the capillary tube, vortex structures forming at the interface with the bottom wall of the cylinder and the cylinder bottom to the entrance of the capillary tube, and some others. To explain the possibilities and conditions of adverse hydrodynamic effects in the workspace, and to assess their impact on the size and quality of the output signal of the viscometer, held a special mathematical experiment in which the viscometer workspace was set conutours, presented in Figure (2). Flow simulation was performed using the two-dimensional mathematical model based on the numerical solution of the Navier-Stokes equations using finite element method and implemented in the software FLUENT complex .The original aim of the scheme has been to simulate full scale modeling and to developing tools to expect likely problems united to incomplete form filling [5].

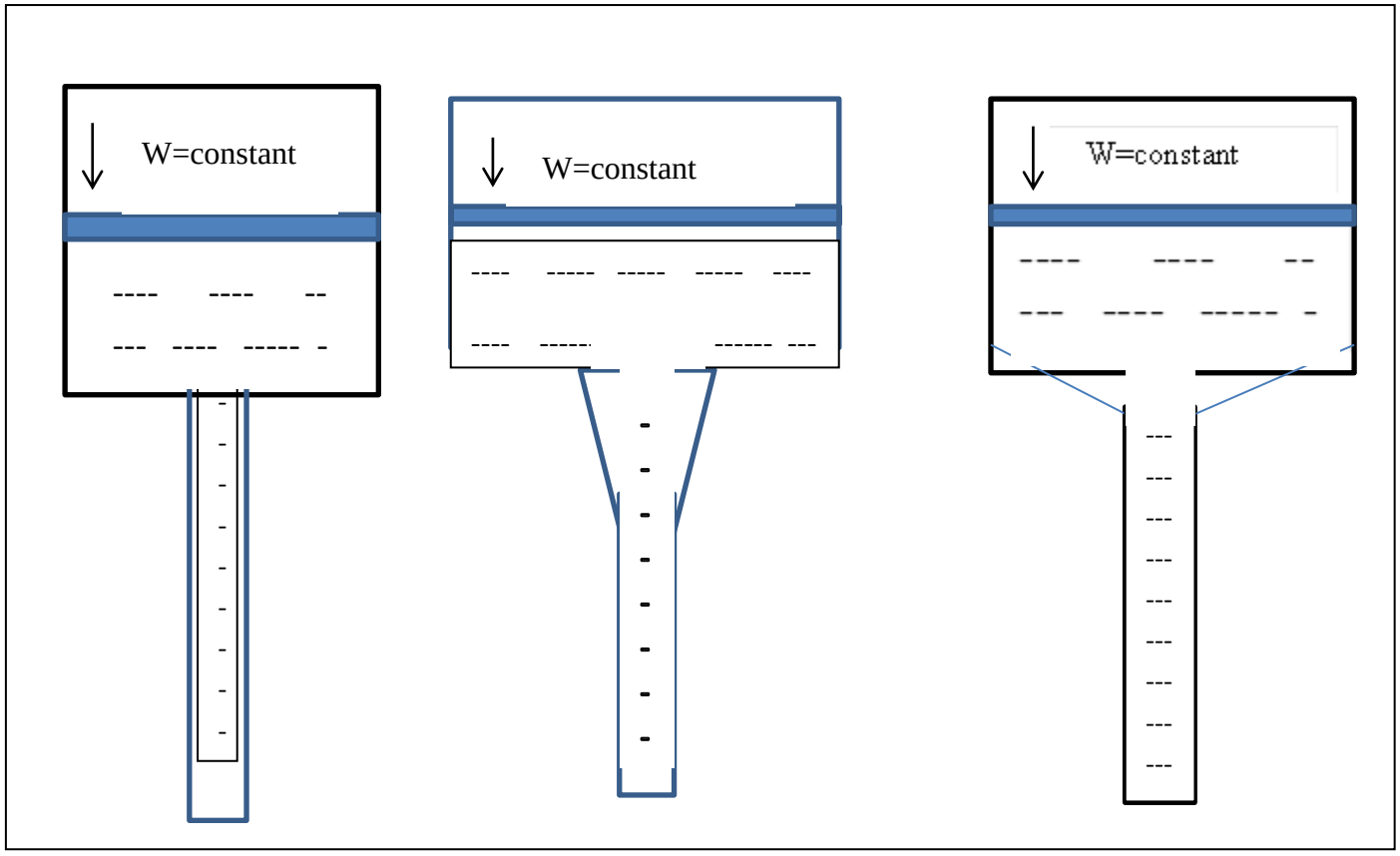


Figure (2) Contours workspace viscometer.

Fluid, in many cases, is part of our life. Our body consists of 80% of fluids, a tiny single cell of plankton consists of fluids, the earth and the atmosphere consist of a large area of fluids[5].

The viscosity of Newtonian fluids is influenced by temperature, pressure, and, in the condition of setting and mixtures, by composition. The effect of pressure and temperature on the viscosity[6].

Measurement marks on the glass body are shown in figure (3), or accurately defined steady sensors, let the measurement of the passage time of the boundary layer between the sample and the air (meniscus), a process which can the passage time of a product volume restricted in such a style to be measured[7].

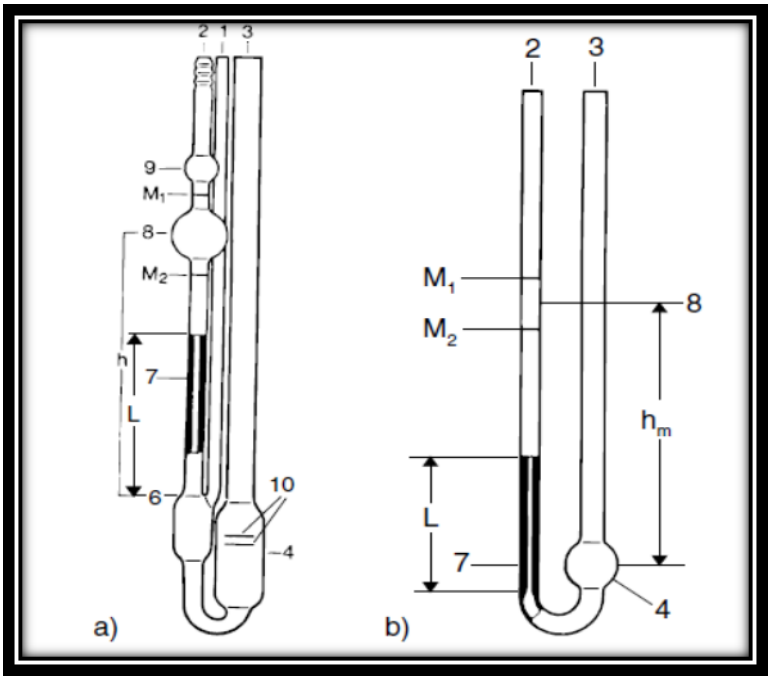


Figure. (3) Glass capillary viscometers after :a) UBBELOHDE and b) OSTWALD[6].

Table (2): Literature values of the density r and the dynamic viscosity h of methanol-water mixtures of different compositions at constant temperature (T = 298.15 K)[8].

$m(CH_3OH)$ /g	$m(H_2O)$ /g	ρ /g·cm^{-3}	η /mPa·s
0	100	0.9970	0.897
10	90	0.9804	1.178
20	80	0.9649	1.419
30	70	0.9492	1.581
40	60	09316	1.671
50	50	0.9122	1.577
60	40	0.8910	1.427
70	30	0.8675	1.234
80	20	0.8424	1.025
90	10	0.8158	0.788
100	0	0.7867	0.557

Table (3): Literature values of the density r and the dynamic viscosity h of water and methanol at various temperatures[9].

T / K	Water		Methanol	
	ρ /g·cm^{-3}	η /mPa·s	ρ /g·cm^{-3}	η /mPa·s
293.15	0.9982	1.002	0.7915	0.608
398.15	0.9970	0.897	0.7868	0.557
303.15	0.9956	0.797	0.7819	0.529
308.15	0.9940	0.726	0.7774	0487
313.15	0.9922	0.653	0.7729	0.458
218.15	0.9902	0.597	0.7690	0.425
323.15	0.9880	0.548	0.7650	0.396

3. **Kinematic viscosity**

There are several ways to find the kinematic viscosity of a fluid, but the most used method is determining the time it takes a fluid to flow through a capillary tube. The time is converted directly to kinematic viscosity using a calibration constant provided for the specific tube. A basic difference between the dynamic and kinematic viscosity measurements is density. Taking density out of the equation provides a way to convert a kinematic and a dynamic viscosity measurement.

4. Kinematic viscosity test

This device used to measure the kinematic viscosity for different types of fluids in viscometer as shown in figure (4).

Figure (4)Viscometer.

5. The steps of this procedures are experimental of region based in viscometer.

1-Fill the water bath with water until (2 cm) from top, then put the sensor into water bath.

2-In this test three types of fluid used to measure their kinematic viscosity (oil, water, ethanol) by using appropriate viscometer.

3-There are six of this tubes each one is deferent from others by its capillary pressure size (from 100 to 600) psi which suits with density of fluid used.

Water with tube of size 100 cm^3.until reach to red line , ethanol in tube 0f size 150 cm^3 ,& oil in tube of size 600 cm^3,then close it from top.

Figure(5) Test capillary tube.

4-Fill the tubes in water bath as shown in figure (6).

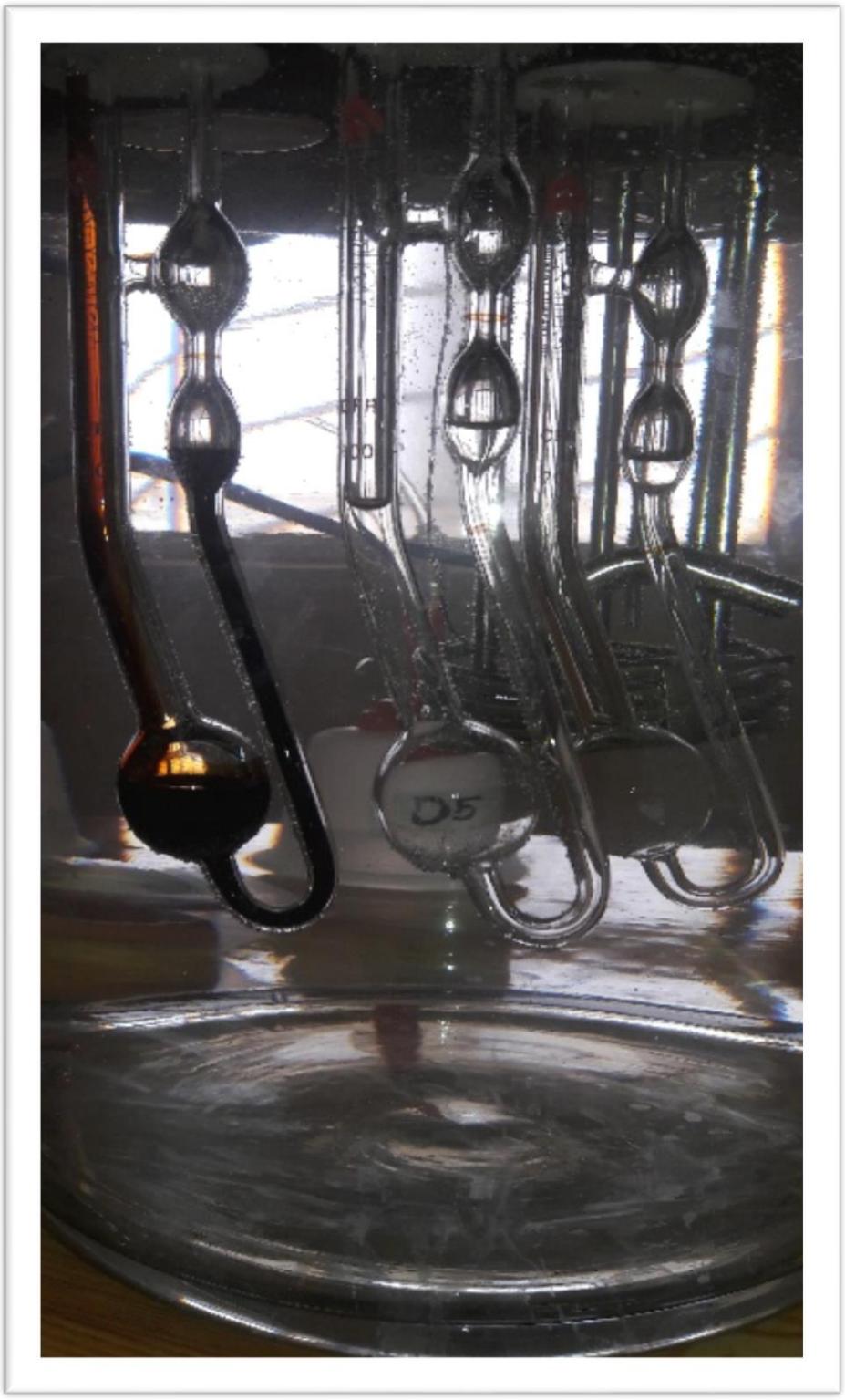


Figure (6) Capillary tube.

5- Turn on the stator and wait to increase temperature in water, then the sample will move from red line to top of viscometer from bottom to top red line, recording temperature as shown in figure (7).
6- Turn off the stator for cooling and record the down time of the sample from top to bottom red line.

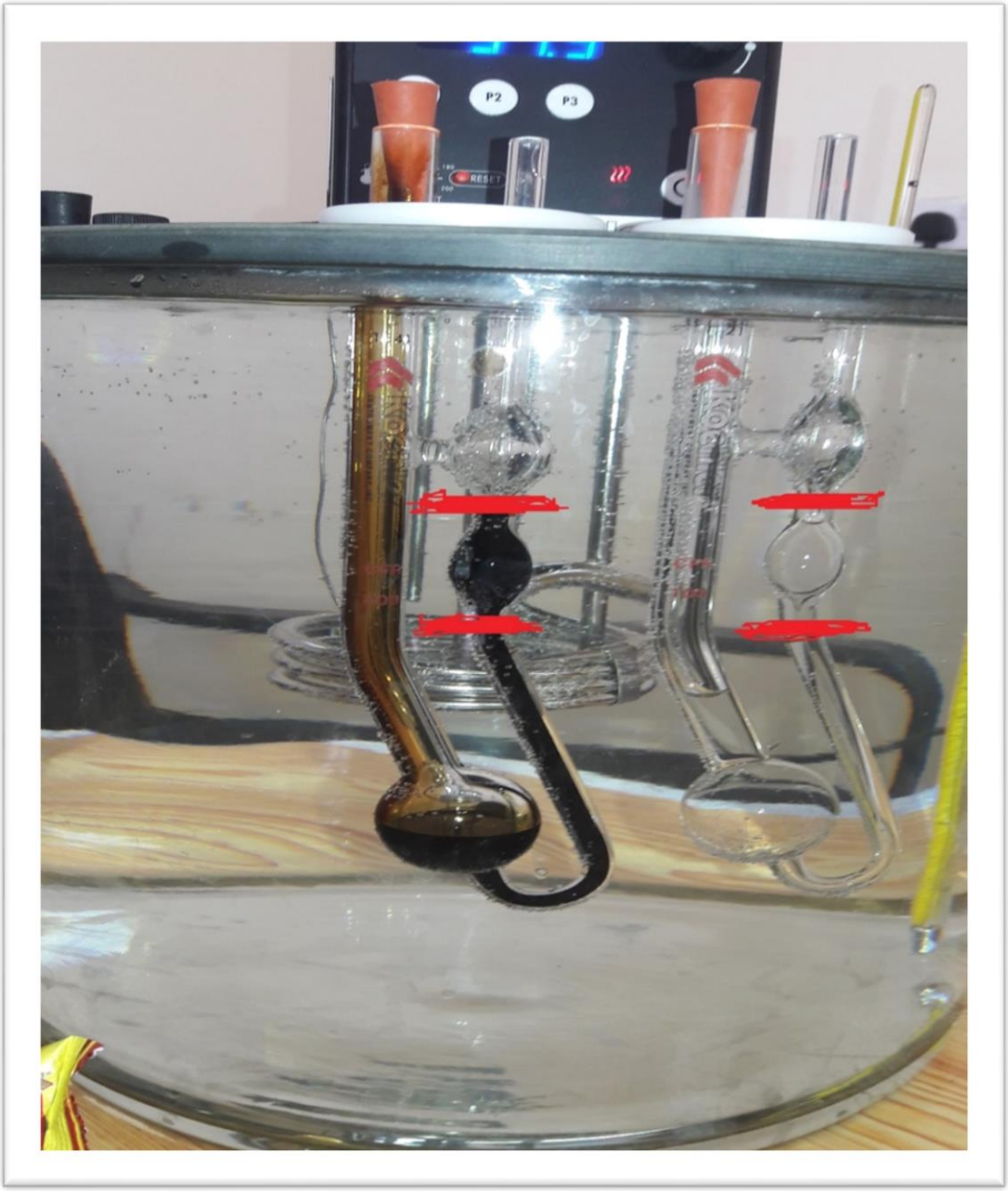


Figure (7) Viscometer with capillary tube.

6. Calculations

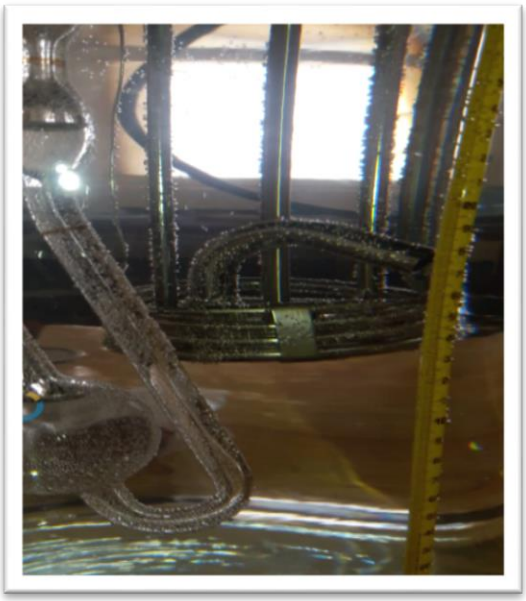
Table (4):Experimental values for the density Kinematic viscosity and Dynamic viscosity for the dynamic viscosity (dv) of Ethanol ,water and oil at different temperatures[9].

Sample	Size of viscometer	C=constant cm^2/s^2	Time s	Density gm/cm^3	Temperature C^0	Kinematic viscosity cm^2/s	Dynamic viscosity gm/cm.s
Ethanol	150	0.0003383	960	789	37	0.3248	256.267
Water	100	0.000146	1260	1000	56	0.18396	183.96
Oil	600	0.18113	2040	904	59	369.505	334032

Kinematic viscosity = C * time when (C= constant for each tube).Dynamic viscosity = kinematic viscosity *density. Where density=1000 for water,960 for oil&789 for ethanol.

(a)

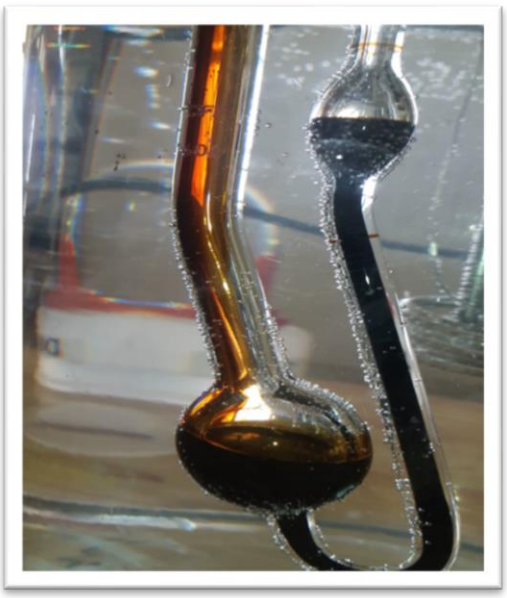
(b)



(c)

(d)

(e)



(f)

(m)

(n)

(k)

Figure(8) Stage recording temperature , time and flow rate in viscometer with oil water and ethanol in (a,b,c,d,e,f,m,n,k).

Left border grid, which set conditions to slide freely, served as the cylindrical axis of symmetry coincides with the axis X. On the border, representing a rigid wall, set conditions of adhesion. The task was, unsteady, set conditions gravity toward the axis X. In the calculations, the variable pitch grid, the finer pitch was placed in the vicinity of the rigid wall and in the bottom of the cylinder interfaces with the entrance to the capillary tube. This allowed more precisely analyze the flow pattern in these areas. mathematical experiment results shown in Figure (10 – 14), shown that the development of the hydrodynamic flow in the initial portion of the capillary tube has a marked effect form the bottom of the cylinder from which the outflow of liquid. This fact significantly affects the accuracy of the parameter μ (Figure 10). The graph in Fig. 4 shows that a significant effect on the readings of capillary viscometer also has a working length of the capillary, but rather the ratio of its total length to the length portion of the hydrodynamic stabilization of the flow. In the normal mode of fluid flow in the capillary tube can influence the processes of vortex formation in the bottom of the cylinder and related phenomena. However, when using a conical shaped barrel bottom of these negative effects substantially weaken. The conical shape of the bottom also contributes to some reduction in the length of the constriction of controlled fluid flow at the inlet into the working capillary. Nearly all absolute measurements of viscosity have been based on capillary flow because of the high precision attainable. The analysis of capillary measurements is based on the Poiseuille equation[10]. This is confirmed by current distributions lines shown in Figure (12–14). This means that large Reynolds stresses will generally be plant in areas of high strain, which most likely produces it easier to get it an accurate experimental formulation for the ratio of a Reynolds stress to the mean rate of strain than a sample of the Reynolds stress itself. In truth, the magnitude of viscosity is defined as this ratio, i.e. the ratio between the Reynolds stress tensor and the pass rate of strain [11].

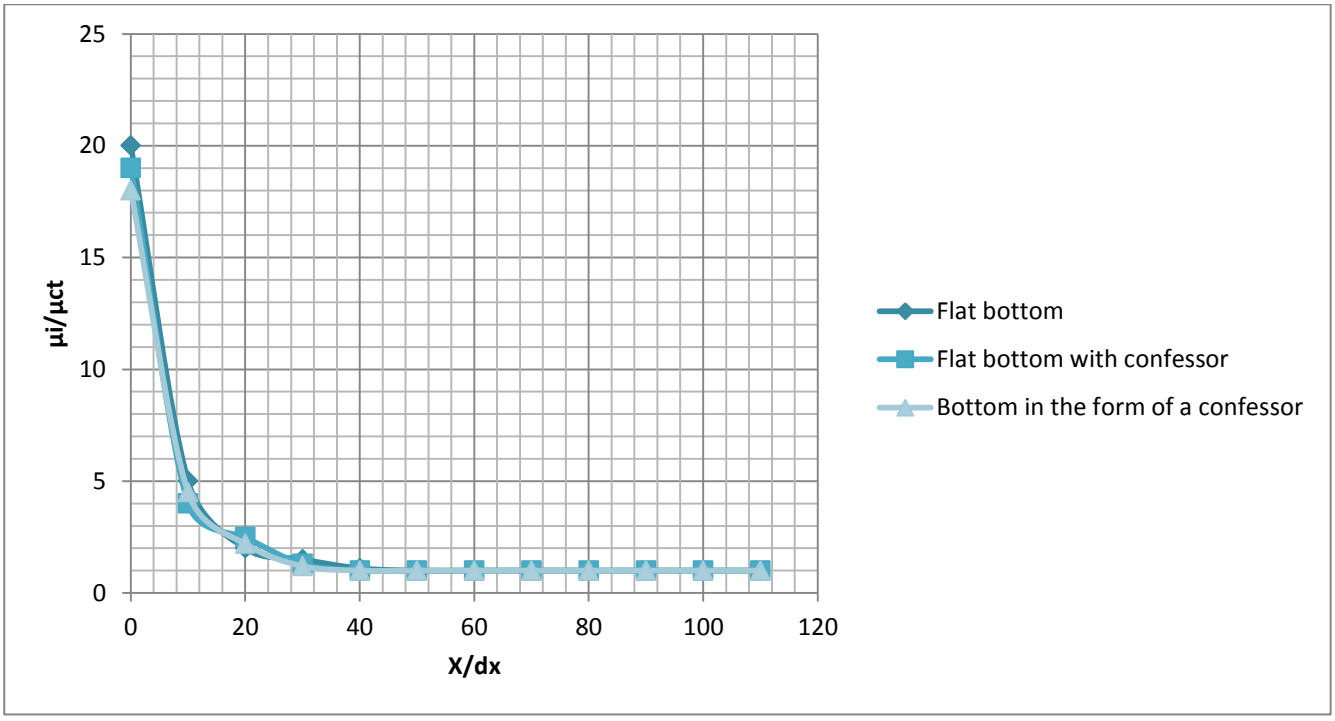


Figure (9) Impact of the shape of the working cylinder on the bottom of the results for the viscosity calculation of dc = 1,31mm, Lc = 120mm at Re = 900.

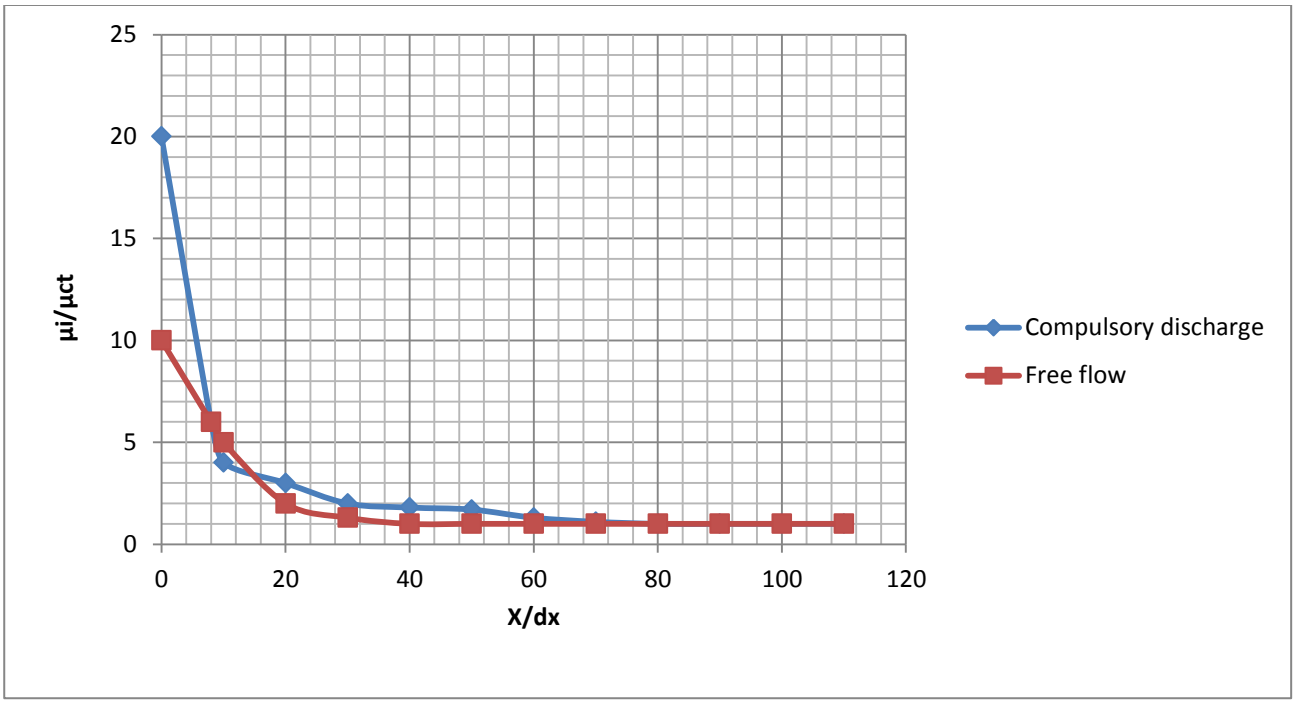


Figure (10) Influence of the working length of the capillary dc = 1,31mm, Lc=120mm viscometer results calculating a parameter μ at Re = 900.

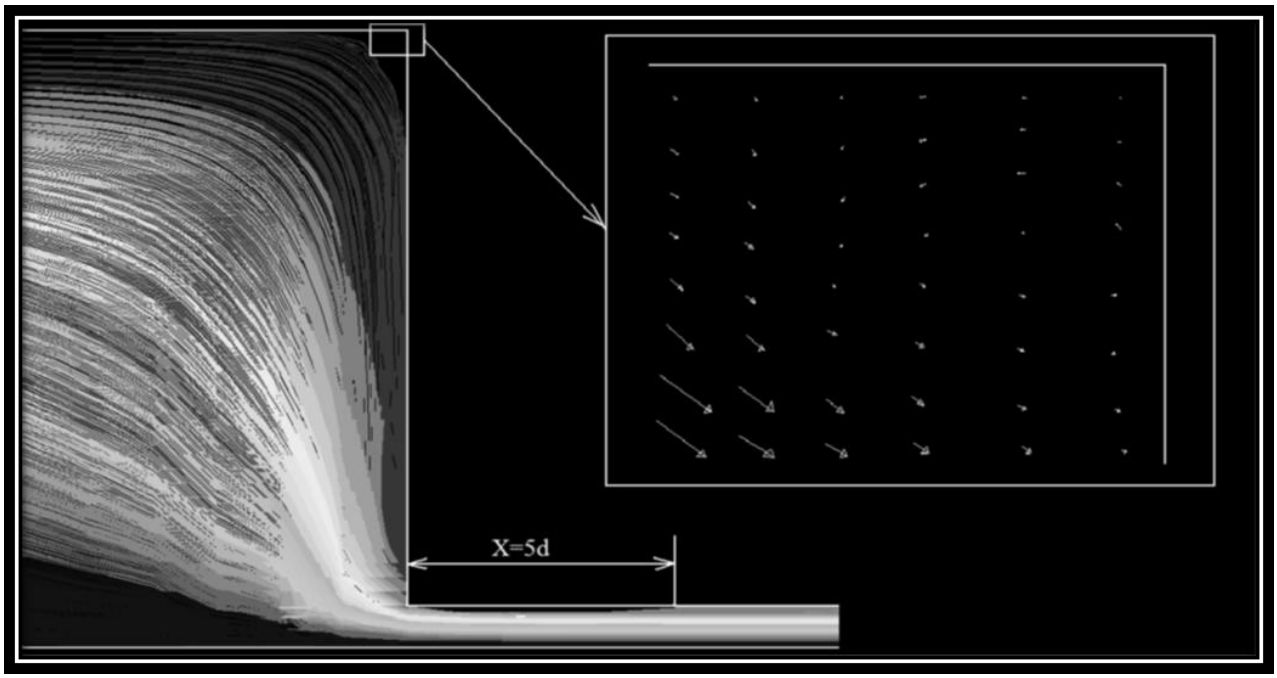


Figure.(11)Distribution of current lines in the bottom region of the working cylinder viscometer with a flat bottom in the forced fluid flow mode (Distilled water) through a capillary dc = 1,31mm, Lc = 120mm, Re = 900.

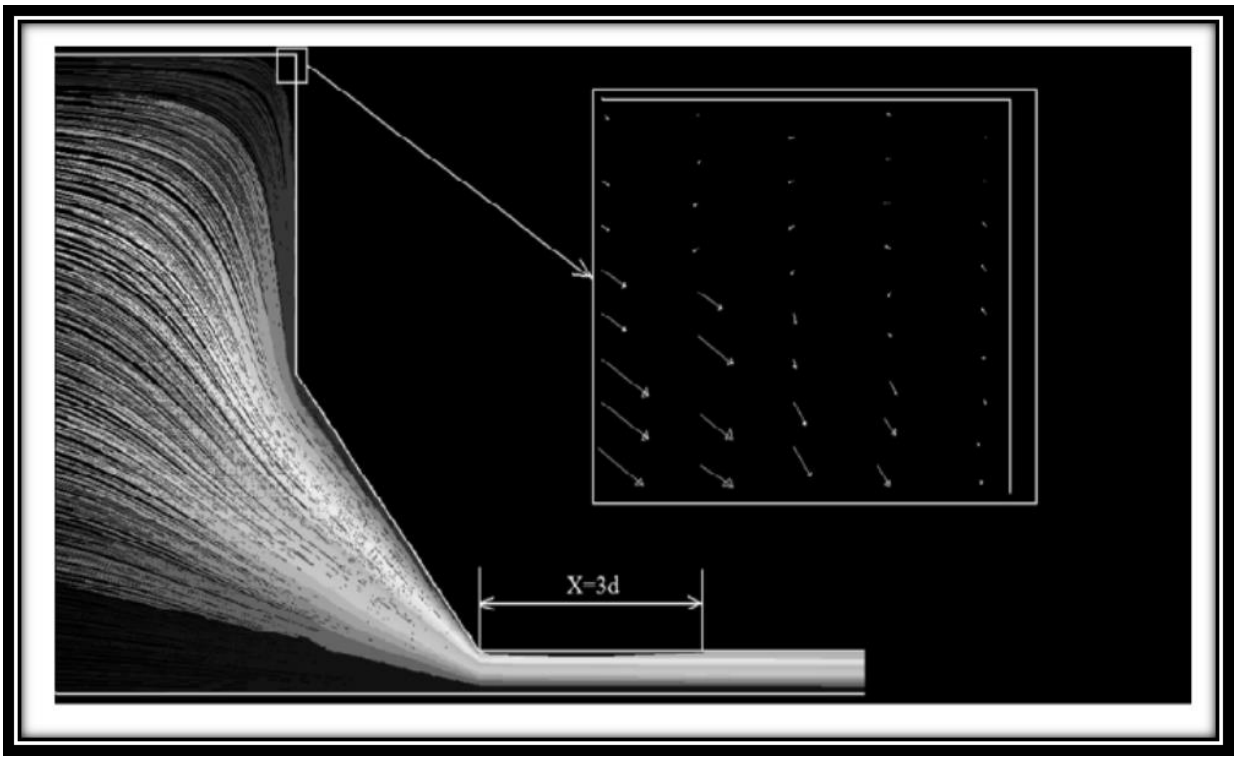


Figure. (12) current distribution lines in the area of the bottom of the working cylinder viscometer the combined form of the bottom (flat and tapered shape) in the forced mode fluid motion (distilled water) through the capillary dc = 1,31mm, Lc = 120mm, Re = 900

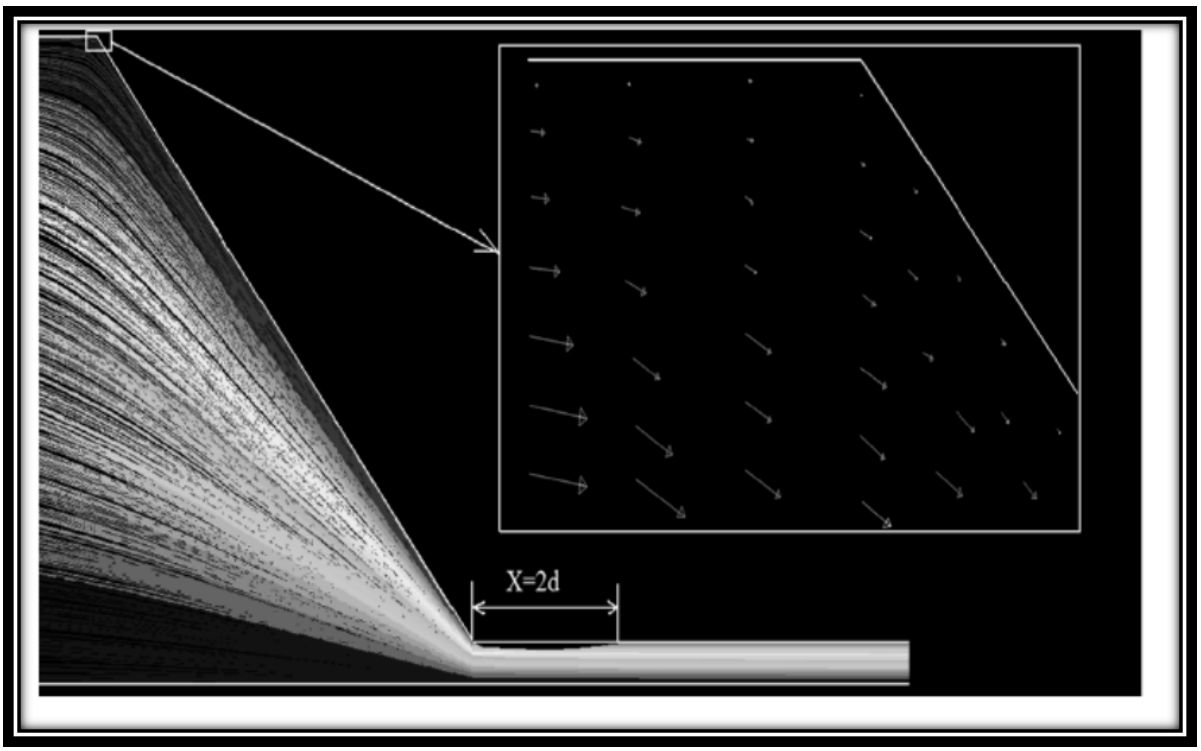


Figure. (13) current distribution lines in the area of the bottom of the working cylinder viscometer with a conical bottom in forced fluid flow mode (Distilled water) through a capillary dc =1,31mm, Lc = 120mm, Re = 900.

7. Physical model by Fluent

Theoretical analysis of hydrodynamic picture in the workspace fixed flow capillary viscometers allow to conclude that this type of viscometers is the most promising for further development and, that their work may have a significant impact geometry of the storage volume, the geometric dimensions of the capillary tube depend on the length of the hydrodynamic the initial section, the restructuring of the kinematic flow along the length of the flow structure tract, vortex formation processes in the bottom part of the storage volume, nonlinearity of the pressure distribution at the entrance to the capillary tube. But found that the negative impact of the above factors on the metrological viscometers characteristics can be reduced using a conical shaped bottom the cumulative volume of the viscometer, the right choice of the capillary tube length and mode of measurement procedures.in Fig. 8 is a functional diagram of the automated Viscosity measurement devices, designed with the results of the mathematical and experimental requirements for modern viscometers. The numerical methods are useful in Fluent, the coupled solver and the discreted solver. Both us control-volume-based technique to convert for controlling equations to algebraic equations that can be solved numerically. In the separated solver path, the governing equations are solved sequentially. Because the governing equations are nonlinear, an repeated procedure is used to solve them [12].in These models solve the multiphase Navier-Stokes equations for turbulent fluid flow, using software such as FLUENT, and provide the flow field for subsequent simulation of inclusion[13]. The temperature dependence of the measured viscosities is including the viscosities of toluene at the calibration points for the saturated liquid viscosity[14].

8. Measurement process Viscometer Flowchart

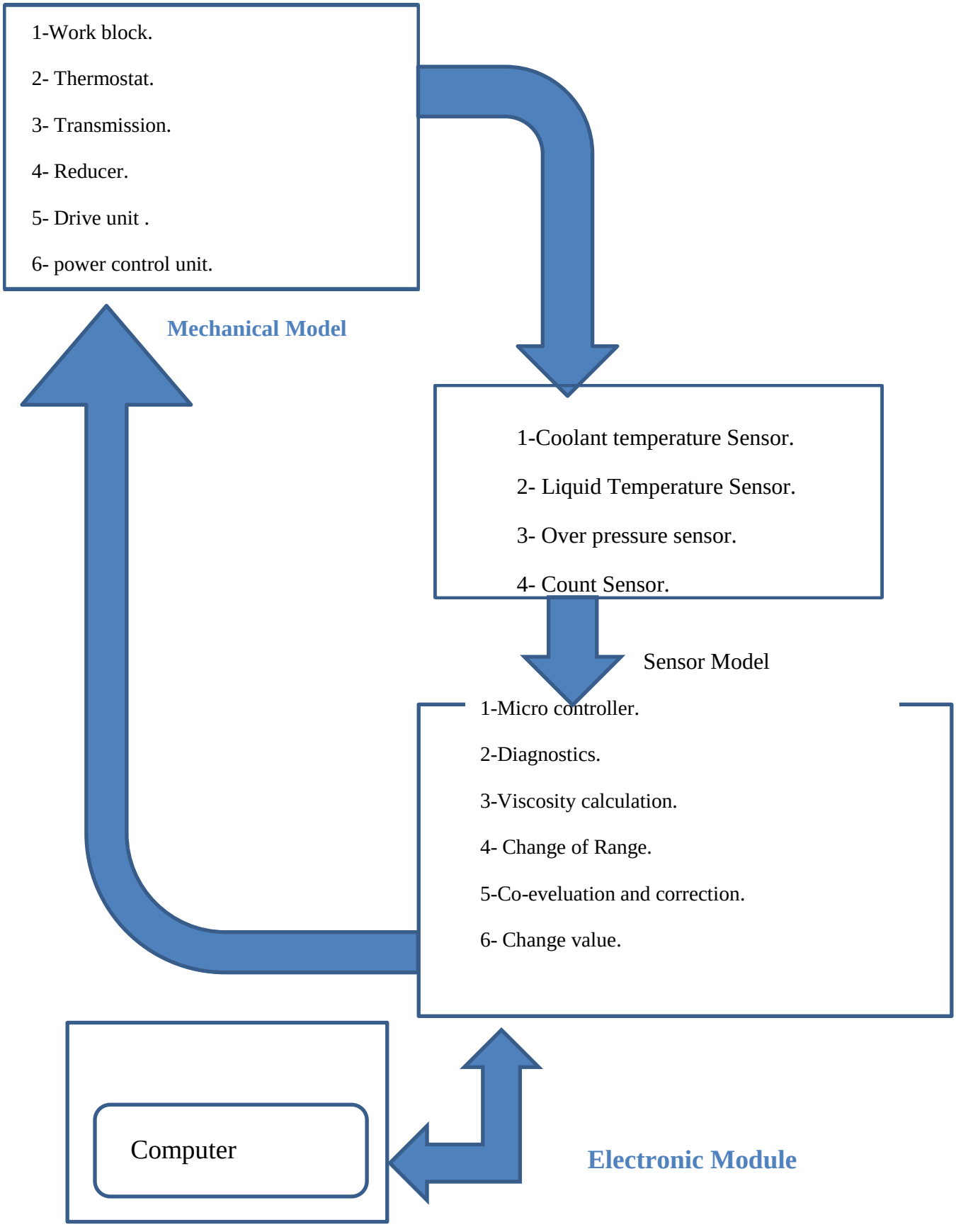


Figure (14) Functional scheme of automated devices for measuring viscosity.

On the basis of this functional unit is divided into 3 modules: mechanical electronic, and sensor . Mechanical module includes 3 units: the working unit of the kinematic transmission and drive unit. The main element of the electronic module is a microprocessor-based controller, with responsibilities for the automatic control functions on algorithms of data processing, implementing the measurement process, adjusting the measurement range, recording time process data, diagnostics and functional units viscometer blocks.

9.Conclusions

1- Reliance of the viscosity of the ethanol, water and oil system on the equalization described by the flat bottom (x) at constant temperature.
2- Reliance of the viscosity of the ethanol, water and oil system on the equalization described by Kinematic viscosity and Dynamic viscosity at constant temperature.
3- Analysis of hydrodynamic model in the workspace fixed flow capillary viscometers allow to conclude that this type of viscometer .
4- Development and, that their work may have a significant impact on the geometry of the storage volume, the geometric dimensions of the capillary tube depend on the length of the hydrodynamic section.
5- Experimentally determined capillary tube(1,2,3)data or alternatively that obtained from Tables 4.
6- This activation impact of the shape of the working cylinder can be determined from the slope obtained by the linear in figure (9).
7- The elimination of classical methods in the testing of Flonte and the extent to which they correspond to the actual results by calculating them in practice with experiments.

Reference

1- G. Castiglioni and J. A. Domaradzki" Characterization of numerical dissipation rates in numerical simulations with complex geometries"Department of Aerospace Engineering ,University of Southern California Los Angeles, CA 90089-1191,pp.(13) .U.S.A. (2015).
2- Dikko A. B." Calculation of Excess Viscosities of Some Liquid Mixtures At 308 K Without Using The Theoritical Viscosity Values Of The Liquid Mixtures 'IOSR Journal of Engineering|V4| pp.(20-23) 07 (July. 2014).
3- Seyed Ali Nabavi'' Double emulsion production in glass capillary microfluidic device: Parametric investigation of droplet generation behaviour" Engineering and Physical Sciences,Elsevier volume 130,pp. (183-196),7(July 2015).
4- Annika Gram" Numerical Modeling of Self-Compacting Concrete Flow" Royal Institute of Technology (KTH) ,pp. (8-10),TRITA-BKN. Bulletin 99, Sweden (2009).
5- S. V. Gupta, Viscometry for Liquids, Springer Series in Materials Science 194. Springer International Publishing ,pp.(1), Switzerland (2014).
6- Hogenrich Damanik "FEM Simulation of Non-isothermal Viscoelastic Fluids" pp. (5-8) Dortmund, on Mai (2011).
7- R.N. Barfield and J.A. Kitchener, "THE CONCEPT OF VISCOSITY", pp. (25-28), New York (1979).
8- Prof. Dr.-Ing. habil. Jürgen Wilke" Theory and Praxis Of Capillary Viscometry" Process and environmental Technology Faculty, pp.(6) Germany.
9- PHYWE series of publications • Laboratory Experiments • Physics • PHYWE SYSTEME GMBH • 37070 Gottingen, Germany.
https://www.nikhef.nl/~h73/kn1c/praktikum/phywe/LEP/Experim/1_4_04
10- Andreas Sveningsson" Analysis of the Performance of Different Turbulence Models in a Stator Vane Passage Flow" Department of Thermo and Fluid Dynamics CHALMERS UNIVERSITY OF TECHNOLOGY ,pp.(5-15), Goteborg, Sweden,(2003).
11- Robert S. Marvin," The Accuracy of Measurements of Viscosity of Liquids" JOURNAL OF RESEARCH at the Notional Bureau of Standards - A. Physics and Chemistry Vol. 75A, No. 6, December (1971).

12- Ali Sahili, " 3-D Modeling of Axial Fans" Department of Mathematics and Physics, Lebanese International University, Beirut,pp.(633) Lebanon.(2013).
13- Brian G. Thomas, "Modeling of Hot Tearing and Other Defects in Casting Processes" pp. (362-374) University of Illinois (2009).
14- A. Laeseck" Viscosity Measurements of Ammonia, R32, and R134a. Vapor Buoyancy and Radial Acceleration in Capillary Viscometers" National Institute of Standards and Technology U.S.A. International Journal of Thermophysics, Vol. 20, No. 2, (1999).