

Research Article

Investigation of Blood Flow in Capillaries Through Rheological Properties at Low Concentration Limit

Ramesh Yadav^{1,*} , Pravin Kumar Srivastava² , Santosh Kumar Dixit³,
Navneet Kumar Singht⁴

¹Department of Applied Science and Humanities, Goel Institute of Technology and Management, Lucknow, India

²Department of Applied Science and Humanities, Bundelkhand Institute of Engineering and Technology, Jhansi, India

³Amity School of Engineering and Technology, Amity University Patna, Bihar, India

⁴Department of Mathematics, Nagrik Degree College, Janghai, India

Abstract

In this study we investigate the blood flow in capillaries through rheological properties as small density limit of fluid. Here we know that blood viscosity is an important for flow of particle RBC, WBC and Platelets. The characteristics of blood flow exhibits shear thinning behavior of flow. It decreases exponentially with increasing shear rates. All these particles WBC, RBC and Platelets increases the viscosity of blood. The shear thinning property of blood is mainly attributed to red blood cell (RBC) rheological properties. RBC aggregation occurs at low shear rates with increase of these particles. Blood flow in human being artery and vein is highly dependent on the ability of RBC to deform, but deformability also affect on blood flow in the high and low concentration. When it is low concentration flow of blood is increases and rate of deformability is increased. The person with highest RBC deformability at steady-state has a higher risk of developing frequent painful. Moreover, regular physical exercise has been shown to decrease blood viscosity in sickle cell mice, which could be beneficial for adequate blood flow and tissue perfusion. The behavior of shear become less dense of blood in the low shear limit is analyses by assuming the approximate of the red blood cells (RBC). This is said to be the rouleaux form of blood. Here the fundamental equation blood flow in higher shear rate is obtained for the numerous flow positions by assuming the unique property of deformation of blood cells. In this study, the changes of the surface are conserving control. The tank treading flow of the blood cells on the rheological properties has been also investigated.

Keywords

Red Blood Cell, White Blood Cell, Rheological Behavior, Shear Thinning

1. Introduction

The theory of red blood cell rheological property is obtained with the help deformability and agregability. There are two phases and their proportional contribution of whole red

blood cell (RBC) volume. These bloods are non-Newtonian fluid. It is also low shear rate fluid with viscoelastic and thixotropic properties of bloods. The addition hypothesis of

*Corresponding author: ramesh.yadav.maths@gmail.com (Ramesh Yadav)

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theory of rheological properties in human blood as a postponement of red blood cells (RBC). Here moreover particularly, we desire to express the procedure for effectual viscosity of red blood cell movement. The efficient thickness of red blood cell is different fundament movement areas by proceeding report to way of behaving of the red blood cell in numerous fundament flow area by proceeding report of the behaviors of RBC likely aggregate at small shear rate limitation, here the area maintaining the deformity in more shear thinning limit. In practical study to find the results from the viscosity computations represents the shear thinning properties of red blood cell. Thus in many numerical studies, the empirical constitutive relation such as Casson's model and biomechanics –mechanical properties of living tissues has been presented by Fung and Nakaruar and Sawada, Young [9, 14, 32]. Schmidt-Schonbein et al. [15] has been studied the experimental analysis on the blood flow at small concentrations limits of RBS (6-9%). The ordinary cells has obtained to be eliminate non rouleaux, at the low concentration rate $k = 4.9$ per seconds. The slight leads of the k separate cells has obtained with the periodic fall down and cycling of mobility in flow. Goldsmith [16] analyzed the alike monitoring from the experimental study of Poiseuille flow. In short way, the experimental proof proposed that at small shear rate of RBC rotate. But the rotation of RBC is not seen in speeds flow of blood cell. In another paper Goldsmith and Skalak [17] has been obtained a hemodynamic in annual review of fluid dynamics. The blood flow close to the arterial wall and arterial sickness has been studied by Caro et al. [5]. Kang, Keller and Skalak, Skalak et al. [12, 13, 22] presented annual report, AFE-92D on blood flow and bio fluid flow.. Smith et al. [23] has been studied anatomically situated model for transitory coronary blood flow in the human heart. Here it is an additional principal characteristic of blood flow. We should assume is therefore said restraint of the area conservation throughout the deformation of RBC cells. The constraint and flexibility of Blood cell layer found special characteristics of the red blood cell deformity. By reason of the restriction of area conservation and nominal resistance to curved. Here the equilibrium region of RBC cells does not pivot on the shearing rate. If its merit is greater than a certain critical merits. As an alternative, the membrane lateral tension leads as the strain rate leads. After some time the cell is fragmented away from each side which is called as hemolysis. It occurs rate of strain is more than it critical value. Srivastava [29] has studied flow of double stress fluids, constituting blood flow through the stenosis vessels accompanied by a outer layer. Deformation and haemolysis of a red blood cell in shear flow has been presented by Recharadson [25]. Roscoe [26] has been studied on the Rheology of a suspension of viscoelastic sphere in a viscous liquid flow.

Mishra and Panda [20] has been studied Newtonian model of the blood flow tin the appearance of an arterial stenosis. In another paper Srivastava [28] has been studied a theoretical model for red blood cell flow in small vessels. The Pulsating

flow of a hydromantic flow between permeable beds has been studied by Malathy and Srinivas [19]. A micro polar model of blood flow through a narrow artery with a stenosis has been studied by Abdullah and Amin [1]. Singh et al. [27] has been studied the red blood flow characteristics behavior in a narrow tubes using of non-linear mathematical models. Chaubey et al. [6] has been studied blood flow of close fitting in elastics particles in very small vessels. Akbar [2] has studied Eyring Prandtl model of red blood flow with convective boundary condition in narrow intestines. Kutev et al. [18] has been studied estimation of the vibrating or fluctuating blood flow taking the Carreau viscosity. Cho [8] has been studied on fluid flow in his M. S. Dissertation in Pohang University of Science and Technology, Korea. Bary et al. [3] has been studied analysis of multi-pion Hanbury brown-Twiss correlation for pion-emitting sources with Bose-Einstein condensation. Qasim et al. [24] has been studied numerical imitation of MHD peristaltic flow with changeable electric conductivity and Joule-dissipation using generalized differential quadrature formula method. Usman and Kausar [30] has been studied the numerical solution of the partial differential equations that model the steady three dimensional flow and heat transfer of Carreau fluid between two stretchable rotatory disks. Yadav et al. [31] has been studied the investigation of blood flow through stenosed vessel using non-Newtonian micro polar fluid model.

In this present study, the above characteristics of blood cells are considered to predict the effective viscosity of blood as a function of shear rate. For our theoretical development, Batchelor's Theory on the suspension of ellipsoidal particles is used.

2. Rheological Theory

Here the theory the suspension Rheology has been expressed by the following researchers. This is presented here.

2.1. Theory of Batchlor's

Batchlor [4] has proposed the a theory in 1970, it has been used the volume mean to explain the mathematical formula for the bulk stress from the microscopic flow is represented here below.

$$\Sigma_{ij} = \frac{1}{V} \int (\sigma_{ij} - \rho u'_i u'_j) dV, \quad (1)$$

with the aid of vector calculus, Batchlor is represented as given below.

$$\Sigma_{ij} = -\delta_{ij} \int_{V-\Sigma V_0} \rho dV + \mu \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) + \Sigma_{ij}^{(p)}, \quad (2)$$

here, V_0 represents the volume of each particle.

$$\Sigma_{ij}^{(p)} = \frac{1}{V} \int_0 \{ \sigma_{ik} x_j n_k - \mu (u_i n_j + u_j n_i) \} dA - \frac{1}{V} \int_{V_0} \rho f'_i x_j dV - \frac{1}{V} \int \rho u'_i u'_j dV, \quad (3)$$

here, the symbol $\Sigma_{ij}^{(p)}$ stand for the ‘Stress of the particle’, and $\frac{\partial u_i}{\partial x_j}$ represents the average velocity gradient of fluids. In fact the equation (2) is quite general equation. It may be presenting point for interruption of the rheological property of red blood fluid for various positions. Batchelor used the formula in relation (2) for the situation of weaker suspension ($\phi \rightarrow 0$) to obtain some investigative results. They considered farther that fluid molecules and Reynolds number are so narrow or low and here last two terms in equations (3) can be carefully eliminated. In low concentration case, the interactivity between fluid molecule is eliminated and assumed to a single molecule in a common straight flow gives the enough information. Now here the mean velocity gradient is equal to velocity gradient given far from the red blood fluid particle.

$$\frac{\partial u}{\partial x_j} = e_{ij} - \epsilon_{ijk} \Omega_k, \quad (4)$$

Batchelor represented that the particle or molecules stress in the low concentration limit can be expressed by

$$\Sigma_{ij}^{(p)} = \frac{4\pi\mu}{V} \sum D_{ij}, \quad (5)$$

$$\Sigma_{ij}^{(p)} = 2\mu e_{ij} \frac{4\pi}{3V} \sum abc \left\{ \frac{4(J_1 + J_2 + J_3)}{15(J_1 J_2 + J_2 J_3 + J_3 J_1)} + \frac{2}{5} \left(\frac{1}{I_1} + \frac{1}{I_2} + \frac{1}{I_3} \right) \right\} \quad (9)$$

where, I_i and J_i ($i = 1, 2, 3$) are the purpose of a, b, and c. The above two equations are tacked to anticipate the constructive viscosity in the blood flow.

2.2. Theory of Hinch and Leal's

Hinch and Leal's [10] has been studied the Batchelor theory and put in an application of the Batchelor's common observation to the adjournment rheological property of the low concentration spherical fluid particles. Their output represented as below.

$$\Sigma^{(p)} = 2\mu\phi \left\{ 2A_H E : \langle pppp \rangle + 2B_H \left(E : \langle pp \rangle + \langle pp \rangle : E - \frac{2}{3} I E : \langle pp \rangle \right) + C_H E + F_H D_r + \left(\langle pp \rangle - \frac{1}{3} I \right) \right\}, \quad (10)$$

Here E stand the rate-of-strain tensor ($E = e_{ij} e_i e_j$), ρ stand for the unit vector direction of rotational axis and D_r represented as the rotator diffusivity. Now taking Batchelor's theory the general output results for the elliptical fluid particles and obtained the limitless or asymptotic expressions for the coefficients when the fluid substances are in spherical shapes.

3. Effect of Approximate Property of Blood Flow

Human blood cell is known to form of collection bundle or

here, D_{ij} stands for the coefficient in the enlargement for the distraction pressure and the distraction vorticity.

$$\frac{p'}{\mu} = -D_j \frac{\partial r^{-1}}{\partial x_j} - D_{jk} \frac{\partial^2 r^{-1}}{\partial x_j \partial x_k} + \dots, \quad (6)$$

$$\omega' = -\epsilon_{ijk} D_j \frac{\partial r^{-1}}{\partial x_j} - \epsilon_{ijk} D_{ji} \frac{\partial^2 r^{-1}}{\partial x_k \partial x_l} + \dots, \quad (7)$$

Effective stress of a low concentration suspension in elliptical fluid particles has non-Newtonian fluid form and represents the complicated behavior of red blood cells. Here in the some special situations the built-in relation can be expressed without much struggling. The first sample of example is the interruption of double-free fluid particles; it is similar in build shape and direction. For this situation Batchelor has represented as given below.

$$\Sigma_{ij}^{(p)} = 3\mu e_{kl} \frac{C_{ijkl} \sum_3^4 \pi abc}{abc V}, \quad (8)$$

for the direction of the elliptical fluid tiny piece with assumed semi-diameter a, b, and c. Other exemplification is the situation of the couple-free fluid particles subject to much powerful Brownian movement that their directions are randomly dispersed with the constant probability, i.e. statistical isotropic situation. In this situation the governing equation is represented by,

aggregates, which is also known as rouleaux. Here when, shearing rates is small or very low, the cluster looks good on prevailing. In this part, we want to study the consequence of clusters on effectual features of human blood cells. In the first try, we consider that the degree of cluster or degree of aggregation in same for all rouleaux. Each rouleau can be estimated by a spherical shape, which is shown in Figure 1.

We shall assume two very great situation of coordination of distribution. One of which is the random distribution. It should be suitable for lower shearing limit. The Second one is the wholly range position in the uni-axial pigment of blood fluid.

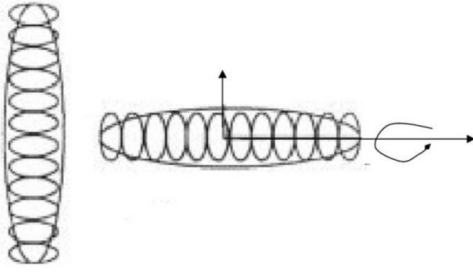


Figure 1. This Figure represent the assumption of Spheroidal form by the aggregation at low shearing rates.

3.1. Randomly Oriented Spheroid Rouleaux

Here we consider the randomly distribution of spherical rouleaux. Now we want to start with the situation of ideal random scattering of orientation. When adjournment has low concentration, Batchelor's equation (9) is proper form of particle which is present in stress term. The relation can be make simpler when region of the fluid particle is spherical of spheroidal (i.e., $b = c$).

$$\Sigma_{ij}^{(p)} = 2\mu e_{ij}\phi \left\{ \frac{4(J_1 + 2J_2)}{15(2J_1 + J_2)J_2} + \frac{2}{5} \left(\frac{1}{J_1} + \frac{2}{J_2} \right) \right\}, \quad (11)$$

where ϕ represent the volume fraction of rigid particles. Here $ab^2 = 1$ for spheroids fluid, the now the equation (11) can be expressed as given below.

$$\Sigma_{ij}^{(p)} = 2\mu e_{ij}\phi f(a), \quad (12)$$

Here, a represents the dimensionless semi-diameter of rouleau and the effective viscosity of blood is presented here

$$\mu^* = \mu(1 + f(a)\phi), \quad (13)$$

here, μ represented the viscosity of the plasma.

In this study, when rouleaux are completely large, we can convey the non-dimensional semi-diameter a in terms of degree of approximation. Let ' n ' be total number of cell in one rouleaux. From the highest width of the fluid cell are nearly to $2.9 \mu\text{m}$ and width or the diameter is $7.5 \mu\text{m}$, a n -cell rouleaux has the characteristic ratio about

$$r = \frac{a}{b} = a^{\frac{3}{2}} = \frac{2.9}{7.5} n \quad (14)$$

And thus

$$a = \frac{n^{\frac{2}{3}}}{2}, \quad (15)$$

In Figure 2, the factor $\left(f(a) = f\left(\frac{n^{\frac{2}{3}}}{2}\right) = \bar{f}(n) \right)$ is being seen as function of the degree of approximation. In command

to see the outcome of approximation more explicitly, we may assume that

$$\frac{\mu^*(n)}{\mu^*(1)} = \frac{1 + \bar{f}(n)\phi}{1 + \bar{f}(1)\phi}, \quad (16)$$

where $\mu^*(n)$ stand for the effective viscosity or working viscosity of the fluid. The degree of aggregation is represented by n . Though the outcome was obtain for the small gathering limit. Let us put in it to the situation of the ordinary erythrocyte volume fraction (hematocrit) $\phi = 0.46$. Then, with $\bar{f}(1) = 2.9$, $\bar{f}(20) = 4.4$, $\bar{f}(40) = 8.6$, $\bar{f}(80) = 22.6$, we have get

$$\frac{\mu^*(n)}{\mu^*(1)} = \begin{cases} 1.4, & \text{for } n = 20 \\ 2.3, & \text{for } n = 40, \\ 4.8, & \text{for } n = 80 \end{cases} \quad (17)$$

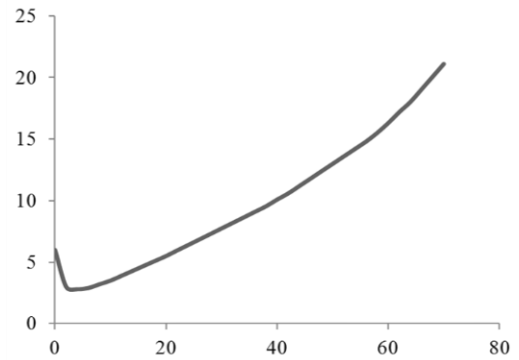


Figure 2. This figure represented the factor function $\bar{f}(n)$ for the effective viscosity.

Here we have seen above that the affect of aggregation is appreciable even when small gathering model is applied. In fact at high gathering assumed it as $\phi = 0.45$, need to assume the interactivity outcome in the middle of the rouleaux. Even though, when especially complex physics of interactivity does not authorize or permit us any attentive or careful analysis an order of lead in the effectual viscosity can be with ease imagined. It has been also observed experimentally by Chein [7].

The consequence of this study lies in such the shear less denser behavior of red blood cell. At low shear rates can be best realized by the reality that the degree of aggregation leads as shear rate leads.

3.2. Spheroidal Rouleaux

The rouleau are put through to the shearing flow. The rouleau are arrange in line in the principal. The rouleaux strain directive is showing the Figure 3.

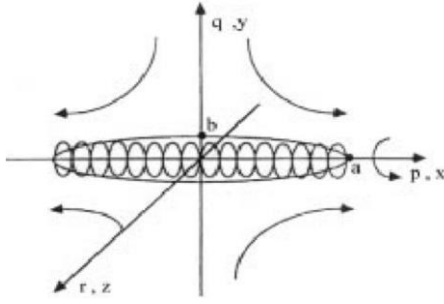


Figure 3. This figure represents the Rouleaux in the uniaxial stretching flow.

In this situation, the effectual viscosity of fluid may be simply acquired. Here the rate of shear tensor in this difficulty is represented as below.

$$e_{ij} = E \left[p_i p_j - \frac{1}{2} q_i q_j - \frac{1}{2} r_i r_j \right], \quad (18)$$

$$\frac{c_{ijkl} e_{kl}}{abc} = E \frac{J_1 \left(p_i p_j - \frac{1}{3} \delta_{ij} \right) - \frac{J_2}{2} \left(q_i q_j + r_i r_j - \frac{2}{3} \delta_{ij} \right)}{\frac{3}{4} (2J_1 + J_2) J_2} = \frac{4}{9J_2} e_{ij}, \quad (19)$$

Then from expression (8), we have obtained the given results.

$$\Sigma_{ij}^{(p)} = 2\mu e_{ij} \phi \left\{ \frac{2}{3J_2} \right\}, \quad (20)$$

Therefore, the effective viscosity is given by

$$\mu^* = \mu \left[1 + f(a) \phi \right] = \mu \left[1 + \left(\frac{2}{3J_2} \right) \phi \right], \quad (21)$$

The component for the mono-axial struggling movement instance $\left(\frac{2}{3J_2} \right)$ is exhibit in Figure 3 for differentiation accompanied by the part for the instance of finish off random diffusion or distribution.

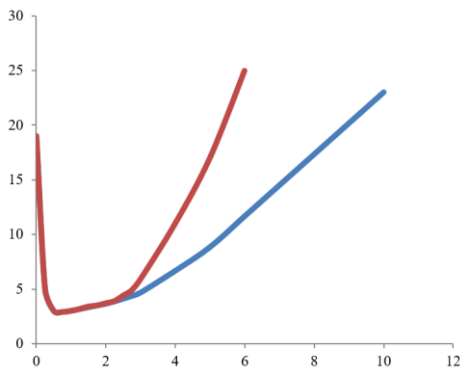


Figure 4. The figure represents the functions of effective viscosities for the rouleaux in uniaxial stretching flow and the randomly distributed of rouleaux.

4. Rouleaux Breakup

In this study we make a start the enlargement of the theory for the shear thinning effectual; it is required to obtain the stage of accumulation in word of shearing rate. In the first stage, it is considered a rouleau which is subject to a mono-axial weakening motion has shown in Figure 3. Despite of the fact that the rouleaux is studied and obtain that it is distorting the shape easily in shear flows. The vital reason of the rouleaux breakup will be convinced by the weakening part of element of the force shearing flow. Consequently by assuming only mono-axial weakening flow, which may be achieved the goal. The weakening strength employed on the middle-position of rouleaux. It can also be estimated. If the weakening strength is greater than the attracting strength between cells in the rouleaux, then rouleaux is fragmented in two small rouleaux. Then the weakening strength can be simply estimated by Jeffery's solution [11]. Pozrikidis [21] has been presented the plane pressure working on the outer plane of an ellipsoid piece or particle, which is submerged in a common straight flow and it, is stated by the equation.

$$f_1 = (-P_0 I + A) \cdot \hat{n},$$

where \hat{n} is unit normal vector outward from the plane of bit or particle. A stand a constant matrix, it is a diagonal matrix if a mono-axial weakening flow is considered, and the x -directional component of the plane stress is obtained in non-dimensional form as given below.

$$f_x = (A_{11} - P_0) \hat{n} \cdot e_x \quad (22)$$

here the tightness is known by $\mu\chi/2$ for rate of shear.

$$\chi = E \left[e_x e_x - \frac{1}{2} e_y e_y - \frac{1}{2} e_z e_z \right], \quad (23)$$

χ Represents the rate of shear, the weakening strength on the right half of the rouleaux is comfortably come by integrating the surface stress.

$$\tilde{F}_x = \int \tilde{f}_x dS = \left[A_{11} \left(\frac{\mu\chi}{2} \right) - p_0 \right] \int (\hat{n} \cdot e_x) dS = \left[A_{11} \left(\frac{\mu\chi}{2} \right) - p_0 \right] (\pi b^2), \quad (24)$$

The dimensional maximum pulling force per unit area of RBC cell to cell boundary can be represented by \tilde{f}_{att} . Then,

$$\tilde{F}_{att} = \tilde{f}_{att} (\pi b^2), \quad (25)$$

When a rouleaux to be fragmented by weakening flow $\tilde{F}_x \geq \tilde{F}_{att}$. Consequently at critical grouping, we have obtained the results.

$$A_{11} \left(\frac{\mu\chi}{2} \right) = p_0 + \tilde{f}_{att}. \quad (26)$$

Pozridis [21] has given that $A_{11} = \frac{8}{3g''}$. Here the function $g_2''(r)$ can be appear to be alike to the function $J_2(a)$ of Batchelor's symbol by taking the equation $r = a/b = a^{1/2}$

$$g_2''(r) = \int_0^\infty \frac{udu}{\left(\chi^{\frac{4}{3}+u}\right)^{\frac{3}{2}} \left(\chi^{-\frac{2}{3}+u}\right)^2} = \int_0^\infty \frac{\lambda d\lambda}{(a^2+\lambda)^{\frac{3}{2}} \left(\frac{1}{a}+u\right)^2} = J_2(a), \quad (27)$$

Here, it has a relationship, which is given by

$$\left(\frac{4}{3J_2}\right)(\mu\chi) = p_0 + \tilde{f}_{att}. \quad (28)$$

Here let us to find the desirable strength has been studied by Chien [7]. They have presented experimentally that the rouleau may be obtained if the shear rate is less than 4sec^{-1} . If the max value of strain rate be χ_{max} . On the other side which the rouleau development is not obtained or observed. Then a two cell rouleau, we may using equation (28) to find χ_{max} . For ease, we accept a fair / logical estimation that a two cells rouleau can be observed as a sphere. For this situation, we should show that Batchelor theory.

$$\frac{2}{3J_2} = \frac{5}{2}. \quad (29)$$

Therefore, we have

$$p_0 + \tilde{f}_{att} = 5\mu\chi_{max}. \quad (30)$$

Form equations (28) and (30), it is obtained a very important equation between them, which is given below.

$$\frac{\chi}{\chi_{max}} = \frac{15}{4} J_2(a), \quad (31)$$

Whichever is among the chief outcomes in this current tasks, the definition of $J_2(a)$ for the asymmetric situation is designated in equation (27). Here the equation (20) can worked to obtain the method for effectual viscosity that reveal shear dilution characteristics. Here it has talk about in foregoing part, the effectual viscosity can be obtain if we possess the stage of aggregation by the methods or relation (3) via (4). So we have get

$$\frac{\mu^*(n)}{\mu^*(sph)} = \frac{1+\tilde{f}(n)\phi}{1+\tilde{f}(sph)\phi}, \quad (32)$$

Here $\mu^*(sph)$ represented the effectual viscosity of interruption of ball-shaped bits of red blood cells. Now form relation (20), we can obtain the non-dimensional semi-diameter, a , of a rouleau for obtain non-dimensional strain rate χ/χ_{max} . The degree of aggregation n can be obtained by equation (15) for the stated value of a . In this way the level of aggregation is represented by n can be calculation as a consequence or function for the non-dimensional shear rate χ/χ_{max} .

The degree of approximation is familiar for the stated rate of shear. The effectual is calculated by using the relation (30). Here the Figure 5 represents the graph between effective viscosity and dimensionless strain rate. The rate of strain for the case of hematocrit $\phi = 0.45$ has been studied. The shear thinning affect has been seen. It is found that the result show qualitative quality consensus with the practical results finding by Chien [7]. This study is established on the theory for the weak interruption. Furthermore, we do not cover any complex aggregate way of behaving, like as split rouleaux creation and deformity of the rouleaux in shearing flow of fluid.

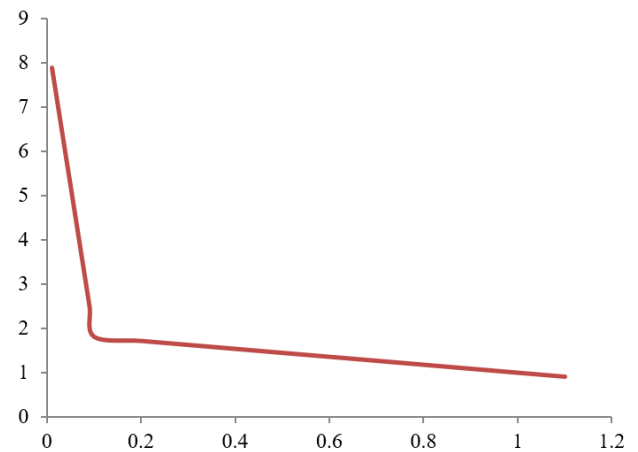


Figure 5. This graph represent the dimensionless effective viscosity as function of dimensionless rate of strain.

5. Results and Conclusions

The present study was to obtain the investigation of blood flow in capillaries through rheological properties at low concentration limit. For instance of small shearing rate, we supposed that the RBC particles form rouleaux that can be assumed as large spheroids. Here applying the Batchelor's classical analysis on the suspension of solid spheroids. They have explained the formula for the effectual viscosity in term of grade of approximation. In order to obtained a connection between forced shearing rate and the grade of approximation. Here we have assumed a rouleau in a uniaxial struggling flow. The combination of two outputs, a relation for effectual viscosity is a grade of the forced shearing rate is found. It is extremely easy and numerous features of rouleau development has not been comprise in this model. This explanation is able to be visible the shear thinning affect, which is a fine harmony agreement at low qualitatively with the experimental findings.

The objective of this study is to explore theoretical study of blood flow in capillaries at low concentration rate has been studied above. The limit of more shearing rates, effectual viscosity of red blood flow is mostly to find out by deformity features of separate red blood cells. Here for more shearing

rate, we supposed two situations. One of them is the problem of totally line up cells in an exhibits symmetry struggling flow. The second one is for the situation of roll over or flip blood cell in shear flow. Here under the axisymmetric stretching flows, the symmetry shapers has been found by the globosity without consider to stated stain rate, if tension rate is tall sufficient for red blood cells to exist individually. This study is conserving Constraints and has a significantly affect on rheological qualities of blood flow in human being. In point of the fact the uniaxial struggling viscosity of human red blood flow is visible fully dissimilar attribute from that of interruption of elastic flow bits or particles. Stretchy particle expand under a pulling movement in human blood. The exterior surface area of the particles leads as lead of rate of stress. Simultaneously the effectual pulling viscosity is alone itself a powerful task of rate of strain. In the instance of person blood cells, the effectual viscosity is a pulling flow is kept constant for a large range of strain rate. It is due to the ease of deformity of cell membrane and the area conserving constraint. From this study, it is also obtained that the effectual viscosity of human blood flow is much higher is the uniaxial pulling flow than in the biaxial pulling blood flow. This fact must be given back in the study for the human blood flow field where pulling components are predominant. For example, the human blood flow in the heart involves pulling (straining) flow components due to suction and pumping of heart in human blood flow.

Abbreviations

RBC Red Blood Cell
WBC White Blood Cell

Author Contributions

Ramesh Yadav: Conceptualization, Software, Methodology & Editing

Pravin Kumar Srivastava: Formal Analysis, Investigation, writing – review

Santosh Kumar Dixit: Resources, Methodology, Data analysis

Navneet Kumar Singh: Reviewing and editing

Conflicts of Interest

The authors declare no conflicts of interest.

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