

Journal of Theoretics

Volume 6-5, Oct/Nov 2004

Viscosity and Cohesion Pressure

Zeljko Prebeg

Lermanova 12a, 10000 Zagreb, Croatia

zeljkoprebeg@hotmail.com

Abstract: This paper describes viscosity and cohesion pressure. On the base of the surface model of the liquid in the motion, it is concluded that transport of molecules between layers causes friction force (or vice versa). By comparing of the results of analysis with Newton's expression, it is concluded that viscosity is proportional to the cohesion pressure and the time necessary for the molecular transport between two liquid layers. Solution of the differential equation of motion in the field of cohesive force shows that two regions exists. In the region of short distances, molecules are transporting with constant velocity (influence of cohesion force is not significant). In the region of long distances influence of force is significant and molecules are accelerated. On the simple example is shown the meaning of cohesion pressure.

Keywords: Viscosity, cohesion pressure.

Introduction

In previous paper [1] is showed that structure of liquid can be described by a surface and string model. These models were made on the basis of analysis of organization of matter under influence of cohesion force. But most of the characteristics of the liquid are result of motion. To obtain the basic properties of the liquid (viscosity and surface tension) it is necessary to express the motion of the surface or the string. In this paper more attention will be given to analysis of the viscosity on the base of surface model of liquid.

Motion of Liquid Surfaces

A very similar model for the expression of the viscosity of the liquid was made by Newton where he examined the motion of the two surfaces in respect to each other (Fig.1).



Figure 1. Newton's model of liquid motion.

By using of this, Newton expressed viscosity trough the acting of friction force (Eq. 1)

$$F_f = -\eta \cdot S \frac{dw}{dx} \quad (1)$$

where:

η (Pas) is the dynamical viscosity of the liquid,

S (m^2) is the surface of interaction,
 dw/dx (s^{-1}) is the gradient of the velocity in the direction of the motion.

In this model everything is pretty clear except the thermodynamic characteristic of the viscosity. It is well known that viscosity strongly depends on temperature which this model can not describe. To show the influence of temperature on viscosity, we will use a surface model of liquid (Fig.2).

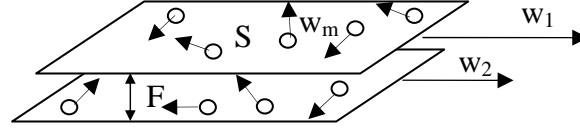


Figure 2. Surface model in motion.

According to this model, the surface has molecular structure and molecules are in two dimensional motions with an average velocity w_m . Cohesion force acting between the two surfaces. During the flowing, these two surfaces have tendency to reach the same velocity of motion. That is happening through the exchange of molecules from one surface to another. The point is that this exchange of molecules is the **transport of mass and can be made only in the direction of the force**. In the other two directions of space this force does not act and the exchange of molecules is not possible.

According to definition,

$$F = \frac{d(mw)}{dt} \quad , \quad (2)$$

only the force which acts in the direction of the exchange of momentum is cohesion, so Eq. 2 can be expressed as;

$$\Delta(mw) = F_{cohesion} \cdot \Delta t \quad . \quad (3)$$

The total quantity of exchange between two surfaces will be the difference between the exchanges of moment from S_A to S_B and from S_B to S_A .

$$\Delta(mw)_{tot} = \Delta(mw)_{AB} - \Delta(mw)_{BA} = 2\Delta(mw) = 2F_{cohesion} \Delta t \quad (4)$$

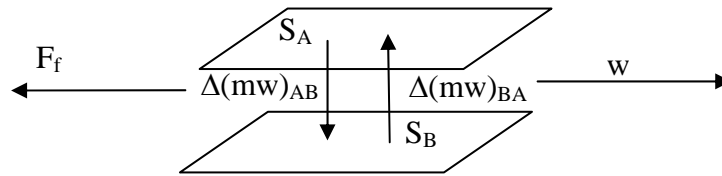


Figure 3. Exchange of moment between two surfaces.

It is interesting to express the friction force as a function of momentum exchange perpendicular to the direction of the motion,

$$F_f = -\Delta(mw)_{tot} \cdot \frac{dw}{dx} \quad . \quad (5)$$

This equation has meaning that minimizing of momentum exchange between two surfaces under a constant velocity gradient will minimize friction force. Exchange of the momentum causes resistance to the motion of the liquid. By introducing Eq. 4 into Eq. 5 we can write,

$$F_f = -2F_{cohesion} \Delta t \cdot \frac{dw}{dx} \quad . \quad (6)$$

By comparing of Eq. 1 with Eq. 6 it can be written,

$$\eta \cdot S = 2F_{cohesion} \Delta t \quad (7)$$

$$\eta = 2 \frac{F_{cohesion}}{S} \Delta t = 2P_{cohesion} \Delta t \quad (8)$$

where $P_{cohesion}$ is so-called internal pressure of liquid. (Fig. 4)

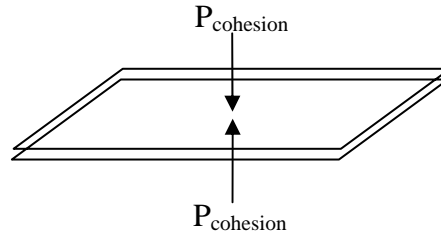


Figure 4. Description of the acting of the cohesion pressure on the surfaces of liquid.

While cohesion pressure is constant for any given liquid it can be concluded that dynamic viscosity is a measure of the time necessary for transferring the molecules between layers.

$$\eta \propto \Delta t \quad (9)$$

Motion of the molecules between two layers is motion in the field of cohesion force,

$$\frac{d^2 x}{dt^2} = \frac{F_{cohesion}}{m} \quad . \quad (10)$$

In a previous paper [2], it was found that cohesion force is proportional to x^3 [3] so Eq. 10 can be written in the form,

$$\frac{d^2 x}{dt^2} = k \cdot x^3 \quad . \quad (11)$$

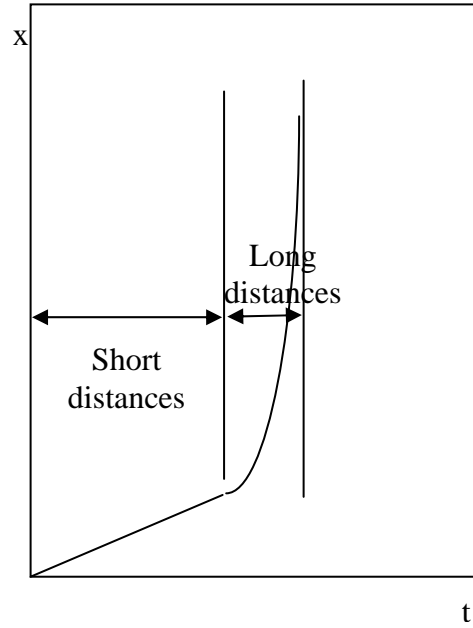


Figure 5. Solution of eq. 11.

The shape of the solution of the eq.11 is shown in Fig.5. It can be seen that at short distances the relationship between distance and time is linear while velocity is constant. At long distances the influence of cohesion force is significant and the molecules becomes accelerated. Here we will make an analysis assuming that the molecules are passing only short distances.

Let the velocity of molecular transport be w_{mt} and the distance between two layers is δ . Time for molecular transport can be estimated as,

$$\Delta t = \frac{\delta}{w_{mt}} \quad . \quad (12)$$

Taking into account that the dynamic viscosity of the liquid η , the cohesion pressure can be estimated. What this number means is presented by Eq. 14 at Fig.6.

$$P_{cohesion} = \frac{\eta \cdot w_{mt}}{2 \cdot \delta} \quad (13)$$

$$m = \frac{\eta \cdot w_{mt} \cdot A}{2 \cdot \delta \cdot g} \quad , \quad (14)$$

where $A(m^2)$ is surface of interaction and $g(ms^{-2})$ is the gravitational constant.

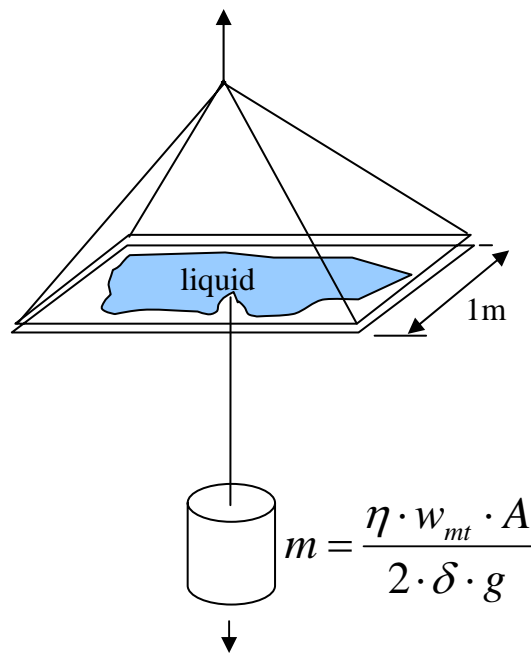


Figure 6. Cohesion.

Conclusion

On the basis of analysis of the motion of the liquid surface it can be concluded that the exchange of molecular motion between two surfaces causes friction. Comparing Newton's model with this surface model of liquid gives the expression for the viscosity of the liquid. According to this, viscosity is proportional to the cohesion pressure and time necessary for the transferring of molecules between layers. A solution of the differential equation of the motion under influence of cohesion force shows that at short distances the influence of force is not significant and motion can be described using kinetic theory. At longer distances, the influence of cohesion is significant. On the basis of simple calculation the meaning of cohesion pressure has been shown.

References

- [1]. Prebeg Z., "[Cohesion and Structure of Liquid](#)", Journal of Theoretics, Vol. 4-5 (2002).
- [2]. Prebeg Z., "[Diatomic Hypothesis and Calculation of Condensation Force](#)", Journal of Theoretics, Vol.2,No.5 (2000).
- [3]. G.V.Calder, "[Refining the Diatomic Model for the Vaporization of Liquids](#)", Journal of Theoretics, Vol. 6-3 (2004).

Received January 2004

[Journal Home Page](#)

© Journal of Theoretics, Inc. 2004