

## Replication of Shear Viscous Property of Crude Oil

M. Shahjahan

*Department of Physics, Dhaka University, Dhaka-1000, Bangladesh*

Email: [mjahan@univdhaka.edu](mailto:mjahan@univdhaka.edu)

Received on 22. 03.2009. Accepted for Publication on 19. 05.2009

When the gradient of a property such as temperature exists in a liquid, a transport process occurs in that liquid. The transport process is a non equilibrium or irreversible process, in which the property can change with time if spatial variation of the property exists within the liquid. The well known transport processes of momentum, mass, and energy involve viscosity, diffusion and thermal conduction respectively. This report is confined to a discussion of the shear viscosity of metallic liquid.

Consider momentum transport process that occurs when an incompressible liquid is subjected to a uniform shear stress. A velocity gradient is set up perpendicular to the direction of the applied stress, as a result of the fluids resistance to the applied motion. This resistance is known as a viscous force. Thus when adjacent parts of a liquid move at different velocities, viscous forces act so as to cause the slower moving regions to move more rapidly and the faster moving ones to move more slowly that caused by an internal fluid layer friction. Thus viscosity is a physical property which only manifest itself when a relative motion between different layers of fluid is set up

We now consider the problem of viscosity from a microscopic viewpoint. Although the nearest neighbor distances and co-ordination numbers in the liquid state at or near the melting temperature are closely similar to those in the solid state, the dynamic behavior of atoms in the two states is entirely different, from the microscopic point of view; the most characteristic feature of a liquid is the high mobility of its individual atoms. However, the motions of atoms through a liquid are impeded by frictional forces set up by their nearest neighbors. Viscosity is, therefore, also a measure of the friction among atoms. Consequently, a liquid's viscosity is of great interest in both the technology and theory of liquid metal behavior.

Viscosity plays an important role to solve quantitatively problems in fluid flow behavior as well as those related to the kinetics of reactions in metallurgic processes. Several theoreticians have proposed equations for the viscosity of liquids based on statistical kinetic theories or non-equilibrium statistical mechanics<sup>[1]</sup>. Consequently, scientists also have a keen interest in the viscosity of liquid metals since they present the simplest forms of mono atomic substances.

The definition of coefficient of viscosity, dynamics viscosity or simply viscosity is based on the following mathematical expression by Sir Isaac Newton:

$$\tau = \eta \, dv / dx \quad (1)$$

When a liquid is subjected to uniform shear stress a velocity gradient is set up, whose magnitude depends upon the coefficient of viscosity  $\eta$ . Viscosity is entirely due to the transport of individual molecules across the plane, carrying drift momentum with them. The higher the rate of transport the faster drift momentum is transmitted across the plane, which is why the viscosity decreases on heating. In liquids, a different mechanism for stress transmission is clearly at work. Langevin and Higgins make the assumption that near the melting point, where the packing fraction is high as 0.46, it is only the direct collision that can matter the process. Hence

$$\eta = 3\xi\zeta / 5\pi\sigma \quad (2)$$

Where  $\xi$  is the packing fraction and  $\zeta$  is the friction coefficient. If we take  $\zeta$  from this equation (2) and incorporate the  $g(\sigma)$  correction<sup>[2]</sup>, we write the shear viscosity within the hard sphere theory may be expressed as:

$$\eta = 1.2 \exp(-04(m T)^{1/2} V^{-2/3} \xi^{4/3} (1 - \xi/2) / (1 - \xi)^3 \quad (3)$$

Where  $m$  and  $V$  are the gram atomic weight and gram atomic volume

We have also used the hard sphere theory<sup>[3]</sup> to calculate the shear viscosity of the crude oil at different temperatures. Results of the present calculations show that the viscosity decreases with increase temperature. Similar trend is also suggested by the experimental data. However, the rate of decrement in the theoretical prediction is much slower than that of experiments. As a result a moderate discrepancy in this case has been noticed.

We attribute the discrepancy to the temperature independent potentials. The used potential is Lennard-Jones type<sup>[4-6]</sup> which is independent of temperature and the density. Consequently, the effective hard sphere diameters determined from the potential do not show the temperature dependent at all. Conversely, the density as well as intermolecular interactions largely depends on the temperature. So we believe that a temperature dependent potential would lead to a more accurate results for the shear viscosity. If the pressure dependence can be included in addition to the temperature dependence then we will be able to predict the thermo physical properties of crude oil under high temperature and pressure in the mine. This challenge is remained to solve.

The values of  $\sigma$ , the packing fraction and number density are shown in a table below.

**Table. 1. Input data for shear viscosity calculation**

number density rho ( $\rho$ )	temperature T(K)	effective hard sphere diameter ( $\sigma$ )	packing fraction ( $\xi$ )
0.0298 a.u.	303.15 K	2.896	0.369

Conclusively, the results for the viscosity decrease with increasing temperature as suggested by the experiment but moderately deviate from the experimental trend following the similar pattern with a fair agreement. So the theoretical studies of thermo physical properties of crude oil require the knowledge of temperature dependent inter ionic interactions.

Finally, theoretical description often requires the knowledge of the number density, for instance it is needed even in calculation of the packing fraction. The packing fraction is the essential ingredient for any hard sphere theory. But it is difficult to determine the molecular weight for liquid hydrocarbon because it has got a complex mixture of different hydrocarbons <sup>[7]</sup> starting from methane to octane, and also other complex compounds. In addition, geological survey depicts that the exact chemical composition of crude oil varies from one locality to another.

#### Acknowledgement

I am thankful to Professor S.M. Mujbur Rahman, Sultan Qaboos University, Muscat, Oman for providing experimental data.

-----

1. Gregory L. Eyink, 1996, Phys. Rev. E **54**, 3419
2. Chu P.C. and C. Fan, 2003, J. Geophys. Res. **108**, 3206
3. Dymond J. H, 1988, I.J. Thermophys, **9**, 1
4. Lennard-Jones, J.E, 1931, proc. phys. society, **43**, 461
5. Hensen J.P. and J.R. McDonald, 1976, Theory of simple liquids, Academic press
6. Lennard-Jones, J.E, 1937, Physica, **4**, 941
7. Geoffrey P. Glasby, 2006, resource geology, **56**, 8

