Journal of Undergraduate Research in Alberta

UNIVERSITY OF CALGARY

EXPERIMENTAL CHARACTERIZATION OF RED BLOOD CELLS WITH A MACROSCALE IN-VITRO MODEL

Alejandro Noboa Lavalle[1], Andrew Walker [2], David Riva1[2]
[1]Chemical Engineering Program, University of Calgary, [2]Mechanical Engineering Program, University of Calgary
noboalaa@ucalgary.ca

INTRODUCTION

In arterial flow, blood is usually modeled as a Newtonian fluid. However, blood has been shown to display non-Newtonian behavior in low shear flows and assuming a constant viscosity can be inaccurate when dealing with flow downstream of a blockage or a stent [1]. To better represent its behavior in such cases it is therefore important to understand the non-Newtonian properties of blood, which are mainly a result of the red blood cells (RBCs) suspended in it. The main focus of these experiments was to develop a better understanding of the mechanism behind the axial migration of RBCs towards the center of a vessel during flow. An exact explanation for the lateral migration of RBCs toward the central axis is not available. The general consensus suggests because RBC's are deformable particles, they move toward the axis. Conversely, rigid bodies like platelets (also present in blood) are pushed towards the wall. [2]. Most studies agree that the parabolic velocity profile in small vessels causes deformation of the RBCs. This deformation is asymmetric for cells that are off center, and this lateral asymmetry induces lateral migration [3]. However for larger vessels (of diameters >1mm) there is no clear understanding of the mechanisms involved. The analysis of this complex problem was approached from a basic large scale physical model in order to quantify the forces responsible for this lateral migration.

METHODS

Balloons filled with fluids of different viscosities were used to model RBCs. The fluids used include water, glycerine and honey. The balloons were towed using a step motor traverse across an aquarium filled with glycerine. A force balance was attached to the traverse, and the balloons were attached to it by means of a string. Tests were performed at constant speeds corresponding to a particle Reynolds number (Re) of 10 for each balloon. Each balloon was tested at varying distances of separation from the wall corresponding to ratios of separation distance to particle diameter (S/D) of 2, 1 and 0.5, running 10 trials for each. Similar tests were also performed with a tennis ball wrapped in electrical tape, which served as a rigid control. The data obtained for the lift force away from the vessel wall was recorded (Figure 1). Average values of the lift forces were then used to calculate the average lift coefficients (C_L).

RESULTS

There was an increase in C_L as the particle got closer to the wall in all cases, with the relative deformability of the particle showing a significant effect on said increases (Figure 1). The difference ranged from a 92.5% increase between a ratio of S/D =1 to S/D= 0.5 in water to a 36.4% increase in the same comparison for honey. Glycerine laid in between at an increase of 51.3%. In the same S/D change, the rigid control showed an increase of only 6.4%.

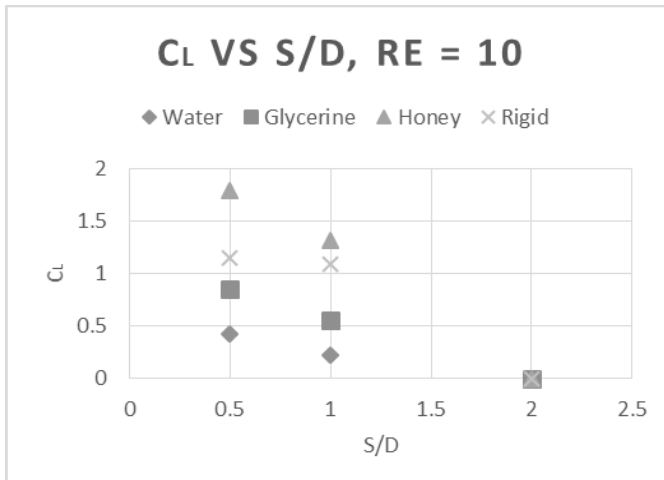

Figure 1. Plot of lift coefficient vs. separation from wall to diameter ratio for all balloons and rigid control.

DISCUSSION AND CONCLUSIONS

Overall this model did allow for the quantification of the lift forces pushing RBCs towards the central axis, showing a significant increase as the particles got closer to the wall. Thus the model suggests that wall interactions are a major contributor to RBC migration and that the deformability of the particle has an effect on those interactions. Future work will aim to further analyze the relationships observed in this large scale model as well as look to apply these concepts to multiple particles and smaller scale experiments.

REFERENCES

1. Walker, A et al. *J Biomech Eng*. **134:** 1-10, 2012
2. Aarts, P et al. *Arterioscler Thromb Vasc Biol*. **8(6):**819-824, 1988.
3. Secomb, T et al. *Ann Biomed Eng*. **35(5):** 755-765, 2007.