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Effect of Viscosity in Biomechanics for the Fluid: A Review

Vinod Kumar Bais[1], Ankur Kulshreshtha[2]
[1]Manav Bharti Universty, Solan, HP, India
[2]GEC, Banswara, Rajasthan, India
Corresponding Author: Ankur_kulshreshtha@yahoo.in

Abstract: The viscosity of a liquid is the correlation of shear stress and velocity gradient. It is the quantity of force need to obtain that substance moving in circular tube. Mathematical techniques are used to find various types of viscosity for fluid and obtain the result with the numerical example to discuss the feature for multiple applications in biomechanics.

Key Terms: Shear stress, Mathematical Model, Fluid Dynamics, Viscosity.

Introduction:

Biomechanics focuses on the application of mechanics in the field of living organism for human development. The biomechanics of human beings is a main part of kinesiology. In this regard, construction of mathematical model to solve the problems of the biomechanics of the human skeleton and its various body parts and other biomaterials like artificial blood vessel and so on. The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress. It is the force per unit area, therefore the viscosity is equal to force divided by the area. In medical field, the viscosity is a direct measurement of the blood to flow through the blood vessels. Also, the study the stress, we focus on the length and diameter of the vessels.Bessonov N. et. al. 2016 discussed methods of blood flow modeling that blood assumed as a heterogeneous fluid and analysis rheology and non-Newtonian properties. The constructive model for incompressible viscous fluids based on the assumption that the extra stress tensor is proportional to the symmetric part of the velocity gradient, $\tau = 2\mu D$. Where μ is the viscosity and $D = \nabla u + \nabla u^T/2$ is the rate of the deformation tensor. Also, analyze an equilibrium stage of blood vessel and internal blood pressure by the Newton method. Alexander R. McN. Has worked on modeling approaches in biomechanics in 2003. In this work, conceptual models, physical models and mathematical models has been provided for the study of folding mechanism of insect wings and study the pattern and behavior of the wings and leg muscles. Boda M.A.et. al. 2015 has provided the analysis of kinematic viscosity for high and low sticky liquids at different level of temperature. Nithiarasu P. published his book "Biofluid Dynamics", in which there are sufficient theoretically information about the biofluids and many other solving techniques to find Stress and strain and other terms. Kim B. H. et. al 2013 has worked on effect of the fluid viscosity on the liquid- feeding flow phenomena of a female mosquito. The study is focused on the feeding mechanism and viscosity of the fluids in food canal. Sanjeev Kumar et. al. 2009 discussed the effect of porous parameter for the blood flow in a time dependent stenotic artery and to find the stress and pressure on wall, used the Navier-Stokes and the continuity equations.

1. Mathematical Models:

Model 1: Kinematic Viscosity

It is the measure of the inherent resistance of a fluid to flow when no external force is exerted, except gravity. Mathematically, it can be calculated by dividing the absolute viscosity of a liquid with the liquid mass density. It is denoted by ν and defined as

$$\nu = \frac{\eta}{\rho}$$

Where $\nu = Kinematic\ Viscosity \eta = Dynamics\ Viscosity$ and $\rho = Fluid\ Density.$

For example: Obtain the kinematic viscosity, for a liter of mercury with weight 1.95 Kg.

Solution: Here, first find the density mass of mercury.

Density of mercury

$$(\rho) = \frac{Mass}{Volume} = \frac{1.95\ Kg}{1\ L} = \frac{1.95Kg}{0.001m^3} = 1950\frac{Kg}{m^3}$$

Since the dynamic viscosity of the mercury (η) = 1.526 Pa*s.

Now the kinematic viscosity is calculated by the formula:

$$\nu = \frac{\eta}{\rho}$$

$$\nu = \frac{\eta}{\rho} = \frac{1.526\ \mathrm{Pa} * \mathrm{s}}{1950\frac{Kg}{m^3}} = \frac{1.526\ \mathrm{N} * \mathrm{s}/m^2}{1950\frac{Kg}{m^3}}$$
$$= 0.00078256\ m^2/s$$

Model 2: Dynamic Viscosity with Tangential Force

It is the tangential force required to move one horizontal plane of a fluid with respect to another plane. It is denoted by η and defined as

$$\eta = \frac{\tau}{\gamma}$$

Where $\eta = Dynamics\ Viscosity$, $\tau = Shearing\ Stress$ and $\gamma = Shear\ Rate.$

For example: Calculate the pressure necessary to move a system of liquid with a shear rate of 0.33 per second and the value of dynamics viscosity is 0.019 Pa*s.

Solution: To find the pressure (stress), use dynamics viscosity formula

$\eta = \frac{\tau}{\gamma} => \tau = \eta * \gamma$……….(1)

Where $\gamma = 0.33\ per\ second\ and\ \eta = 0.019\ Pa * s.$ Then from equation (1) we get

$$\tau = \eta * \gamma = (0.019\ Pa * s) * (0.33\ per\ second)$$
$$\tau = 0.00627\ Pa = 0.00627\ N/m^2$$

Model 3:Viscosity, Shear Stress and Shear Rate

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- Fluid mechanics of polymers are modeled as steady flow in shear flow.
- Shear flow can be measured with pressures in the fluid and a resulting shear stress.
- Shear flow is defined as flow caused by tangential movement. This imparts a shear stress on the fluid.
- Shear rate is a ratio of velocity and distance and has units per second. It is defined as
- $\dot{\gamma} = \frac{v}{h}\left(\frac{m}{s}.m\right) = \frac{v}{h}\left(\frac{1}{s}\right) = \frac{v}{h}\ (s^{-1})$
- Where h is the distance between two layer of tube and v is the velocity of upper layer.
- Shear stress is proportional to shear rate with a viscosity constant or viscosity function.
- Shear Stress is defined as $\tau = \frac{F}{A}(N/m^2)$
- Where F is force applied on the area (A) of the tube.

2. Result and Conclusion:

Biomechanics is used to explanations of the mechanical behavior of living organisms. Also, there is an important to understand the basic relationship between stress and strain. It has many mathematical techniques to construct the model for the study of mechanical behavior like pressure and stress of vessel of human body as shown in the figure.

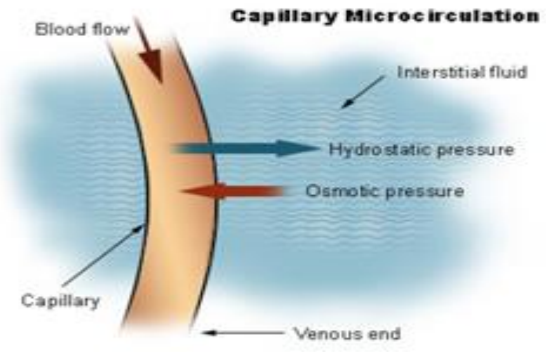

Figure1: Human body system

Source: Book Bio fluid Dynamics

Biomechanics has advantage of engineering principles and requires understanding of mathematical modeling, mechanics and biology. We have discussed some model with numerical examples to find various factors as shear stress, shear rate, and viscosity.It has play an important role in the field of medical sciences specially in orthopedics and obtains a good joint implication, it is also optimizing the different shape of implants so they may better resist extreme a long time mechanical demands in medical field. In this field shear stress, shear rate, viscosity is the important tools for designing the new shapes of various fluid tube and various parts of skeleton and so on and provide a new way to researchers, mechanical manufactures and software designer to develop existing and new shapes.

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