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STUDIES ON ELASTIC AND ACOUSTIC PARAMETERS OF HUMAN BLOOD AND ITS PLASMA

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ABSTRACT

Blood is a wonderful and complex substance which contains many chemical compounds to perform various functions. For describing the dynamics of blood flow, the viscoelastic parameters such as viscosity and elasticity, should be obtained from the measurements under oscillatory shear flow.

Viscoelastic materials have interesting properties. They exhibit both viscous behaviour as well as elasticity. When a constant displacement is applied, the stresses of a viscoelastic material gradually relax over time because of these properties. Conversely, under a constant applied force, elastic strains continue to accumulate, deforming further more. Because of this complex behaviour, the use of linear material properties is generally inadequate in accurately determining the final shape of viscoelastic material, the time taken to arrive at that geometry, and the stresses on the part. In these cases, the material’s viscoelasticity must be taken into account in the simulation.

This paper presents the data on elastic and acoustic parameters of human blood and its plasma by using the ultrasonic interferometer. The ultrasonic interferometer with multiple frequencies is used to find out the ultrasonic velocity of blood. By knowing the density of blood, elastic constant and acoustic parameters like coefficient of absorption, modulus of elasticity and loss modulus are determined for different frequencies.

Key Words: Elastic Constant, coefficient of absorption, modulus of elasticity and loss modulus

1. INTRODUCTION

Human blood is a highly Complex substance. It is thicker than water and has a little bit salty in taste. It is a mixture of cells and watery liquid, called plasma. It also contains other things like nutrients (such as sugar), hormones, clotting agents, and waste products to be flushed out of the body. These blood elements are suspended in blood plasma, which is a yellowish liquid that comprises about 55% of human blood.

It is seen from a biological point of view that blood can be considered as a tissue comprising various types of cells (i.e., RBCs, WBCs, and platelets) and a liquid intercellular material(i.e., plasma). But from a rheological point of view, blood can be thought of as a two-phase liquid; it can also be considered as a solid-liquid suspension, with the cellular elements being the solid phase. However, blood can also be considered as a liquid - liquid emulsion based on the liquid - like behaviour of RBCs under shear.

Blood can also be considered from a hemorheological point of view as (1) Newtonian fluid, (2) Non-Newtonian fluid, (3) Micro polar fluid and (4) viscoelastic fluid, based on the molecular composition, cellular constituents and diameter of tube (blood vessel) in which it is flowing. In view of this, several mathematical models have been developed; instruments are designed; experiments are setup. Though there are different schools of thought, but, still it is a moot point to assign a definite type of hemorheological behaviour of blood, belonging to different physiological and environmental conditions.

Keeping this in view, an attempt has been made to examine the rheological behaviour of blood as viscoelastic by determining dynamic modulus of elasticity and loss modulus of human blood and its plasma, by measuring velocity and absorption of ultrasound at different frequencies.

2. MATERIALS AND METHODS

In the present investigation an ultrasonic interferometer with multiple frequencies, ie.1MHz, 2MHz, 3MHz, 5MHz and 10MHz were used to measure the ultrasonic velocity of blood. For this study the quantity of sample required is about 10ml. By using the anticoagulant, EDTA, 5 samples of fresh human blood is collected. The samples are stored at low temperatures until use. Plasma was separated from blood by centrifuging the blood at the rate of 1500 rmp about 10 to 15 minutes. The elastic and acoustic properties are studied.

3. DESCRIPTION OF ULTRASONIC INTERFEROMETER

The Ultrasonic Interferometer consists of two parts:

(i) The High Frequency Generator
(ii) The Measuring Cell (Least Count: 0.01 mm).

An ultrasonic interferometer is a simple and direct device with high degree of accuracy. The principle used in the measurement of velocity (v) is based on the accurate determination of the wavelength in the medium. Knowing the wavelength, the velocity (v) can be obtained by the relation:

Velocity =Wavelength x frequency

4. EXPERIMENTAL PROCEDURE

Before starting the experiment the blood samples are standardized with water, since water is Newtonian liquid. For different frequencies ultrasonic velocity and elastic parameters are determined. As discussed above the ultrasonic interferometer consists of multiple frequencies, 1MHz, 2MHz, 3MHz, 5MHz, and 10MHz.All the adjustments are made to the ultrasonic Interferometer. The cell is inserted in the square base socket and the sample blood is poured middle portion of it. The cell is connected to the High frequency Generator by co-axial cable. When the micrometer is moved up and down in liquid the number of maximum deflections in the meter is noted down.

The micrometer is slowly moved till the anode current on the meter on the High Frequency Generator shows a maximum. The anode current and the micrometer readings are noted for different frequencies, viz 1MHz, 2MHz, 3MHz, 5MHz. and 10MHz. The Least count of the micrometer (L.*C*) is 0.0001cm. For different frequencies Ultrasonic velocity is determined. By determining the density of the blood, the elastic constant or bulk modulus (K),$K= V^2 \rho$; and the absorption coefficient (α), $\alpha=\ln (I_2/I_1)/2x$ are determined.

5. RESULT AND DISCUSSION

The average values of elastic and acoustic parameters blood at different frequencies and the same parameters of plasma of human blood, and the Average values of Ultrasonic Acoustic and Elastic Parameters of plasma of normal blood at different frequencies are presented in table 1, table 2 and table 3 respectively. The ultrasonic velocity is determined for water for different frequency ranges of 1MHz, 2MHz, 3MHz, 5MHz and 10 MHz There is no variation in the case of water for ultrasonic velocity. but there is a significant variation is observed in the case of, absorption coefficient, modulus of elasticity and loss modulus of human blood and its plasma as shown in Fig(1), Fig(2), Fig(3),Fig(4), Fig(5) and Fig(6)respectively.

Table1: The values of Acoustic and elastic parameters of Water

Sample Code	Frequency, υ (MHz)	Ultra sonic Velocity m/sec	Absorption co-efficient, α (cm^{-1})	Modulus of Elasticity($\times 10^{11}$) dyne/cm2	Loss modulus, ($\times 10^8$) dyne/cm2
W1	1	1457	0.016	0.217	0.158
	2	1463	0.015	0.219	0.077
	3	1470	0.014	0.221	0.048
	5	1477	0.013	0.223	0.0271
	10	1483	0.012	0.224	0.0127

Table 2: The Average values of Ultrasonic Acoustic and Elastic Parameters of normal blood at different frequencies.

Sample Code	Frequency, υ (MHz)	Wave length	Ultra sonic Velocity m/s	Absorption co-efficient, α (cm^{-1})	Modulus of Elasticity, M^1 ($\times 10^{11 dyne/cm2}$)	Loss Modulus, M^{11} ($\times 10^8$ cm^2/dyne)
HB	1	0.1522	1555	0.029	0.2542	0.36
	2	0.0820	1634	0.025	0.2834	0.1845
	3	0.0549	1667	0.022	0.2952	0.1133
	5	0.0347	1770	0.020	0.3328	0.0731
	10	0.0188	1868	0.017	0.3704	0.0367

Table 3: The Average values of Ultrasonic Acoustic and Elastic Parameters of plasma of normal blood at different frequencies.

Sample Code	Frequency, υ (MHz)	Wave length	Ultra sonic Velocity m/s	Absorption coefficient, α (cm^{-1})	Modulus of Elasticity, M^1 ($\times 10^{11 dyne/cm2}$)	Loss Modulus, M^{11} ($\times 10^8$ cm2/dyne)
HP	1	0.1516	1510	0.026	0.2336	0.293
	2	0.0774	1561	0.021	0.2498	0.129
	3	0.0522	1597	0.019	0.2614	0.0825
	5	0.0324	1632	0.017	0.273	0.0469

HB: Human Blood
HP: Plasma of human Blood

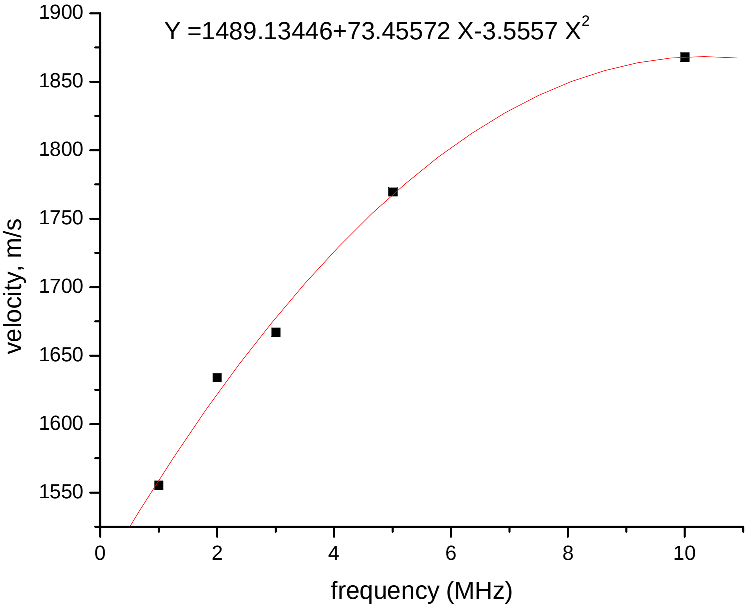

fig. 4.4.2

Fig1: A plot between frequency on X-axis and Velocity on Y-axis for Human Blood .

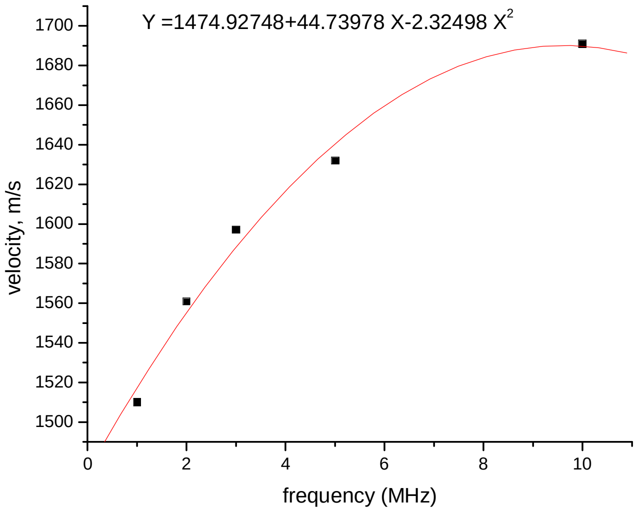

fig. 4.4.3

Fig2: A plot between frequency on X-axis and Velocity on Y-axis for Plasma of human blood

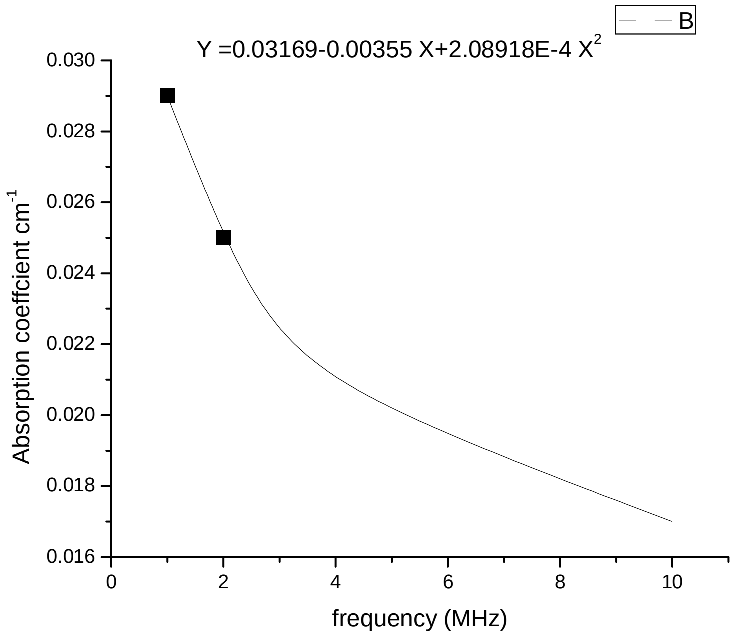

fig. 4.5.2

Fig 3: A plot between Frequency on X-axis and Absorption coefficient on Y-axis for human blood

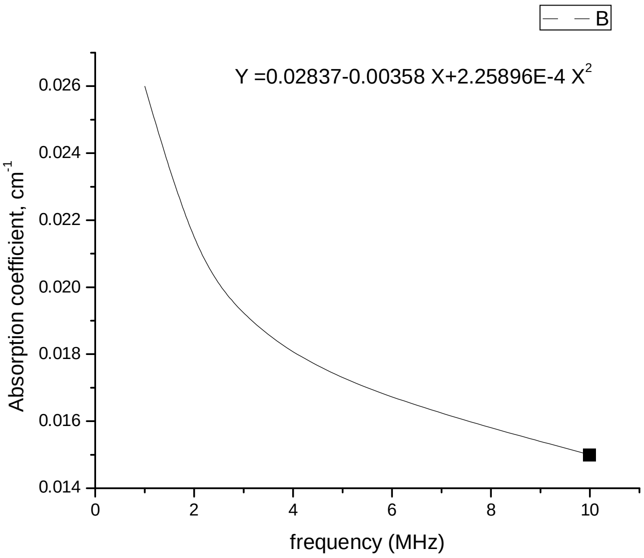

fig. 4.5.3

Fig 4: A plot between Frequency on X-axis and Absorption coefficient on Y-axis for plasma of human blood.

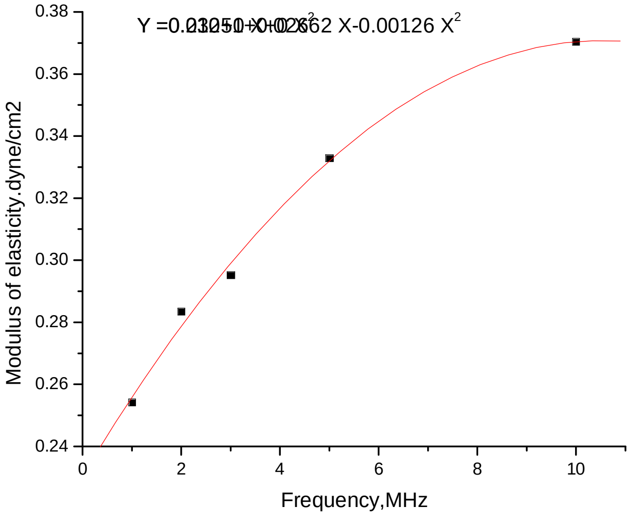

Fig: 4.7.1

Fig 5: A plot between frequency on x axis and modulus of elasticity on y-axis for Normal human blood

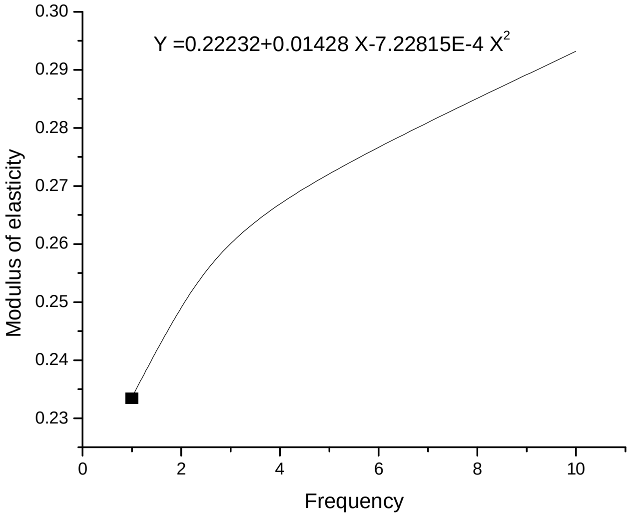

Fig: 4.7.2

Fig 6: A plot between frequency on X-axis and Modulus of elasticity on Y-axis for plasma of human blood.

6. CONCLUSION

For Newtonian liquids like water, the velocity is independent fordifferent frequencies and thus the velocity is almost constant for water.But from the present study observations are made that for viscoelastic or **Non-Newtonian** fluids like blood, there is a significant change in the values. The velocity increases with the increase of frequency. The coefficient of absorption decreases with the increase of frequency. The modulus of elasticity increases with the increase of frequency and the loss modulus decreases. Hence the blood, as a rule, can be considered as viscoelastic, when modulus of elasticity increases and loss modulus decreases with increase of frequency of ultrasound.

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