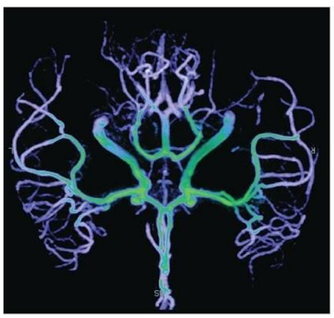
Mobile In-Vitro Neurovascular Cast System (C3 ATI-Neuro)

Individual Analytical Analyses

Individual Analysis performed by Naser Alosaimi

Calculating Pressure Drop for a Non-Newtonian Fluid

Due Date: October 20, 2017



Mobile In-Vitro Neurovascular Cast System

NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry, and Natural Sciences

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Introduction

This individual assignment focuses on the calculations related to the pressure drop of a non-Newtonian fluids and Blood in the human body is considered a non-Newtonian fluid. Furthermore, the definition of a non-Newtonian fluid is that the shear viscosity is not constant at any given temperature and pressure but it is a variable [1]. This assignment discusses the measures and calculations to solve for the viscosity of non-Newtonian fluids using the power law equation. And the specific contemporary issue here is that we need to calculate the pressure drop of blood which is a non-Newtonian fluid which means we need to discard some of the assumptions of the Newtonian fluids. Furthermore, in order to solve this issue, we need to use the power law equation with assumptions made along with it to continue with solving for the variables and in the end, solve for the pressure drop and solve for the Reynolds number to see if the fluid is turbulent or laminar.

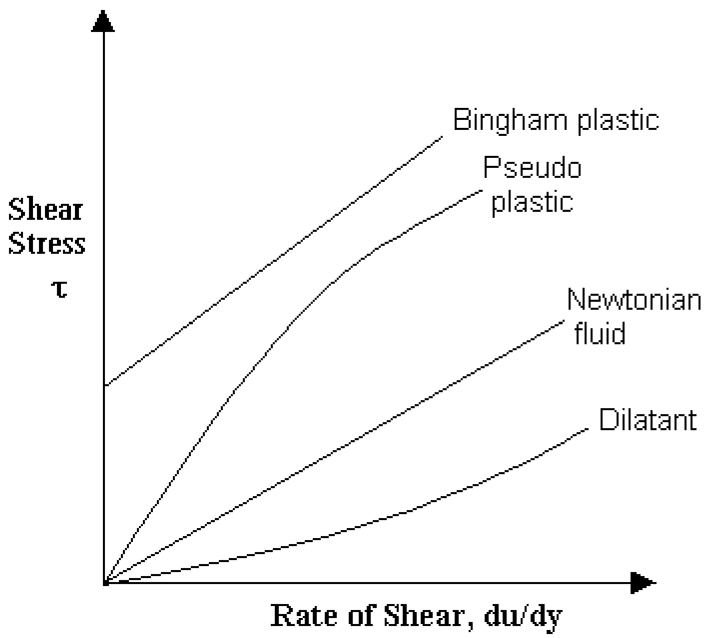

Figure 1 – Shear stress vs shear rate graph displaying Newtonian fluid and Non-Newtonian fluid (Pseudo plastic) [2]

Assumptions and Calculations

In order to solve for the change in pressure, we need to first assume that the non-Newtonian fluid is treaded as a Newtonian fluid which we will assume steady state in order to use the figures below. In addition, we will assume that the density of the artificial blood used here is the same as the density of the water since both densities are close to each other [3]. Then we need to solve for multiple variables first using multiple equations starting with the power law equation which is used to solve for the shear stress. The power law equation for a non-Newtonian fluid is as follows

$$\tau = \mathrm{m} * (\frac{du}{dy})^{n} \qquad (1)$$

where τ is the shear stress in pascals (Pa), $\frac{du}{dy}$ is the shear rate in s^{-1}, n is flow consistency index in s^{-1}, and m is the flow behavior index in s^{-1} and it is given [4], [5]. With this equation we need to solve for the shear stress using the other variables in the equation. To explain, the shear stress for a non-Newtonian fluid is different depending on the shear rate and the minimum shear rate is given as 1.4901*10^{-8} (s^{-1}) [3] and the flow consistency index can be solved using figure 2 and the following equation

$$\frac{du}{dy} = \frac{8*V}{D} \quad (2)$$

Where V is the velocity of the blood flow in m/s which is assumed to be approximately 150 cm/s based on knowledge and D is the diameter of the blood vessel in (cm).

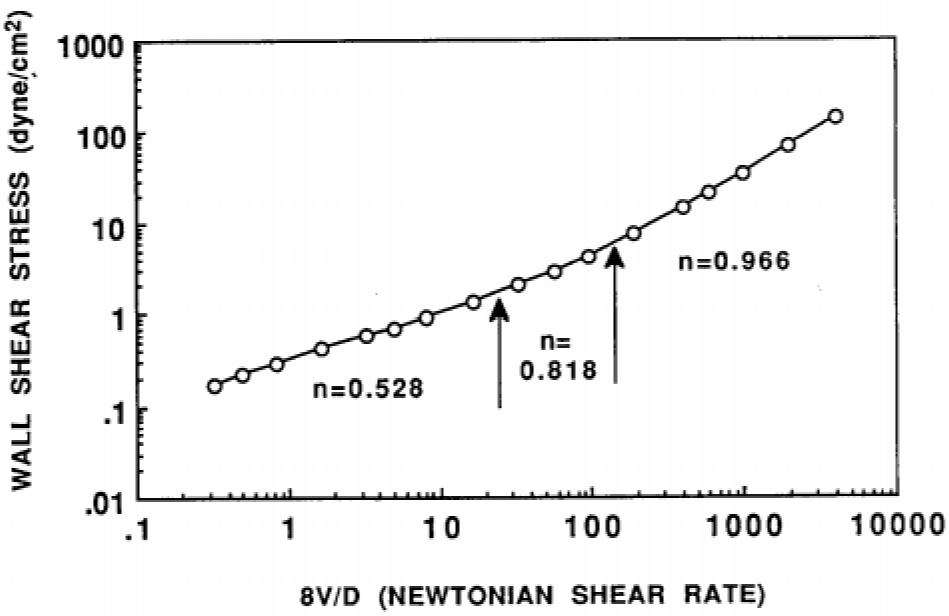

Figure 2 – Newtonian shear rate vs wall shear stress which is used to solve for n [5]

With this information we can solve the apparent viscosity of the blood μ in (cmPa*s) by using the curve figure below which is figure 3 and we notice by the figure that as the apparent viscosity increases, the shear stress will decrease.

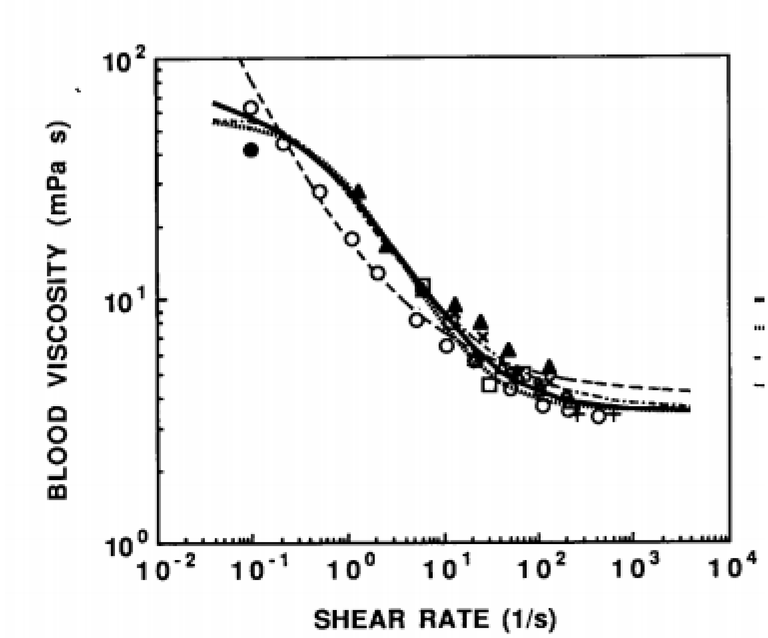

Figure 3 – Shear rate vs Blood viscosity [5]

Now to calculate the Reynolds number in order to determine if the flow is turbulent or laminar and based on the calculations used by excel available in the appendix, the flow is turbulent and the equation used is

$$Re = \frac{p*V*D}{\mu} \tag{3}$$

Where p is the density of the water in ($\frac{k}{m^3}$), V is the velocity of the blood flow (m/s), μ is the viscosity of blood in (mPa * s)

We can also solve for the change in pressure (Pa) using the following equation

$$\Delta P = \frac{L}{D} * \frac{du}{dy} \tag{4}$$

Where L is the length of the blood vessel's length in (cm) and D is the diameter of the blood vessel in (cm). Every numerical calculation is available in the excel sheet in the appendix below. And with the results we can calculate the pressure drop of the blood in the Circle of Willis which is considered one of our design issue for the project.

Conclusion

In conclusion, this assignment has discussed the calculations related to the pressure drop of a non-Newtonian fluid and discussed the contemporary issue of this assignment which is finding calculations for the pressure drop of blood in the Circle of Willis. In addition, this assignment discussed the assumptions related to the calculations starting with assuming that non-Newtonian fluid is a Newtonian fluid which means we can assume steady state in order to find the Reynolds number and the pressure drop. Furthermore, calculations have been conducted using the equations and figures mentioned above and in the end we were able to achieve results for the pressure drop and the Reynold number which is the goal of this assignment.

References

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[3] Bartholmem, W Gonzalez, C, Goodrich, K, Holter, A, Merritt, W, Swartz, A. (2017). *In-vitro Tube Model System*. [online] Available at: https://www.cefns.nau.edu/capstone/projects/ME/2017/BDLInvitroTubeModel/documentation/Final%20Report%20Team%2023%20In%20vitro.pdf [Accessed 21 Oct. 2017].

[4] Cheguide.com. (2017). *Power Law Fluid – ChE Guide*. [online] Available at: https://cheguide.com/2015/08/power-law-fluid/ [Accessed 21 Oct. 2017].

[5] Cho, Y. Kensey, K. (2017). "*EFFECTS OF THE NON-NEWTONIAN VISCOSITY OF BLOOD ON FLOWS IN A DISEASED ARTERIAL VESSEL. PART 1; STEADY FLOWS,"*. 28; 241 -262, 1991.

Appendix A: Excel Sheet with Calculations

Individual Analysis

	L (cm)	1.37	given
	D(cm)	0.49	given
	Re	7277.227723	Calculated
	ΔP (Pa)	4.1662E-08	Calculated
	m (1/s)	0.8	Assumed
	n (1/s)	0.966	(Retrieved from figure 2)
	$\frac{du}{dy}$ (1/s)	1.4901E-08	given
τ	(N/cm^2)	98	(Retrieved from figure 2)
	V (cm/s)	150	given
density (kg/m^3)		1000	given
	8V/D	2448.979592	Calculated
μ (cmPa *s)		10.1	(retrieved from figure 3)

Re = (p*V*D)/μ
ΔP=(L/D)*(du/dy)