IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

Mathematical Analysis On Two layer Human Blood flow in Capillaries With Effect Iron –Deficiency Anemia in Adolescence Female .

[1] Lakshmi Devi , [2] V. Upadhyay , [3]S.K. Chaturvedi
[1] Research Scholar, [2]Associate Professor, [3]Professor
Department of Physical Sciences MGCGV Chitrakoot , Satna ,MP , India
Department of Physical Sciences MGCGV Chitrakoot , Satna , MP, India
Department of Biological Sciences MGCGV Chitrakoot ,Satna, MP India

Abstract- In this paper the mathematical analysis of two phase blood flow in capillary is disease iron deficiency Anemia .There are two phase in the capillary one is plasma (Newtonian) and other is RBCs (Non- Newtonian . By the Fahreaus –Lindqvist influence the blood flow of two single layers as from fleeting side to side capillaries .

Key words – Two layer human blood flow , blood pressure , Hematocrit , Iron deficiency Anemia.

1):- Introduction-

Blood flow in arteries , arterioles , capillaries are read in hemodynamic[5] .The circulatory system in the human body is divided into two parts pulmonary and systemic circulation .we observe both two phase one is plasma and second phase is red blood cells . Circulatory system deals with all the course of blood in the system[16].

Capillaries are small normally around 3-4 µm, but some capillaries can be 30-40 µm in diameter . The largest capillaries are found in the liver . Capillaries connected arterioles to venules. They allow the exchange of nutrients and waste between the blood and the tissue cells together with the interstitial fluid.

The Fahreaus –Lindqvist influence the blood flow of two single layers as from fleeting side to side capillaries That blood flow possible through capillary those they are for enough from pumping station that is heart. Core layer supposed to be Non- Newtonian pawer low because here the ratio of blood cells is to high in the comparison to plasma (Upadhay V ,2000).(I)Fahraeus effect , which is the heatocrit dependence on the vessels diameter.

Various rheological model of Non -Newtonian fluids are used in small blood vessels. Blood vessels are often defined by combined two layer model [6].

Anemia is defined as a low number of red blood cells . In a routine blood test , Anemia is report as a low haemoglobin or haematocrit .women are at risk of iron deficiency Anemia because of blood loss from there periods and pregnancy .IDA happens because your diet have enough of the mineral iron in your body . Your bone marrow needs iron to make hemoglobin . The part of the RBc that takes oxygen to organs (medically revied by sabrina felson , MD on August 11, 2000). IDA is the third greatest global health risk After obesity as unsafe sex [1].In spite of increased iron needs many adolescence women / girl have iron intake of only 10-11 mg/ day[2].

2):- Blood and its Composition –

Blood is composed of plasma and formed elements . The plasma contains water 91.5, and Proteins 7% and other 1.5% . Blood is a fluid connective tissue composed of 55% plasma and 45% WBCs, RBCs and platelets . science these living cells are suspended in plasma ,blood is known as a fluid connective tissue and not fluid [3].

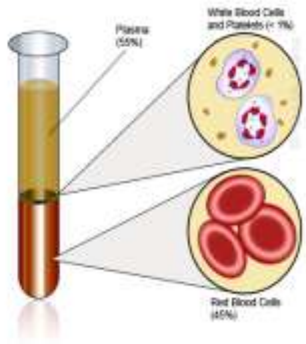


figure (1)

3):- Mathematical model –

1) Equation of continuity - The continuity equation of two phases – one is plasma and second is core (cells)layer are equally distributed , then the blood may be treated as a homogeneous mixture .

   $v,_{j}^{i} = 0$ …………………..(1)

2) The equation of power low model in two phase Non- Newtonian blood flow –

   $\tau=\eta e^{n}$ is Constitution Equation of Fluids

   If n≠ 1 = $Then\ the\ Nature\ of\ fluids\ is\ Non-Newtonian$. Where η is viscosity coefficient . The constitutions equation is called Non- Newtonian Power Low model . The strain rate is whole body between 5and 200 sec-1.[7]

Where 0.68≤ $n \le 0.80$ blood flow (Upadhyay et al., 2012 & Kumar etal., 2017).
η_c= Viscosity Coefficient of blood cells.
η_m = Viscosity Coefficient of Mixture of two plasma .
η_p = Viscosity of Coefficient Plasma .
ΔP= Pressure gradients.
ΔZ = Length of capillaries .
R = Radius of capillaries .
Q = flow flux.

4):-Boundary Condition –

1) The Velocity of blood flow on the axis of blood vessel at r=0 will be Maximum and finite . Say v_0 = Maximum Velocity .
2) The Velocity of blood flow on the blood vessel at r=R when R is the radius of blood vessel. This condition is Known as no Slip.

5):- Mathematical Formation –

Power low is the simplest model that approximates the behaviour of a Non -Newtonian Fluid. Blood is liquid form ,whenever Haematocrit (H) increase .The effective viscosity of blood flowing in the arteries remote proximate heart depends upon the strain rate .the blood flow become Non -Newtonian . in this model the study of RBCs becomes high .

Model of blood flow in capillaries –

Let The viscosity of core layer η_m and the viscosity of plasma layer η_p is give by . where η_c is the viscosity of blood cells phase and X is the portion of blood cells in unit volume .

η_m = Xη_c + (1-X) η_p *(2)*

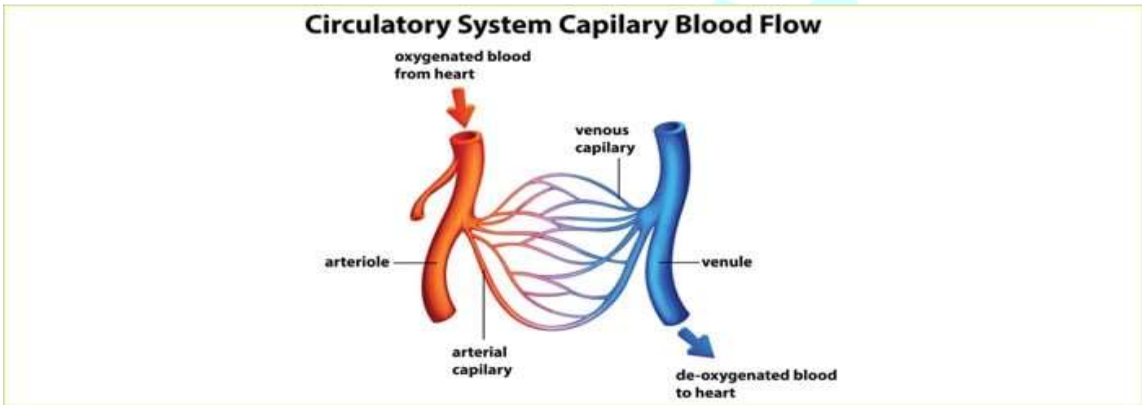


Figure (1)

Where τ^{ij} =stress tensor

τ'^{ij} =shearing stress tensor .

The relative velocity of core layer with plasma layer .

Numerical analysis of model for human capillaries and Blood flow in two layer .

Equation of continuity –

The equation of continuity in tensorial form for Power law will be as follows[19] -

$$\frac{1}{\sqrt{g(\sqrt{g v^i})_{,i}}} = 0 \qquad (3)$$

Equation of Motion -

Again the equation of motion is extended as follows [20]-

$$\rho_m \frac{\partial v^i}{\partial_t} + (\rho_m v^j) v,^i_j = \tau^{ij}_{,j} \qquad (4)$$

Where T^{ij} is power law constitutive equation of power law model(2) . the density of blood ρ_m= Xρ_c+(1-X)ρ_p (5)

η_m = Xη_c + (1-X) η_p is the viscosity of mixture of blood .

X= $\frac{H}{100}$ is volume ratio of blood cells .

H = is Haematocrit .
where are the symbols have their usual meanings .
The above formula is repeated until a sufficiently precise value is obtained .
The blood vessels are cylindrical; the above equation have to be transformed into cylindrical Co- Ordinate . As we know earlier.
$X^1 = r, X^2 = \theta, X^3 = z$ be cylindrical Co- ordinates.
$[g_{ij}]$ be matrix of matrix tensor and $[g^{ij}]$ matrix of conjugate matrix tensor where $g_{ij} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & r^2 & 0 \\ 0 & 0 & 1 \end{pmatrix}$ $g^{ij} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & \frac{1}{r^2} & 0 \\ 0 & 0 & 1 \end{pmatrix}$

Metric elements g_{11}=1 g_{22}= r^2, g_{33}=1
Or g_{11}= 1, $g_{22} = \frac{1}{r^2}$, g_{33}=1
Christoffel's symbols of second kind for cylindrical co-ordinate(18).

$$\begin{Bmatrix} 1 \\ 2 \ \ 2 \end{Bmatrix} = -r \quad , \begin{Bmatrix} 2 \\ 2 \ \ 1 \end{Bmatrix} = \begin{Bmatrix} 2 \\ 1 \ \ 2 \end{Bmatrix} = \frac{1}{r}$$ Remaining others are zero.

Physical components

Since $\sqrt{g_{11}} \quad v^1 = v_r \quad or \quad v_r = v^1$
$\sqrt{g_{22}} \quad v^2 = v_\theta \quad or \quad v_\theta = rv^2$
$\sqrt{g_{33}} \quad v^3 = v_z \quad or \quad v_z = v^3$

Matrix of physical components of shearing stress tensor
Again the physical components of $-P_{,j}g^{ij}$ is $-\sqrt{g_{ij}}\ P_{,j}g^{ij}$
Matrix of physical components of shearing stress tensor

$\tau'^{ij} = \eta_m (e^{ij})^n$

$= \eta_m\ (g^{ik}v^i_{,k} + g^{jk}v^j_{,k})^n$

$$\tau'^{ij} = \begin{bmatrix} 0 & 0 & \eta_m(\frac{dv}{dr})^n \\ 0 & 0 & 0 \\ \eta_m(\frac{dv}{dr})^n & 0 & 0 \end{bmatrix} \quad (7)$$

$\tau'^{ij}_{,j}$ = is the covariant derivation

$$\tau'^{ij}_{,j} = \frac{1}{\sqrt{g}} \frac{\partial}{\partial x^j} (\sqrt{g} T^{ij}) + \begin{Bmatrix} i \\ jk \end{Bmatrix} \tau'^{kj} \quad (8)$$

The governing tensorial equation can be transformed into cylindrical

The equation of continuity : $\frac{\partial v}{\partial z} = 0$ (9)

The equation of motion :

r- component : $-\frac{\partial p}{\partial z} = 0$ (10)

θ – components : 0 = 0 (11)

z- components : $-\frac{\partial p}{\partial z} + \frac{\eta_m}{r}\frac{\partial}{\partial r}[r\{\frac{\partial v_z}{\partial r}\}^n] = 0$ (12)

Here , this fact has been taken in view that the blood flow is axially symmetric in capillaries concerned , V_θ=0 and V_r = 0 , V_z and p do not depend upon θ.

$\frac{\partial p}{\partial t} = \frac{\partial v_r}{\partial t} = \frac{\partial v_\theta}{\partial t} = \frac{\partial v_z}{\partial t} = 0$

6):-Solution –

Integration equation (9) we get

$v_z = v_r$ because v does not depend upon θ (13)

The integration of equation of motion (10) yields.

P = p(z), p does not depend upon θ (14)

Now , with the help of equation (13)and (14) , the equation of motion (12) convert in the following form -

$$0 = -\frac{dp}{dz} + \frac{\eta_m}{r}\frac{d}{dr}\left(r\left(\frac{dv}{dr}\right)^n\right) \quad (15)$$

The pressure gradient $-(\frac{dp}{dz})$= P of blood flow in the artery remote heart can be supposed to be constant and hence the equation (15) takes the following form –

$$\frac{d}{dr}\left(r\left(\frac{dv}{dr}\right)^n\right) = -\frac{P_r}{\eta_m} \quad (16)$$

On integration the equation (16) we, get

$$r\left(\frac{dv}{dr}\right)^n = -\frac{Pr^2}{2\eta_m} + A \quad (17)$$

We know that the velocity of blood flow on the axis of cylindrical artery is maximum and constant . so that is we apply the boundary condition at r = 0, v = V_0 (constant), on equation (17) to get the arbitrary constant A= 0 . Hence the equation (17) takes the following form –

$$r\left(\frac{dv}{dr}\right)^n = -\frac{Pr^2}{2\eta_m} = -\frac{dv}{dr} = \left(\frac{P_r}{2\eta_m}\right)^{\frac{1}{n}} \quad (18)$$

Again integration the equation (18) we, get

$$V = -\left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{r^{\frac{1}{n}+1}}{\frac{(n+1)}{n}} + B \quad (19)$$

To determinate the arbitrary constant B , the non- slip condition on the inner wall of the artery at r= R , v= 0 , where R= radius of vessel , on equation (19)

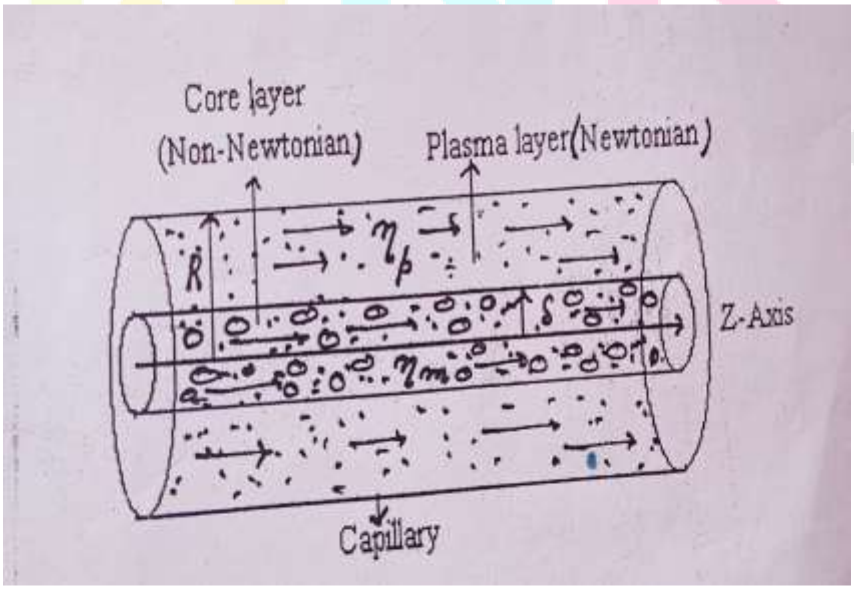
$$B = \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{r^{\frac{1}{n}+1}}{\frac{(n+1)}{n}}$$

Hence the equation (19)takes the following form

$$V = \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{n}{n+1}\left(R^{\frac{1}{n}+1} - r^{\frac{1}{n}+1}\right) \quad (20)$$

Which determines The velocity of the blood flow in the capillary where P is gradient of blood pressure and the velocity of the blood mixture is η_m.

Two layer blood flow one layer is Newtonian while The other is Non- Newtonian power law –



Now the velocity of blood flow can be obtained by interchange η_m and η_p in Newtonian as follows –

$v_p = \frac{P}{4\eta_p}(R^2 - r^2)$; R-$\delta \leq r \leq R$ (21)

Where δ is the radius of core layer .

The velocity of core layer is obtained as the formula of power law model –

$$v_m = \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{n}{n+1}\left(R^{\frac{1}{n}+1} - r^{\frac{1}{n}+1}\right) + \left[\frac{P}{4\eta_p}(R^2 - (R - \delta)^2 - \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{n}{n+1}\left(R^{\frac{1}{n}+1} - (R-\delta)^{\frac{1}{n}+1}\right)\right] \quad (22)$$

$0 \leq r \leq R - \delta$

Where the second term is the relative velocity of plasma layer with respect to core layer

7):- Bio -Physical interpretation –

The flow flax blood in capillaries is –

$$Q = \int_0^{R-\delta} v_m 2\pi r dr + \int_{R-\delta}^{R} v_p 2\pi r dr$$

$$Q = \int_0^{R-\delta}\left[\left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{n}{n+1}\left(R^{\frac{1}{n}+1} - r^{\frac{1}{n}+1}\right) + \left\{\frac{P}{4\eta_p}(R^2 - (R - \delta)^2 - \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{n}{n+1}\left(R^{\frac{1}{n}+1} - (R-\delta)^{\frac{1}{n}+1}\right)\right\}\right] 2\pi r dr + \int_{R-\delta}^{R}\left[\frac{P}{4\eta_p}(R^2 - r^2\right] 2\pi r dr \quad (23)$$

8):-RESULTS-

Table no . 1 Haemoglobin V/S Blood Pressure in clinical data

Date	HB (Haemoglobin) in (gram /dl)	Blood pressure (BP)in (mmhg)	Haematocrit in $(3HB)$ (kg/m³)	Capillary Blood Pressure Drop in Pascal- $\Delta P = \frac{2}{3}\left(\frac{\left(\frac{S+D}{2}+D\right)}{3}\right) - \frac{\left(\frac{S+D}{2}+D\right)}{3}$	Blood Pressure in Pascal Second P=133.32
11/05/22	8.5	110/70	0.02405	-17.22	-2666.45
20/05/22	8.6	110/80	0.024339	-18.89	-1999.84
2/06/22	8.5	100/80	0.02405	-22.22	-1333.22
13/06/22	8.7	120/70	0.024622	-17.78	-3333.06
30/06/22	8.8	120/80	0.024905	--21.11	-2666.45

Let H (Hematocrit)= 0.02405 and capillary blood pressure Drop BPD= 2666.45 pascal second

η_m=0.0271

η_p = 0.0013

Q= 425ml/min = 7.0833 m^3 /second

Z= 19000m (Approximate length of capillary)

R= 0.0965 m (Approximate R radius of capillary)

$\delta = \frac{1}{3} R$(Thickness of RBc layer)

δ = 0.0322 m. and

R- δ = 0.0643 m

$P = \frac{\Delta P}{\Delta Z} = \frac{2666.45}{19000}$ =0.1403 m

Using relation (2) and we find out

$\eta_m = X\eta_c + (1-X)\,\eta_p$

$0.0271 = \eta_c \frac{H}{100} + (1-\frac{H}{100}) \times 0.0013$

$0.0271 = \eta_c \frac{0.02405}{100} + (1-\frac{0.02405}{100}) \times 0.0013$

η_c= 107.27737394 pas

Again ,

Change to hematocrit

$\eta_m = X\eta_c + (1-X)\,\eta_p$

$\eta_m = 1.0727737394H + 0.00129968$

Now putting the values of r_p and R in equation (23)

$$Q = \int_0^{R-\delta} v_m 2\pi r dr + \int_{R-\delta}^{R} v_p 2\pi r dr$$

$$= \int_0^{R-\delta} \left[\left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{n}{n+1} \left(R^{\frac{1}{n}+1} - r^{\frac{1}{n}+1}\right) + \left\{ \frac{P}{4\eta_p} (R^2 - (R - \delta)^2 - \left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}} \frac{n}{n+1} \left(R^{\frac{1}{n}+1} - (R-\delta)^{\frac{1}{n}+1}\right) \right\} \right] 2\pi r dr + \int_{R-\delta}^{R} \left[\frac{P}{4\eta_p} (R^2 - r^2 \right] 2\pi r dr$$

$$= \int_0^{0.0643} \left[\left(\frac{0.1403}{2\times 0.271}\right)^{\frac{1}{n}} \frac{n}{n+1} \left(R^{\frac{1}{n}+1} - r^{\frac{1}{n}+1}\right) + \left\{ \frac{0.1403}{4\times 0.0013} (0.0965)^2 - 0.0643)^2 - \left(\frac{0.1403}{2\times 0.0271}\right)^{\frac{1}{n}} \frac{n}{n+1} \left((0.965)^{\frac{1}{n}+1} - (0.643)^{\frac{1}{n}+1}\right) \right\} \right] 2\pi r dr + \int_{0.0643}^{0.0965} \left[\frac{0.1403}{4\times 0.0013} (0.0965)^2 - r^2 \right] 2\pi r dr$$

$$Q= \left[(0.25)^{\frac{1}{n}} \frac{n}{n+1}\left((0.0965)^{\frac{1}{n}+1}\left[\frac{r^2}{2}\right]_0^{0.0643} - 2\pi\left[\frac{n\, r^{\frac{3n+1}{n}}}{3n+1}\right]_0^{0.0643}\right) + \left\{26.98((0.0965)^2 - (0.0643)^2)\, 2\pi\left[\frac{r^2}{2}\right]_0^{0.0643} - (0.25)^{\frac{1}{n}} \frac{n}{n+1}(0.0965)^{\frac{1}{n}+1} - (0.0643)^{\frac{1}{n}+1} 2\pi\left[\frac{r^2}{2}\right]_0^{0.0643}\right\}\right]$$

$$+26.98\,(0.0965)^2\, 2\pi\left[\frac{r^2}{2}\right]_{0.0643}^{0.0964} - 2\pi\left[\frac{r^4}{4}\right]_{0.0643}^{0.0964}$$

$$Q= \left[(0.25)^{\frac{1}{n}} \frac{n}{n+1}\left((0.0965)^{\frac{1}{n}+1} \times 0.01298 - \frac{n(0.0643)^{\frac{1}{n}}}{3n+1} \times 0.00167\right) + \left\{0.001299 - (0.25)^{\frac{1}{n}} \frac{n}{n+1}((0.0965)^{\frac{1}{n}+1} - (0.0643)^{\frac{1}{n}+1})0.01298\right\}\right]+13.23$$

$$Q= (0.25)^{\frac{1}{n}} \frac{n}{n+1} \times (0.0965)^{\frac{1}{n}+1}[0.01298 - 0.01298] - (0.25)^{\frac{1}{n}} \frac{n}{n+1}\left[\frac{0.00167n\,.0.0643^{\frac{1}{n}}}{3n+1} - 0.01298\right]+13.23$$

$$Q= -(0.25)^{\frac{1}{n}} \frac{n}{n+1}(0.0643)^{\frac{1}{n}}\left[\frac{0.00167n\,.}{3n+1} - 0.01298\right]+13.23$$

$$Q= -(0.01607)^{\frac{1}{n}} \frac{n}{n+1}\left[\frac{0.00167n\,.}{3n+1} - 0.01298\right]+13.23$$

Putting Q value

Q=7.0833m^3 /s

$$7.0833- 13.23 = -(0.01607)^{\frac{1}{n}} \frac{n}{n+1}\left[\frac{0.00167n\,.}{3n+1} - 0.01298\right]$$

$$- 6.1467 = -(0.01607)^{\frac{1}{n}} \frac{n}{n+1}\left[\frac{0.00167n\,.}{3n+1} - 0.01298\right]$$

n = 3.241

Now putting all values in equation (23)

$$\int_0^{R-\delta}\left[\left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}}\frac{n}{n+1}\left(R^{\frac{1}{n}+1}-r^{\frac{1}{n}+1}\right)+\left\{\frac{P}{4\eta_p}\left(R^2-(R-\delta)^2-\left(\frac{P}{2\eta_m}\right)^{\frac{1}{n}}\frac{n}{n+1}\left(R^{\frac{1}{n}+1}-(R-\delta)^{\frac{1}{n}+1}\right)\right\}\right]2\pi r dr+\int_{R-\delta}^{R}\left[\frac{P}{4\eta_p}(R^2-r^2\right]2\pi r dr$$

$$Q=\int_0^{0.0643}\left[\left(\frac{P}{2\eta_m}\right)^{\frac{1}{3.241}}\frac{3.241}{3.241+1}\left((0.965)^{\frac{1}{3.241}+1}-r^{\frac{1}{3.241}+1}\right)+\left\{\frac{P}{4\eta_p}\left((0.0965)^2-0.0643)^2-\frac{3.241}{3.241+1}\left((0.965)^{\frac{1}{3.241}+1}-(0.643)^{\frac{1}{3.241}+1}\right)\right\}\right]2\pi r dr+\int_{0.0643}^{0.0965}\left[\frac{P}{4\eta_p}\left((0.0965)^2-r^2\right]2\pi r dr$$

$$Q=\left[0.005716\left(\frac{P}{2\eta_m}\right)^{0.3085}\right]$$

$$Q=\left[0.005716\left(\frac{\Delta P}{2\eta_m\times\Delta Z}\right)^{0.3085}\right]$$

$$7.0833=\left[0.005716\left(\frac{\Delta P}{1900\ \eta_m}\right)^{0.3085}\right]$$

$$\left(\frac{\Delta P}{1900\ \eta_m}\right)=\left(\frac{7.0833}{0.005716}\right)^{0.3085}$$

$$\Delta P=8.9998\times\ 1900\ \eta_m\ =17099.62\ \eta_m$$

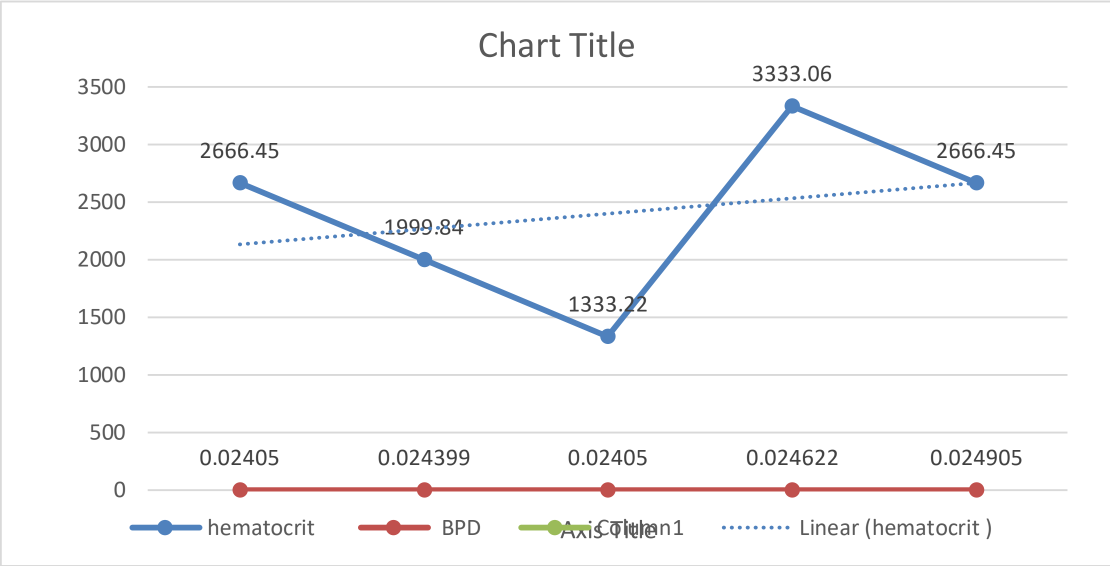
$$\Delta P=17099.62(1.0727737394H+0.00129968)$$

$$\Delta P=18344.02328H+22.2240$$

Table :2 Haematocrit v/s BP Drop :

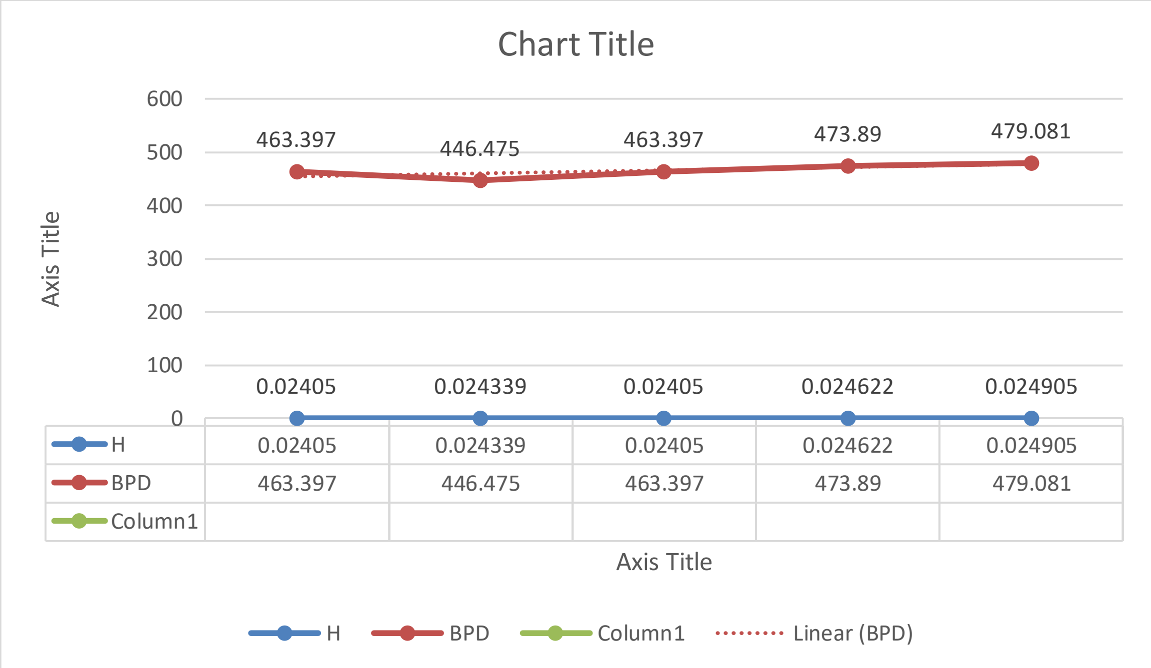
Date	Hematocrit	BPD in pascal
11-05-22	0.02405	463.397
11-05-22	0.024339	446.475
11-05-22	0.02405	463.397
11-05-22	0.024622	473.890
11-05-22	0.024905	479.081

(a)Graphical presentation of Clinical data :



Graph 1 : Hematocrit v/s Clinical BP Drop

(b)Graphical presentation of Mathematical Modulated Data :



H	0.02405	0.024339	0.02405	0.024622	0.024905
BPD	463.397	446.475	463.397	473.89	479.081
Column1					

Graph 2 : Haematocrit v/s Mathematical Modulated BP Drop

9):- Conclusion –

In Clinical Data graph (1) , mathematical data graph. (2) The graph between haematocrit and blood pressure drop in iron -deficiency Anemia patient we have conclude that when haematocrit increased then the blood pressure drop is also increased . and Shows a non linier graph.

10):- Acknowledgement - I feel it to be a privilege to express my deepest sense towards Supervisor of my advisory committee Dr. Virendra Upadhyay . I Sincere Thanks to Dr. Bhanu Pratap Singh (MBBS,MD) LG, Hospital Ahmedabad

11:-- References-

1.“Structure and function of blood vessels Anatomy and Physiology ” Lumen learning .com Retrieved 19 Nov. 2021.

2.Guyton AC , Hall JE (2006), textbook of medical Physiological. ElsevierInc. india 11th edition , ISBNO-8089-2317-X.

3. Ajmani Rs , Rif kind JM, Hemorheological changes during human , Gerontology (1998), 44: 111-120.

4.A.E. Medvedev . Two – Phase blood flow model , Russian journal Of Biomechanics (2013), vol.17 , no- 4(2), 18-32.

5 . JoisanKrunal ,Bhoraniya Ramesh , marichanumAtal (2019). Numerical Analysis two phase blood flow in idealizedcartery with blackage . Springer Nature SinggaporePte Ltd, DOI:10071978-13-2697-429.

6.Siddiqui S.U,AwasthiChhama,Geeta (2017).Analysis mathematical modelling on blood flow through stenosed artery under the influence of magnetic field.(IJMTT),Vol 49(4):2231-5373.

7.Verma S.R. and Srivastava. Anuj(2014).Analytical study of two –phase model for steady flow of blood in circular tube by mathematical model.(JERA),Vol4(12):2248-9622.

8.Harper, J.L. Maecel, E.C. and Emmanuel, C.B. (2015). Anemia :Practice essentials, pathophysiology and Etiology. JOSTI-Vol 1(1) :2456-8082

9.Paricha SR. Flecknoe-Brown Sc,AllenKJ,et al. (2010) Diagnosis and management of iron –deficiency anemia :clinical .Med J. Vol193(9):525-32.

10.Basavarajappa.KS and Katiyar, VK and Manjunatha , (2008). A study on mathematical modelling on human blood in reference to the variation of hematocrit (JA&C), Vol.4(1).

11.Kanpur J.N. (2008). Mathematical model in biology and medicine . EWP, Delhi :344-389.
12.Mazumdarjagan N.(2004). Bio fluid Mechanics world scientific , ISBN 978-9814713979. Page (17).
13.Upadhyay v.(2001). Some Phenamena in two phase blood flow ,phD. Thesis , central university , Allahabad.
14.Fung ,Y.C. (1993). Biomechanics Mechanical Properties of Living Tissue , Springer-veray , New yark, ISBN 978-4419-3104-7
15. Glenn Elert 2010 "Viscosity ,The physics hypertext book''.09-14-2010
16.Gustafson Daniel R.1980, Physics , Health and The Human Body , Wadsworth.
17 B. Divya and K. Kavitha " A review on mathematical – modelling in biological and medicine " Adv Math Sci, J, vol. 9 , no. 8, pp. 5869-5879, 2022.
18- G. kaiser , " Mathematical modelling and applications in education, " Encyclopaedia of mathematics education , pp. 553- 561, springer , cham, 2020.
19-M. J. Kirby , "Hillslope process -response model based on the continuity equation," Inst Br Geogr Spec Publ, vol. 3 ,pp. 5- 30, 1971
20 – M. A. J. Chaplain , " Multiscale mathematical modelling in biology and medicine , " IMA Journal of Applied Mathematics , vol. 76, no. 3, pp. 371-388, 2011.