editorial

Viscosity – a symptomatic problem of actual metrology

The untruth is of conjuncture use for one or a small group of persons;
The truth remains as eternal and universal.

The previous editorial tried to reveal that metrology can and must ensure moral and technological progress by considering at least that it can and must give at any moment the measure of quality of our life. The new structure and acting principles of national metrology proposed and discussed there was based mainly on Romanian serious real facts, but submitted for debates of international experts.

It is a notorious fact that metrology belongs to the physics. On the other hand physics, by considering all its domains, is a living science never in stand-by or giving the perfect solution. Let us remember models for atomic or solid state structure in continuous development: new experimental facts improve the old model creating the new one. All stages in the real evolution represent truth and remain valid.

However, generally in all sciences, particularly in physics, there were, still are and probably will be for always contributions without experimental support, but driven by political reasons serving a group of peoples. These untruth assertions have marked drastically their contemporary technology and the quality of life. This would be the good topic for a lecture regarding history of sciences, so I mention only that in the present time metrology tends to be driven more and more by political forces. This is somehow explainable taking into account that metrology has become an important and certain source of money and it is considered only as such.

In last February our small technical group intended to open a joint research study entitled as “Viscosity standards: high accuracy measurements of viscosity and interrelated quantities”. This action was based at least on the following reasons:

(i) our intense experience in designing and realizing the ViscoDensCalorimeter (VDC) in four progressively improved models based on original principles ;

(ii) the fact that the actual measurements do not take into account the correct definition of viscosity (see below);

(iii) non-existence of viscosity standards in Romania;

(iv) the joint of many specialists and their efforts for a common interest eventually in substantiating, improving and/or standardizing our methods;

(v) the lack of Romanian money to continue a such project, but which can be supported by European organisms. We have tried prior to obtain the support from the Romanian Research Agency (CALIST 269/8 November 1999) who was financing many other projects with a lot of money (certainly much more important).

We have contacted some important national metrological and top testing institutes in Europe[#]: PTB (Germany), NPL, NEL (UK), VNIIM (Russia), LNE (France), some Universities engaging researches on viscosity and some companies directly interested for correct measurements of viscosity or performing measuring devices for viscosity. The immediate result was zero.

But, once engaged deeply in this topic, we have continued to collect and complete information about technical norms, measuring techniques used for viscosity standards, scientific literature, etc.

Taking into account our prior experience with torsion pendulum, but used in evidencing kinetics of phase transitions in polymers, we have concluded that this apparently simple technique can be adapted as additional technique to the our one, to evidence also the correct viscosity values for liquids. We have found immediately in the literature the basic and classic works.

Ironically, this technique appears to be suitable for molten salts, so a huge number of scientists, even my past colleagues from Chemical-Physics Institute in Bucharest were used the techniques of oscillating sphere, cylinder and cup in performing their doctorate Theses so their results are reported as databases.

It is important for further discussions to repeat the detailed definition of viscosity.

Experiment: two plan, parallel and solid surfaces with equal area A at the distance D and containing a volume of liquid (A*D) under test between them, are moving uniformly and linearly with the relative speed v.

Premises: The following premises are considered during this motion:

(P1) The values A, D and v remain as constant.

(P2) The volume of tested liquid remains as constant.

(P3) The adherence between liquid and the two solid surfaces (LSSA) is total, this means that the first contact surface of the liquid is 100% adherent to the solid surface.

(P4) All other parasite motions in the system are neglected. For instance: the flow of the liquid under proper weight; turbulences due by inhomogeneities, structural changes, etc.

(P5) Temperature gradients due by thermal effects associated to liquid deformation are neglected.

Quantitative relationships:

Let be F the force applied to the two moving surfaces, so that the following relationship exists:

$$F/A = DV*(v/D) \quad (1),$$

where DV is the dynamic viscosity of the liquid under test. Subsequently, kinematic viscosity (KV) of the liquid is defined by considering the density of the liquid, d, as

$$KV = DV/d \quad (2).$$

In view to clear up the actual aspects of viscosity measurements, I will note them as separately in the following discussion without longer comments.

1.Water is considered as unique primary standard for viscosity whose absolute value was measured in several thorough studies on capillary flow and by several oscillating-body viscometers (OBV) measurements [1,2].

2. OBV using torsion pendulum method are still considered as the main techniques for determination of absolute value for viscosity.

3.The transmission of measurement unit for viscosity is standardized by using water as primary standard and capillary flow techniques based on also standardized shapes and dimensions [3,4]. Capillary flow techniques have very good repeatability and reproducibility, but because these are far from the basic definition of viscosity are not used as absolute methods.

4. There are a large number of other standardized techniques for determination of viscosity using secondary and/or working standard liquids for their calibration.

5.No standardized technique considers quantitatively LSSA (P3). These methods impose the use of particular materials, but these do not measure LSSA in view to correct the apparent viscosity. Our VDC method measures simultaneously density, viscosity and LSSA on the same specimen of liquid (see next paper).

6.It is important to observe that the real viscosity represents the interaction (friction) between shearing layers in the tested liquid, while the apparent viscosity for which LSSA is not total contains in addition the contribution of the interaction between the liquid and the solid surfaces. From these observations it results that:

(6.1) the two phenomena are independent;

(6.2) a separation process occurs at the liquid-solid interface as a result of selective adherence of structural units, so LSSA becomes an important characteristic of the tested liquid;

(6.3) definitions of viscosity by Stokes' or Hagen-Poiseuille's experiments may lose from structural significances in comparison to the above mentioned one.

7.Rotational viscometers [5] and some particular OBV using low shear rates appear to satisfy the above mentioned premises, even the approximation of total LSSA.

8.Theory of OBV extensively used for absolute measurements (including for water) was mainly developed by Nieuwoudt, Kestin, Shankland and Sengers [6,7] and considers as the basic quantity the notion of boundary-layer thickness (BLT) defined by [8]:

$$BLT = (KV*To/(2*\pi))\hat{}0.5 \qquad (3),$$

where To is the period of oscillation of the overall system in vacuum. BLT appears from Navier-Stokes eqns. and its significance must be established experimentally in respect to the above definition of viscosity and in particular to LSSA. Although the real KV has nothing to do with LSSA (see 6.1), the notion of BLT can be considered as a combination of contributions of the two phenomena which does not result from eqn. (3).

9.This theory did not establish up to now any practical clear method of measurement as "ready to use" [7] although there are several clear experimental dispositions. The premises for practical applications are much complicated and confused [6,7,9]. This brain-storming technique is a trick taken over by other authors trying to explain theoretical background of their reported results based on OBV.

10.A successful result of this theory is considered [7] the motion eqns. of cylindrical OBV (both for body and cup!) obtained by Torklep & Øye [10]. Unfortunately, Torklep could not demonstrate in any way how he has deduced his eqns. [12]. For instance eqns. 2 and 3 must exist simultaneously because they should represent the real and imaginary parts of a complex eqn., but in fact they don't.

11.The group from Trodheim have used these eqns. for absolute measurements of viscosity of water [11]. This thorough study (with high accurate measurements of the base quantities) gives in fact untruth final results of viscosity. I invite any one who wish to check himself this fact to read carefully chapter 2.2.2 and to verify the used eqns. with the reported experimental data from Table II in this paper. For instance, theoretical background assumes that for cylindrical body, h means the half height of it, but the results are close to reported ones for h as entire height. It is important to mention that the referees of this paper in the prestigious journal were some of the above mentioned theoreticians [12].

12.I have read some Theses devoted to viscosity measurements in molten salts using OBV. For instance, I have tried to check the data from [11] with some of the eqns. presented for similar experiments, but the results are much more unrealistic (solutions as imaginary or of ~100 mPa.s order of magnitude).

13.Concerning the idea of simultaneous viscosity and density measurements [7] according to this theory of OBV, this remains as a simple fantasy. There is no clear theoretical basis and also no experiment reports such a result.

In conclusion, the measurement of viscosity remains as an open problem like all other scientific fields of physics, more exact of metrology. But, first of all, we must separate their natural evolution based on truth experimental facts, by untruth contributions. It is possible to estimate a period of at least 30 years long for which the metrology of viscosity did not progress any more mainly due by these bad contributions.

An international and transparent cooperation must start in next future involving both governmental institutes and private laboratories in view to establish main aspects of metrology of viscosity. I mean by transparent cooperation: an international project coordinated by a permanent commission acting according to a clear policy, with common funds and the reported results and the final adopted solutions as metrological procedures must not be used as industrial property by any one (both natural or conventional person).

# PTB = Physikalisch-Technische Bundesanstalt
NPL = National Physics Laboratory
NEL = National Engineering Laboratory
VNIIM = Mendeleev Institute of Metrology
LNE = Laboratoire National d'Essais

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