INDIAN INSTITUTE OF TECHNOLOGY, KANPUR

SURGE-2021

Project-Report

“Pulsatile Flow”

Submitted by

Aditya Singh Kaurav

SURGE No.: 2230137
Department Of Chemical Engineering
IIT, Kanpur (U.P.)

Under the Guidance of

Prof. Ishan Sharma

Department Of Mechanical Engineering
IIT, Kanpur (U.P.)

CERTIFICATE

This is to certify that the project entitled **“pulsatile Flow”** submitted by **Aditya Singh Kaurav**(2230137) as a part of Summer Undergraduate Research and Graduate Excellence 2022 offered by the Indian Institute of Technology, Kanpur, is a Bonafede record of the work done by him under my guidance and supervision at the Indian Institute of Technology, Kanpur from 19th May, 2022 to 14th July, 2022.

Prof. Ishan Sharma
Department of Mechanical Engineering
Indian Institute of Technology Kanpur

Acknowledgements

Firstly, I will thank IIT Kanpur for giving me such an opportunity in which I learned a lot, and thanks again for giving me an opportunity to work under the supervision of such an inspiring mentor, Prof. Ishan Sharma.

I am extremely grateful to sir for encouraging me at every moment. I am thankful to him for guiding and mentoring my project. His motivation gave me a chance to explore my calibre.

I am thankful to Priyanshu Dhradhomar(M.Tech student) for helping me understand the concepts and theoretical aspects related to this work. He was always there for me whenever I was stuck. He really helped me in doing experiments and how to analyse theresults. Further, I will thank Yash Gawai(M.Tech Student) for helping me in understanding the basic concepts and how we will be using them in the software . Thanks to everyone in the department of Mechanical Engineering, IIT Kanpur for providing me with such an environment, which was filled with motivation and knowledge that helped me develop my interest in research and further studies. Thanks to everyone who supported and encouraged me.

Aditya Singh Kaurav

Abstract

Heart diseases are one of the major causes of death in recent years. Most of them are related to the atherosclerosis of coronary arteries, whereas the mechanism of atherosclerosis is still unknown and the only known is that the atherosclerosis occurs under the influence of blood flow and the wall stresses on vessel walls. In the present study, in order to obtain the information of unsteady flow in the blood vessels, the flow structures of pulsatile flows in an elastic tube modelled as a blood vessel are investigated. We are making sinusoidal flows in an elastic pipe with the help of a peristaltic pump. To apply pressure on the flow we are making a acrylic box in which with the help of air bag we are trying to maintain certain pressure across fluid flow and taking the readings from the arduino.

Keywords: atherosclerosis, elastic tube, sinusoidal flow, acrylic box, air bag

Contents

1. Introduction:

The heart diseases are one of the major causes of death in recent years. The most severe one, the acute myocardial infarction, is known to occur due to the necrosis of the cardiac muscles caused by the atherosclerosis of coronary artery, which supplies nutrition into the cardiac muscles. The mechanism of atherosclerosis, i.e. inception, growth and break down of atherosclerotic lesion is still unknown, and the only known is that the atherosclerosis occurs under the influence of blood flow and the wall stresses on vessel walls.

Recently, many researchers have begun to study the mechanism of atherosclerosis in the fluid dynamics sense. Many of them1)-" are based on the computational fluid dynamics (CFD), which is developing rapidly, and have provided the detail descriptions of unsteady flow structures in modeled blood vessels. However, there seems not to be sufficient data for the validation of CFD results, and most of experimental works done before are limited to steady3' or pulsatile4) flows in model vessels with rigid wall, where the interaction between the elastic motion of vessels and the pulsatile blood flow produced by the real heart might play an important role in the atherosclerosis.

We have developed a pump system consisting of a constant flow pump, three sinusoidal wave plungers and a rectified sinusoidal wave pump with delivery and suction valves5', which have been found to be able to produce any periodic flows including the imitated pulsatile blood flow in arteries. In the present study, with the aid of the above pump system, the flow structures of pulsatile flows in an elastic tube modelled as a blood vessel are investigated.

2. Experimental Setup:

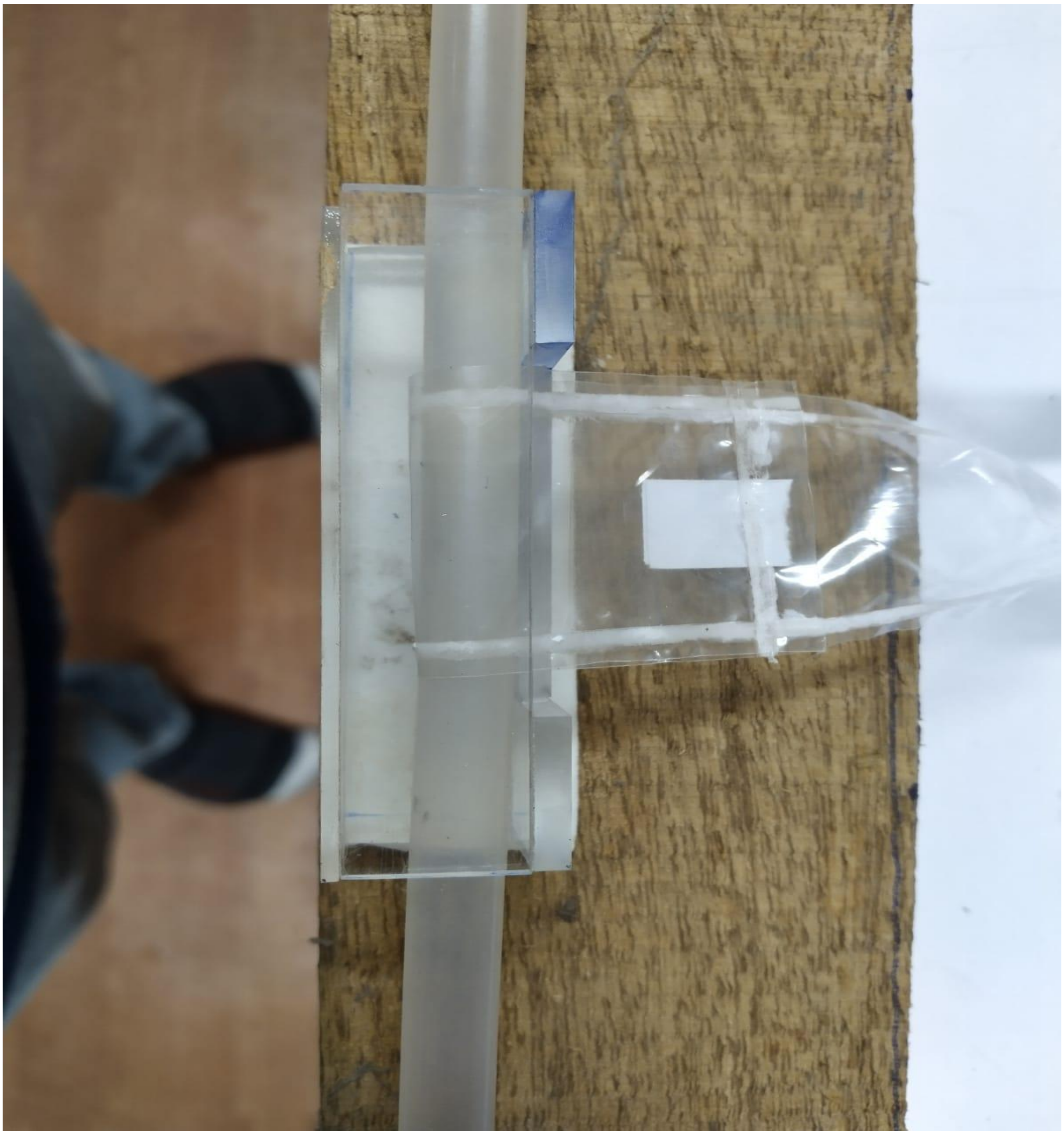
Airbag making:-

The sheet thickness here used is 50 micrometers. First, we are using a sheet of 23 micrometers but it was not able to hold the pressure and was again and again breaking. So we choose 50 micrometers. There was issue with the flex coming due to which the camera was not able to tae the proper picture but it can't be resolved completely. We have used a plastic bag sealing machine to make airbags from the sheet.

Picture of the air bag

Acrylic box making:-

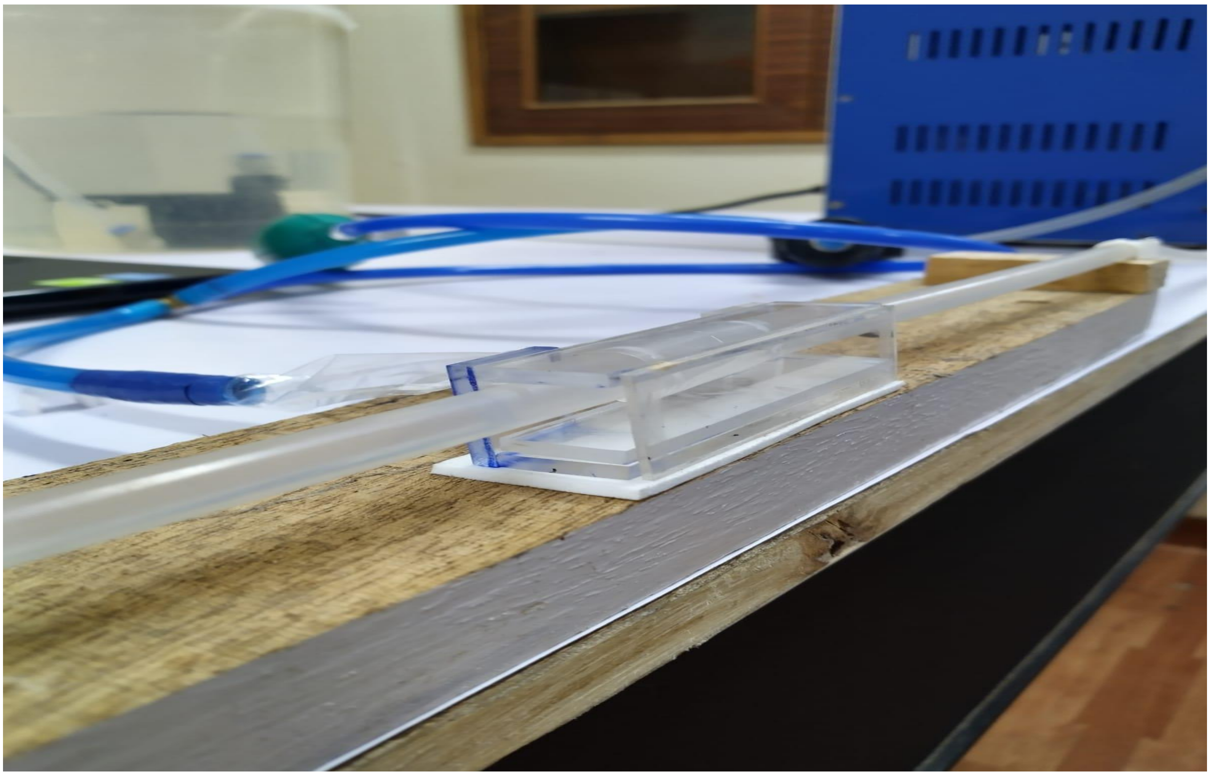
We have taken the sheet of a thickness of 3mm for making the acrylic box. The dimensions of the box are 70x15x15. For making it we have done grinding and cutting by both hands and by machine in the lab. Chloroform is used to make the final box by joining several pieces of the sheet. The final box looks like as:-



To make our system stable while doing experiments we have fixed acrylic box with pipe and airbag on the wooden box. The whole setup has now been fixed on the table.

Airbag and pipe both will look like as:-

Airbag, pipe, and acrylic box together are combined like as:-



3.Results

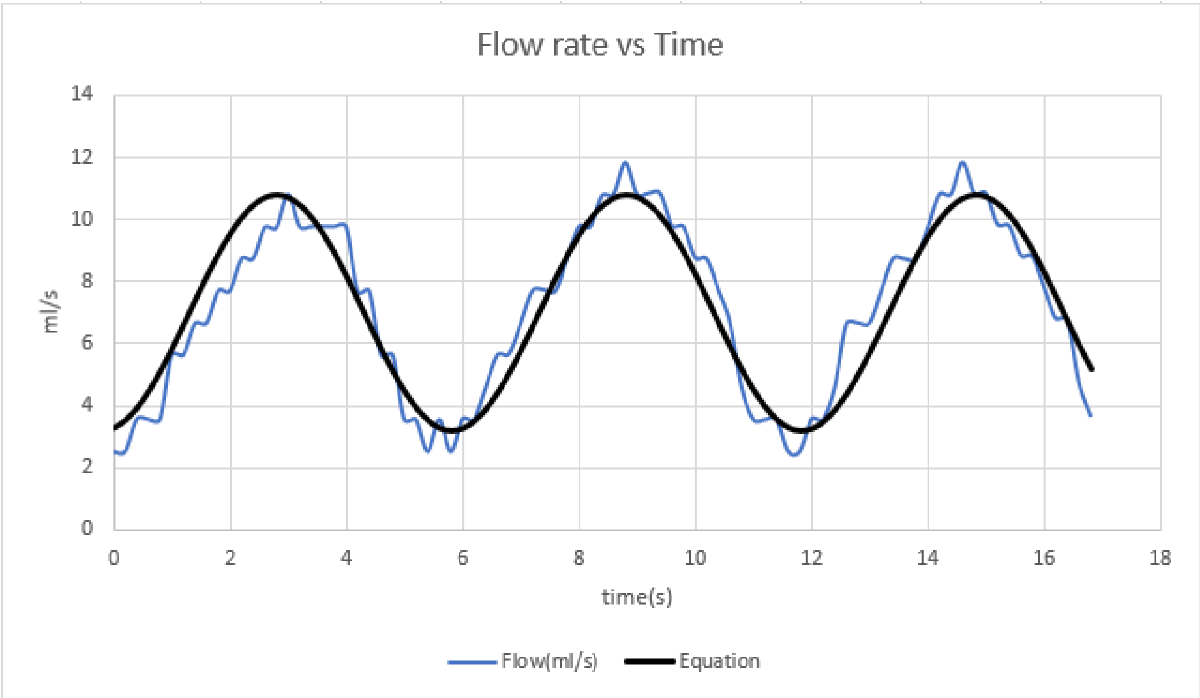
Using water as a fluid and 66.6 frequency in peristaltic pump.

We got the following data:

1	Time(s)	Flow(ml/s)	Pressure(mmHg)	Equation	pressu	velocit	velocit
2	0	2.531353116	0	3.29543854	-0.12928	0.089574	0.116611
3	0.2	2.536484241	1.9	3.5527586	-0.0516	0.089755	0.125717
4	0.4	3.572968483	0.75999999	3.96012482	0.065614	0.126432	0.140132
5	0.6	3.572968483	1.9	4.49981919	0.217273	0.126432	0.159229
6	0.8	3.572968483	1.519999981	5.14836825	0.396775	0.126432	0.182179
7	1	5.645936966	1.9	5.87756398	0.596316	0.199785	0.207982
8	1.2	5.645936966	1.9	6.65569075	0.807215	0.199785	0.235516
9	1.4	6.656765938	1.139999986	7.44890469	1.0203	0.235554	0.263585
10	1.6	6.682421207	1.9	8.22270574	1.226302	0.236462	0.290966
11	1.8	7.718904972	0.379999995	8.94343819	1.416263	0.273139	0.31647
12	2	7.718904972	1.519999981	9.57975448	1.58192	0.273139	0.338986
13	2.2	8.75538969	1.139999986	10.1039787	1.716067	0.309816	0.357536
14	2.4	8.75538969	1.9	10.4933102	1.81287	0.309816	0.371313
15	2.6	9.75538969	1.519999981	10.7308153	1.86812	0.345201	0.379717
16	2.8	9.750824928	2.279999971	10.8061641	1.879412	0.34504	0.382384
17	3	10.82835865	1.9	10.7160793	1.846255	0.383169	0.379196
18	3.2	9.791873932	2.279999971	10.4644791	1.770093	0.346492	0.370293
19	3.4	9.791873932	2.279999971	10.0623066	1.654237	0.346492	0.356062
20	3.6	9.791873932	1.9	9.52705382	1.503726	0.346492	0.337122
21	3.8	9.791873932	1.9	8.88200111	1.325107	0.346492	0.314296
22	4	9.791873932	2.279999971	8.15520439	1.126149	0.346492	0.288578
23	4.2	7.688118935	1.9	7.37827497	0.915504	0.27205	0.261085

Corresponding graph and equation will be:

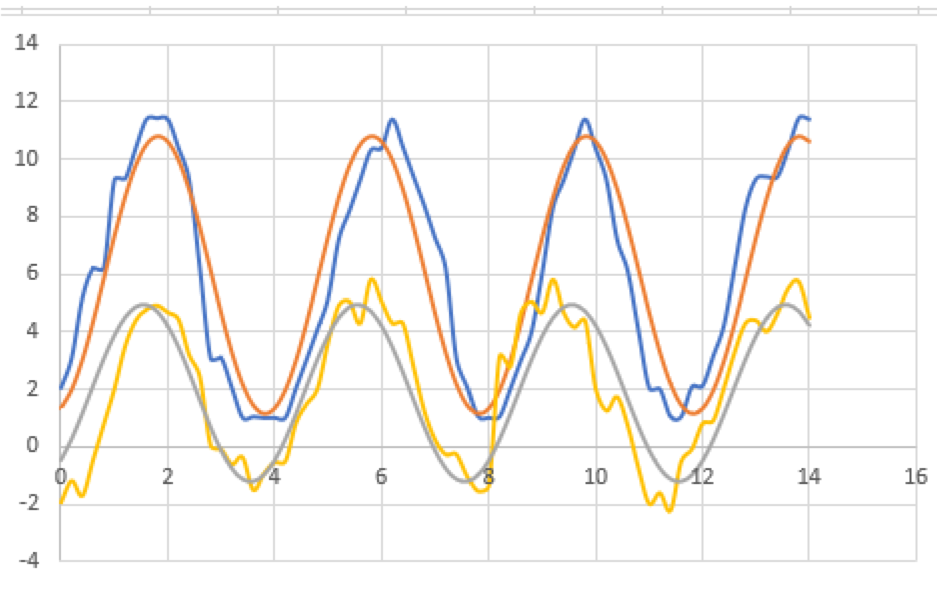
Equation = 5.59479 - 3.82431sin(29.2559 - 1.08273x)



If we use 100 frequency in peristaltic pump then the graph would be like as :

Time(s)	Flow rate	Curve fit	ADC	PRESSURI	pressure curve fi	velocit	velocity (
0	2.07296848	1.37035678	151	-1.960001	-0.481468166	0.073353	0.048491
0.2	3.10945249	2.01318325	152	-1.2000008	0.253454102	0.11003	0.0712379
0.4	5.18242121	3.04587479	155	-1.7200012	1.144390771	0.183384	0.1077804
0.6	6.21890497	4.36744598	157	-0.4799995	2.104218427	0.22006	0.1545452
0.8	6.21890497	5.84866228	159	0.76000023	3.039076906	0.22006	0.206959
1	9.28217793	7.34467767	161	2	3.857547743	0.328456	0.2598966
1.2	9.32835865	8.70919897	159	3.47999954	4.479593855	0.330091	0.3081811
1.4	10.4013262	9.80879161	158	4.37999916	4.844386246	0.368058	0.347091
1.6	11.4013262	10.535928	155	4.76000023	4.916252394	0.403444	0.3728212
1.8	11.4378099	10.8195025	151	4.89999962	4.688164613	0.404735	0.3828557
2	11.4013262	10.6317848	149	4.65999985	4.182427277	0.403444	0.3762132
2.2	10.4013262	9.99113157	146	4.42000008	3.448495714	0.368058	0.3535432
2.4	9.28217793	8.9601913	137	3.18000031	2.558140033	0.328456	0.3170627
2.6	6.21890497	7.63977818	138	2.42000008	1.598426834	0.22006	0.2703389
2.8	3.10945249	6.15901352	146	0.03999901	0.66320509	0.11003	0.217941
3	3.10945249	4.66269916	139	-0.1000004	-0.156071211	0.11003	0.1649929
3.2	2.07296848	3.29715752	146	-0.6200008	-0.779286221	0.073353	0.1166722
3.4	1.03648424	2.19592295	150	-0.3800011	-1.14549664	0.036677	0.0777043
3.6	1.07296848	1.4666836	149	-1.5200005	-1.218891279	0.037968	0.0518996
3.8	1.03135312	1.18075074	155	-0.9400005	-0.992292982	0.036495	0.0417817
4	1.03648424	1.36608532	158	-0.5600004	-0.48786047	0.036677	0.0483399
4.2	1.03648424	2.00456374	156	-0.5200005	0.245078528	0.036677	0.0709329
4.4	2.07296848	3.03375013	160	0.81999969	1.134850963	0.073353	0.1073514

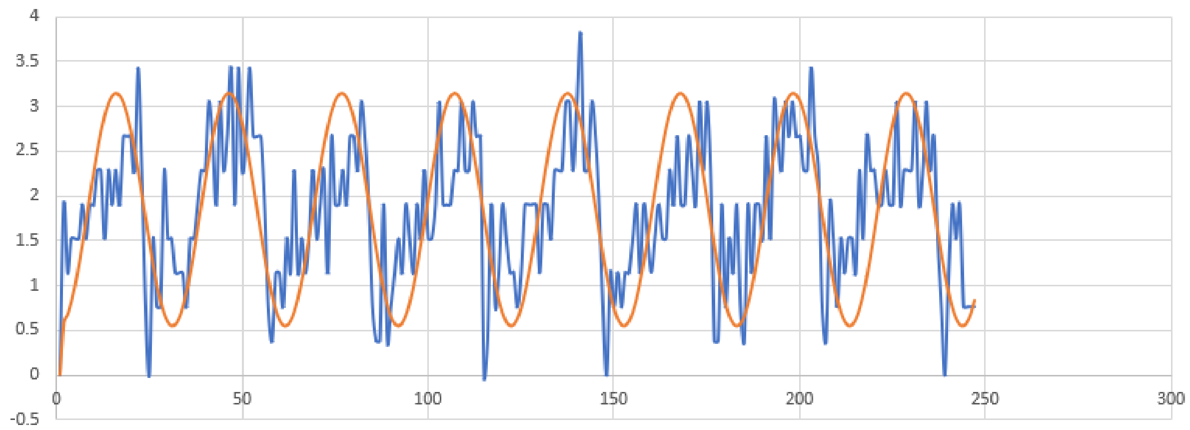
pressure	mmHg
flow rate	ml/s
velocity	m/s



Now using 50% mixture of glycerol and water the graph would be like as:

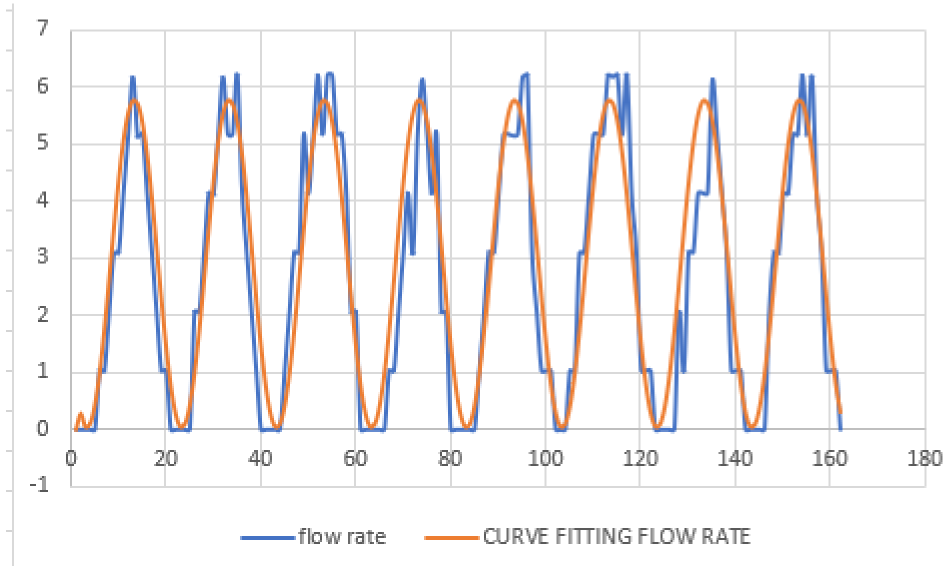
With 66.6 frequency

1	Time	flow rate	pressure	flow rate curve fitting	pressure curve fitting	velocity	velocity curve fitting
2	0	0	1.9	0.360981712	0.584538869	0	0.012773592
3	0.2	0	1.13999999	0.167219795	0.67351096	0	0.00591719
4	0.4	0	1.51999998	0.093912253	0.812764644	0	0.003323151
5	0.6	0	1.51999998	0.144188558	0.996355461	0	0.005102214
6	0.8	0	1.51999998	0.315902431	1.216446286	0	0.01117843
7	1	0	1.9	0.601723471	1.463641884	0	0.021292409
8	1.2	0	1.51999998	0.989450081	1.72738997	0	0.035012388
9	1.4	0	1.9	1.46253035	1.996431668	0	0.051752666
10	1.6	0	1.9	2.000768654	2.259282126	0	0.070798608
11	1.8	1.03648424	2.27999997	2.581187794	2.504720787	0.0366767	0.091337148
12	2	2.07296848	2.27999997	3.179009885	2.722270365	0.0733534	0.112491503
13	2.2	3.10945249	1.51999998	3.768714121	2.902644105	0.1100302	0.133358603
14	2.4	2.07296848	2.27999997	4.325126238	3.038142215	0.0733534	0.153047638
15	2.6	4.14593697	1.9	4.824493206	3.122980551	0.1467069	0.170718089
16	2.8	3.09405947	2.27999997	5.245497228	3.153537536	0.1094855	0.185615613
17	3	4.14593697	1.9	5.570165796	3.128508752	0.1467069	0.197104239
18	3.2	5.18242121	2.65999985	5.784638924	3.048962628	0.1833836	0.204693522
19	3.4	5.18242121	2.65999985	5.879760833	2.918294829	0.1833836	0.208059477
20	3.6	6.18242121	2.65999985	5.851470804	2.742083302	0.2187693	0.207058415
21	3.8	5.18242121	2.27999997	5.700976526	2.527850162	0.1833836	0.201733069
22	4	6.18242121	3.42000008	5.434702546	2.284740593	0.2187693	0.192310777
23	4.2	6.18811894	2.27999997	5.064016005	2.023132455	0.2189709	0.179193772
24	4.4	5.18242121	0.75999999	4.604741377	1.754193275	0.1833836	0.162942016



With 100 frequency

Time	Flow rate	pressure	flow rate curve fitting	pressure curve fitting	velocity	velocity curve fitting
0	0	0.75999999	0.275450563	0.236612041	0	0.009747012
0.2	0	1.9	0.052949492	0.516206466	0	0.001873655
0.4	0	1.13999999	0.109744332	0.877256173	0	0.00388338
0.6	0	1.51999998	0.440281199	1.284454632	0	0.01557966
0.8	1.03648424	1.51999998	1.012237369	1.697982491	0.0366767	0.035818732
1	1.03648424	1.51999998	1.76968207	2.077401457	0.0366767	0.062621446
1.2	2.07296848	1.51999998	2.638545876	2.385608695	0.0733534	0.093366804
1.4	3.09405947	1.51999998	3.533863847	2.592465063	0.1094855	0.125048261
1.6	3.10945249	2.65999985	4.368084127	2.677742376	0.1100302	0.154567733
1.8	4.14593697	2.65999985	5.059629516	2.633101486	0.1467069	0.179038553
2	5.14593697	3.03999996	5.540874787	2.462907763	0.1820926	0.196067756
2.2	6.18242121	2.65999985	5.764759657	2.183804206	0.2187693	0.20399008
2.4	5.14593697	2.27999997	5.709390748	1.823083949	0.1820926	0.202030812
2.6	5.18242121	2.27999997	5.380182504	1.416021307	0.1833836	0.190381547
2.8	4.15676594	1.51999998	4.809327727	1.002422351	0.1470901	0.170181448
3	3.10945249	-1.14	4.052649483	0.622732325	0.1100302	0.143405856
3.2	2.07296848	0.75999999	3.184142248	0.314080572	0.0733534	0.112673116
3.4	1.03648424	1.51999998	2.288736094	0.106649701	0.0366767	0.080988538



4. Summary and Conclusions:

So, to set the same environment as we are having in our arteries , we have made an elastic pipe in which water is flowing in the form of sinusoidal waves with the help of a peristaltic pump. And with the help of acrylic box and air bag we are able to put it in the condition of a pressure and controlling frequency of sinusoidal wave with the peristaltic pump , so that our objectives of doing this experiment would be fulfilled.We were taking inputs using arduino.

By analysing these graphs we can say that after changing composition of mixture we can observe no such changes in the graph , so not much frequency. But as frequency is decreasing wave form is becoming weak , so the time interval is also increasing.

References:

1. Development of Pulsatile Flow Experiment System and PIV Measurement in an Elastic Tube
   By Takashi EGUCHI * , Satoshi WATANABE * * , Hisasada TAKAHARA * * * and Akinori FURUKAWA * * * *