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Design and Simulation of Blood Flow Meter in IntelliSuite

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Abstract

Blood flow measurement is important for the monitoring and diagnosis of various diseases in different parts of the body. The flow rate value will vary depending on the geometry and shape of the flow meter. In this paper, flow meters of three different channels are simulated for non-Newtonian blood flow and the pressure difference across the channels is calculated. This simulation is done using IntelliSuite software.

Keywords: MEMS, IntelliSuite, Blood, Flow rate, Pressure

Subject classification: MEMS

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1. Introduction

Blood is the body fluid that carries oxygen, nutrients such as amino-acid, fatty-acid and glucose to all cells of the body. It collectsthe wastes like carbon dioxide, lactic acid and urea. Body temperature is also controlled by blood. Blood transports hormones and it assists the immune system. Blood is composed of plasma and blood cells. Plasma constitutes for 55% and the blood cells constitute for 45%. The plasma contains water up to 92% and the remaining being proteins, glucose, mineral-ions and several other components. The blood cells have erythrocytes, leukocytes and thrombocytes.

Blood flow rate will vary according to the functioning of the organ. It will depend on the blood pressure and resistance to flow offered by the blood vessels. The flow rate in the brain is called cerebral circulation. It is the flow of blood through the arteries and veins that supply blood to the brain. The flow rate in adult is about 750 milliliters per minute. It represents 15% of the cardiac output. Renal Blood flow is about 1.1 Liters per minute. It represents about 25% of the cardiac output. RBF will depend on the weight and height of an individual. If the renal blood flow rate is low, it will affect the glomerular filtration rate(GFR) which in turn will affect the composition and volume of body fluids.

Blood flow meters are the devices used for measurement of flow rate. Various types of blood flow meter are available yet MEMS based flow meters have greater advantage over the conventional one.The power consumption, cost, size, accuracy are better in MEMS flow meter.Even low amount of flow rate can be measured accurately using MEMS flow meters. Micro-electro-mechanical system (MEMS) is the integration of mechanical and electrical properties in micro scale.

2. Flow sensor design during using intellisuite

2.1. Blood flow measurement

Blood flow rate is not constant throughout the body. It will vary based on the functioning of a particular organ. Cornea is the only part that receives oxygen directly from air whereas other parts of the body receive oxygen only through blood. If bloodflow rate falls, then the amount of oxygen supplied to the organ will be low. If adequate amount of oxygen is not supplied to afront part of optic nerve, it causes*eye stroke*. Eye stroke or anterior ischemic optic neuropathy is caused when the blood flow to the optic nerve is reduced or blocked. It will lead to loss of vision. Brain is the central part of human body. If the blood supply to the brain is reduced, it will lead to serious ill effect compared with any other part of the organ. It causes stroke, cardiac arrest and loss of memory. In worst case it may lead to permanent brain damage and cause coma.

Coronary artery supplies blood to the heart. If the blood flow rate is decreased, it will lead to a condition called *Angina.* If timely medical treatment is not taken, it causes heart attack. If blood flow rate to the kidney is not sufficient, the filtering capacity of kidney falls low which in turn affects the toxicity rate and may even cause kidney failure. So in total if the blood flow rate falls down at any part of the organ the cells will die and leads to the failure of the organ. In turn if the blood flow rate is high then it will be lead to rupture of the blood vessels and capillaries which causes internal bleeding. So the monitoring of the flow rate is very important in every aspect.

2.2 Design of different channels

For the simulation of flow meter in the *micro fluidics* module*,* we have to initially make the design of the different channels in *3D builder* module. Here a straight channel, a bend channel and a contraction channel has been designed. The design of all the three channels is made and it is exited to analysis module. The top view of all the channels is shown in Figure 1.

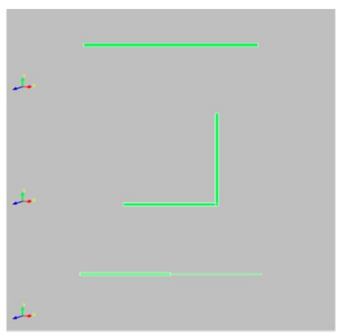

Fig 1.Top view ofdifferent channels- straight, bend, contraction

2.3 Simulation

Non-Newtonian fluid does not obey the Newton's law of viscosity. The ratio of shear stress to shear strain is not constant. Blood is a non-Newtonian fluid. In the simulation setting checknon-Newtonian in fluid flow. The relaxation factor is set according to the properties of blood. The values of moment, pressure, electric temperature and mass are being set.

These values may affect the speed of simulation and convergence. So the values are mostly preferred to be 1 for faster convergence.The variations in these values will proportionality affect the speed.

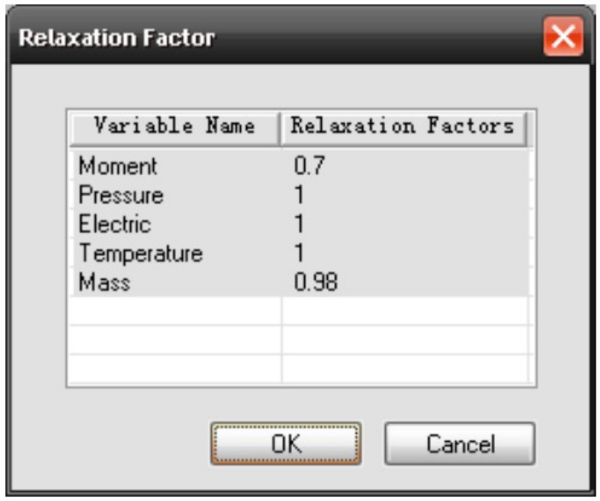

Fig 2. Set Relaxation Factor

2.4 Properties of blood

The viscosity of blood can be applied on a non-Newtonian flow model called the power-law.

$$\mu = K|\dot{\gamma}|^{n-1}$$

where K is the consistency of the material and *n* is the power-law index. The effective shear $|\dot{\gamma}|$is defined by,

$$|\dot{\gamma}| = \sqrt{\frac{1}{2}\dot{\gamma}_{ij}\dot{\gamma}_{ij}}$$

The *edit fluid is* selected from the property icon so that the properties can be changed. Now *edit property* dialog box appears. In that the viscosity and density properties are changed. Viscosity is the resistance offered by the fluid to flow. The minimum and maximum viscosity limit of blood is set to be 0.001 Ns/m^2 and 0.1 Ns/m^2 respectively.The consistency index is set to be 0.00733 and the power law index to be 0.932 which depends upon the constituents of blood.

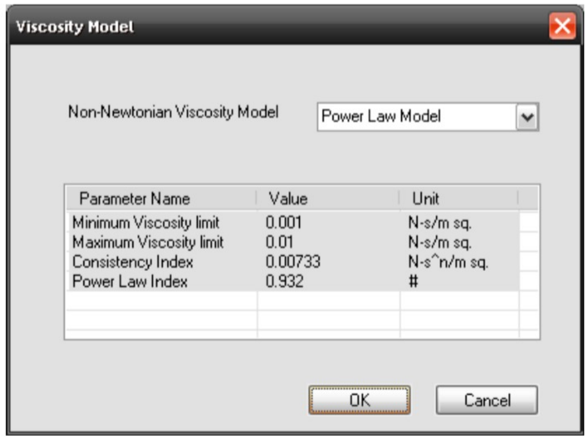

Fig 3.Viscosity model Dialog box

2.5 Boundary conditions

The boundary condition is set for both the inflow and out flow. The bottom face is chose for inflow and the top face is chose for outflow. For inflow rate, the volume flow rate condition is set to be constant value of 1 microliters per second. For outflow rate, the ambient pressure is set to 0MPa. Then meshing of the flow meter is done.

2.6 Meshing

Meshing is anintelligent, general-purpose, automated high-performance product. It produces appropriate mesh for accurate and efficient multiphysics solutions. Meshing will increase the accuracy of measurement. Higher the mesh size higher will be the refinement of output.

Here both the maximum and minimum mesh size is varied. The mesh count should have the moderate value, large enough to get the accuracy. The maximum and minimum mesh size is 100 and 10 respectively.

3. Simulation results and analysis

The transient analysis of all the three channels is performed. Transient analysis is used to analyze loads that change with respect to time. From the analysis, the pressure difference is obtained. It is individually obtained for bend, straight and contraction channel. The result analysis is shown in Fig 4, Fig 5 and Fig 6.

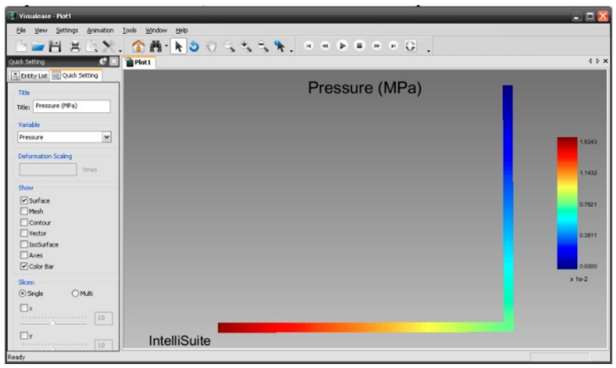

Fig 4. Pressure difference across the bend channel

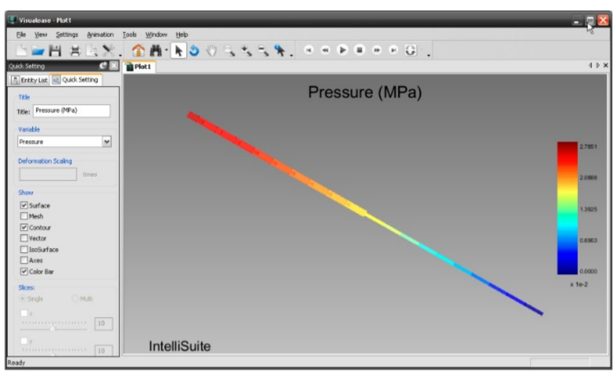

Fig 5. Pressure difference across the contraction channel

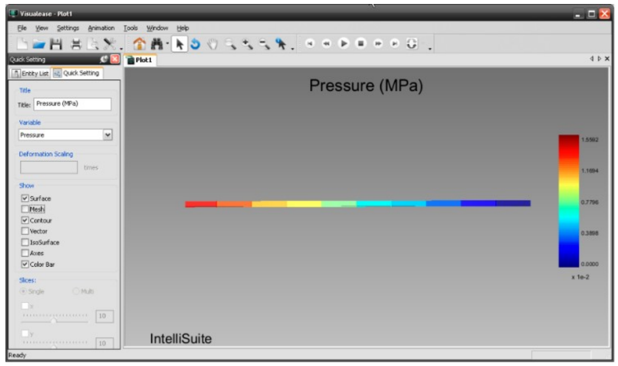

Fig 6. Pressure difference across the straight channel

4. Results and Discussion

For the flow rate of 1µl/s, the pressure difference value of straight, bend and contraction channel is obtained as 15592, 15243 and 27651 respectively.

5. Acknowledgment

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