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Research Article

VISCOSITY OF BLOOD FLOW USING HAGEN-POISEUILLE METHOD

Sangeetha Selvakumaran

Department of Mathematics C.Kandasamy Naidu College for Women

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ABSTRACT

In this paper we calculate the coefficient of viscosity of blood flow using vectorial method.

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INTRODUCTION

Fluid dynamics is that branch of science which deals with the study of the motion of fluids, the forces that are responsible for this motion and the interaction of the fluid with solids. We describe three main approaches to the study of fluid dynamics: i) theoretical, ii) experimental and iii) computational.

Importance Of Fluids

We somewhat arbitrarily classify these in two main categories: i) physical and natural science, and ii) technology. In the modern era of emphasis on interdisciplinary studies, the more scientific and mathematical aspects of fluid phenomena are becoming increasingly important.

Preliminaries

Inviscid Fluid

An Ideal fluid is one, which has no property other than density. No resistance is encountered when such a fluid flows. Ideal fluids or inviscid fluids are those fluids in which two contacting layers experience no tangential force (shearing stress) but act on each other with normal force (pressure) when the fluids are in motion. In other words inviscid fluids offer no internal resistance. The pressure at every point of an ideal fluid is equal in all directions, whether the fluid is at rest or in motion. Inviscid fluids are also known as perfect fluids or friction less fluids. However, no such fluid exists in nature. The concept of

ideal fluids facilitates simplification of the mathematical analysis. Fluids with low viscosities such as water and air can be treated as ideal fluids under certain conditions.

Viscous Fluid

Viscous fluids or real fluids are those, which have viscosity, surface tension and compressibility in addition to the density. Viscous or real fluids are those when they are in motion, two contacting layers of the fluids experience tangential as well as normal stresses. The property of exerting tangential or shearing stress and normal stress in a real fluid when it is in motion is known as viscosity of the fluid. Internal friction plays a vital role in viscous fluids during the motion of the fluid. One of the important features of viscous fluid is that it offers internal resistance to the motion of the fluid. Viscous fluids are classified into two categories.

a) Newtonian fluids b) Non-Newtonian fluids

Newtonian Fluid

According to Newton's law of viscosity, for laminar flows, the shear stress is directly proportional to the strain rate or the velocity gradient.

$$\tau = \mu \frac{du}{dy}$$

where μ is the constant of proportionality and is the dynamic viscosity of the fluid. The shear stress is maximum at the surface

*Corresponding author: Sangeetha Selvakumaran

Department of Mathematics C.Kandasamy Naidu College for Women

where the fluid is in contact with it, due to no slip condition. The fluids obeying the Newton's law of viscosity are called as Newtonian fluids. It is clear from Newton's law that equation (1) represents an ideal fluid if $\tau = 0$ then $\mu = 0$. A fluid in which the constant of proportionality μ does not change with shear strain is said to be Newtonian fluid. Water, air, mercury are some of the examples of Newtonian fluids.

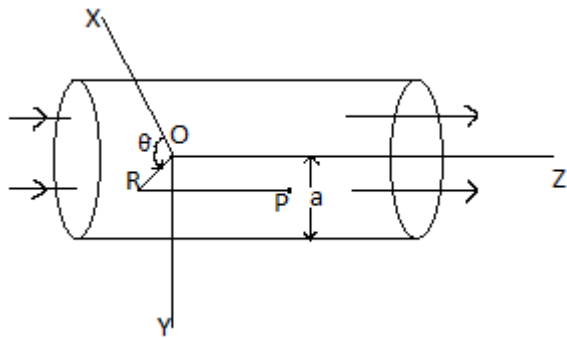
Non - Newtonian Fluids

Non-Newtonian fluids are those fluids which do not obey Newton's law of viscosity and the relation between shear stress and rate of shear strain is non-linear. i. e. the viscosity of non-Newtonian fluid is not constant at a given temperature and pressure but depends on other factors such as the rate of shear in the fluid, the container of the fluid and on the previous history of the fluid. Many important industrial fluids are Non - Newtonian in their flow characteristics. These include paints, coaltar, polymers, lubricants, plastics, printer ink and molecular materials etc.

The non-Newtonian fluids are further classified into three classes.

1. Time dependent non-Newtonian fluids, for which the rate of shear at any point is a function of the shear stress at that point.
2. In some fluids the relationship between shear stress and shear rate depends on the time the fluid has been sheared or on its previous history during its motion. These fluids are known as time dependent non- Newtonian fluids.
3. The third category of fluids contains characteristics of both solids and fluids and exhibit partial elastic recovery after deformation. These are known as viscoelastic fluids.

Analysis



The steady flow of an inviscid incompressible fluid through a circular tube of radius a . P is a point in the fluid having cylindrical polar coordinates (R, θ, z) , referred to the origin O on the axis of the tube which is taken as the z -axis. We assume there are no body forces. Then continuity considerations applied to an annular-shaped element of radii $R, R+\partial R$ of the fluid indicate that the fluid velocity is of the form

$$q = \omega(R)k \tag{1}$$

Let us take the Navier-Stokes vector equation in the form

$$\frac{\partial q}{\partial t} + (q \cdot \nabla)q = \frac{1}{\rho} \nabla p - \gamma \nabla (\nabla \cdot q) \tag{2}$$

Here we consider $\gamma \nabla (\nabla \cdot q)$ and not $+\gamma \nabla^2 q$. Because the axes are not fixed in space. For the same reason the form given on LHS is more useful than $\frac{\partial q}{\partial t}$. Then we have

$$\frac{\partial q}{\partial t} = 0 \text{ (steady condition)}$$

$$(q \cdot \nabla)q = \omega \frac{\partial}{\partial z} [\omega(R)k] = 0$$

$$\nabla p = \left(\frac{\partial}{\partial R} \hat{R} + \frac{1}{R} \frac{\partial}{\partial \theta} \hat{\theta} + \frac{\partial}{\partial z} \hat{k} \right) \cdot p$$

$$\text{Also } \nabla \cdot q = \frac{1}{R} \begin{vmatrix} \hat{R} & R\hat{\theta} & \hat{k} \\ \frac{\partial}{\partial R} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial z} \\ 0 & 0 & \omega(R) \end{vmatrix} = \omega'(R)\hat{\theta}$$

$$\text{Hence } \nabla \cdot \nabla q = \frac{1}{R} \begin{vmatrix} \hat{R} & R\hat{\theta} & \hat{k} \\ \frac{\partial}{\partial R} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial z} \\ 0 & R\omega'(R) & 0 \end{vmatrix} = \frac{1}{R} \frac{d}{dR} (R\omega')k$$

Thus the equation(2) becomes

$$\left(\frac{\partial p}{\partial R} \hat{R} + \frac{1}{R} \frac{\partial p}{\partial \theta} \hat{\theta} + \frac{\partial p}{\partial z} \hat{k} \right) \frac{1}{\rho} + \frac{\gamma}{R} \frac{dR\omega'}{dR} k = 0$$

$$\frac{\gamma}{R} \frac{dR\omega'}{dR} k = \frac{1}{\rho} \left(\frac{\partial p}{\partial R} \hat{R} + \frac{1}{R} \frac{\partial p}{\partial \theta} \hat{\theta} + \frac{\partial p}{\partial z} \hat{k} \right)$$

Equating the coefficients of the unit vectors gives

$$\frac{1}{\rho} \frac{\partial p}{\partial R} = 0 = \frac{1}{R} \frac{\partial p}{\partial \theta} \text{ since } \rho \text{ and } R \neq 0 \tag{3}$$

$$\frac{1}{\rho} \frac{\partial p}{\partial z} = \frac{\gamma}{R} \frac{dR\omega'}{dR}$$

$$\frac{\partial p}{\partial z} = \frac{\rho \gamma}{R} \frac{dR\omega'}{dR} \tag{4}$$

$$\frac{\partial p}{\partial z} = \frac{\mu}{R} \frac{dR\omega'}{dR} \text{ here } \mu = \rho \gamma$$

Equation (3) shows that $p = p(z)$, so that (4) becomes

$$\frac{\partial p(z)}{\partial z} = \frac{\mu}{R} \frac{dR\omega'}{dR} \tag{5}$$

The LHS of (5) is a function of z only; the RHS is a function of R only. Hence each is constant. As flow is supposed to occur in the +direction, we suppose $\frac{\partial p}{\partial z} < 0$. Take each side of (5) to be $-P$, where P is a positive constant.

$$\text{Then } \frac{dR\omega'}{dR} = \frac{PR}{\mu} \tag{6}$$

$$\text{Integrating (6) we get } \omega(R) = B + A \log R - \frac{1}{4} (PR^2/\mu) \tag{7}$$

Now ω is finite on $R = 0$. Thus we require $A = 0$. Also on $R = a, \omega = 0$ since there is no slip. Then $B = \frac{1}{4} (PR^2/\mu)$.

$$\text{Hence } \omega(R) = \frac{1}{4} \left(\frac{P}{\mu} \right) (a^2 - R^2) \tag{8}$$

The form (8) shows that the velocity profile is parabolic. That is, the plot of ω against R from $R = 0$ to a is of parabolic shape. The volume of fluid discharged over any section per unit time is

$$Q = \int_0^a \omega(R) 2\pi R dR$$

$$Q = \frac{\pi P a^4}{8\mu}$$

Here the flux is proportional to the pressure gradient and to the fourth power of the radius of the tube. where μ is the coefficient of viscosity.

CONCLUSION

Blood viscosity is the thickness and stickiness of blood. It is a direct measure of the ability of blood to flow through the vessels. Importantly, high blood viscosity is easily modifiable with safe lifestyle-based interventions. Increased blood viscosity is the only biological parameter that has been linked with all of the other major cardiovascular risk factors, including high blood pressure. In this method we can calculate the coefficient of viscosity using vectorial and integral calculus method. Normal adult blood viscosity is 40/100 in units of millipoise.

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