

ANALYSIS OF MICROMIXER FOR BLOOD FLOW USING ANSYS

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ARTICLE INFORMATION

Citation: Saher Manzoor, Maham Akhlaq, & Faheem Qasim. (2022). ANALYSIS OF MICROMIXER FOR BLOOD FLOW USING ANSYS. Pakistan Journal of Emerging Science and Technologies, 2(2), 8. <https://doi.org/10.5281/zenodo.5851259>

Received: 5th January 2022

Revised and Accepted:

09-January-2022

Published On-Line

18-January-2022

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Original Research Article

ABSTRACT

In the last few decades, micro-fluidic devices have gain enormous attention due to their excellent applications in the field of bio-medical, electronics and energy. However, among various types of micro-fluidic devices, micro-mixers are gaining much attention due to their applications in drug delivery, insulin and medicine insertion. Passive micromixers without any external power can be used to reduce the viscosity of the blood in human body by inserting an anticoagulant medicine. This work analyzes various ambient parameters including velocity, temperature and pressure when an anticoagulant is inserted to the blood in human body to reduce the hyperviscosity syndrome. ANSYS fluid flow simulation is used to design two inlets, one donating the human blood and other donating the anticoagulant and an outlet with consist of the mixture of both inlet fluids. The results show that the basic parameters can largely affect the passive micromixers resulting in better mixing of the fluid owning the change in their velocity, pressure and temperature profiles.

Keywords: ANSYS, fluid flow, micromixer, flow rate

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Introduction:

Micro-fluidic device gained enormous attention in the last few decades owing to the reason of its enhanced applications in the field of bio-medical, diagnostic and food safety [1]. These devices gain special attention due to their small size, automatic operation, faster fluid movement and less use of the fluid [2, 3]. These devices are usually found on centimeter level chips as an integrated device for use to drug and insulin delivery with in human body. Micro-fluidic devices comprises of various different device among which micromixers are an important type of device [4]. Micromixers devices shows excellent efficiency and sensitivity in terms of various other micro-fluidic devices [5, 6].

These devices does not rely on convection effect but depends upon the external turbulence to manifest the flow of fluid throw the micro-channels [7]. This provide enhanced mass as well as heat transfer rate along with superior surface area to volume ratio. With low flow rate and laminar flow regime, the mixing in micromixers depends on the diffusion with less mixing efficiencies. In a typical water based micro-fluidic system, it takes 1s to diffuse the fluid by 1 μm , which requires an increase in efficiency of the micro-mixing system for micro-fluidic devices [8].

Micromixers are classified in two different types including active and passive micromixers for the mixing of different fluids. In active micromixers, pressure, temperature and other external factors contribute towards the flow and controlling of fluid mixing. In passive micromixers, no external factors and forces are applied to the mixing of fluid, thus this process is slow and depends on molecular mixing [9]. Within the passive micromixers, the mixing of fluid depends on factors including (a) Laminar flow [10] (b) Eddy formation (c) SAR (split and recombination process). The laminar flow for fluid mixing is subsequently used for T mixing where fluid flow in two parallel layers without any disruption before mixing [11]. This type of micro-mixing have applications in drug delivery and insulin delivery in blood via the blood vessel. The micro-mixer provide applications in the addition of medicine which reduces the viscosity of blood in time of blood thickening. The cause of blood thickening is based on the hyperviscosity syndrome which reduces the blood flow, and results in chances of combination of blood cells to make a clot [12]. In hyper viscosity case, the blood viscosity increases more than 5.5 cP. In this case, anticoagulants are used to prevent and reduce the formation of blood clot. Using anticoagulants reduces the effect of heart attack and stroke [13].

Several studies has been performed to analyze the blood flow in micro-channels for bio-medical applications [14-22]. On the other hand, the micromixing of blood with other medicine has been examined however, the requirement of Reynolds number having a value between 0.01 to 100 to maximizing the flow of fluid for proper mixing and diffusion of both the fluid. In this work, a laminar flow based on T mixing of blood under hyperviscosity syndrome and anticoagulants to study the effect of velocity, temperature and pressure of the two fluids on the outlet mixture is analyzed using ANSYS fluid flow simulations.

ANSYS Simulations

Fluid flow (fluent) simulations has been performed for micro mixture flow. The commercial ANSYS fluent software has been used for the simulations. The designed geometry comprises of two inlets and one outlet. One inlet is a vein containing blood and the other inlet consisting of an anticoagulant. At both the inlets different liquids flow toward the conjunction point and then combined fluids flow toward the outlets as a mixture. The viscosity of both the fluids is different resulting in varied pressure and velocity at both inlets.

The geometry designed in design modular is shown in figure 1. The model consists of two inlets, one output and fluid domain with the diameter equal to 3mm.

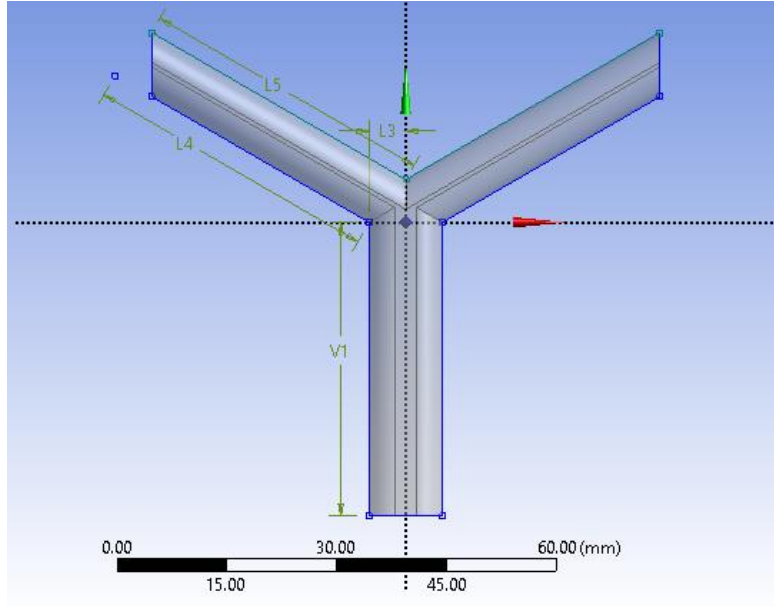


Figure 1: Designed geometry for micro mixture flow

The second and most important step of the simulations is meshing. For accurate results, cell density of the model has been varied for similar boundary conditions. The meshing has been done for up to 7524 elements and 2541 nodes.

Tetrahedron meshing has been done the designed geometry to discretize the computational area for up to 55081 elements and 11286 nodes. Figure 2 represents the meshed geometry.

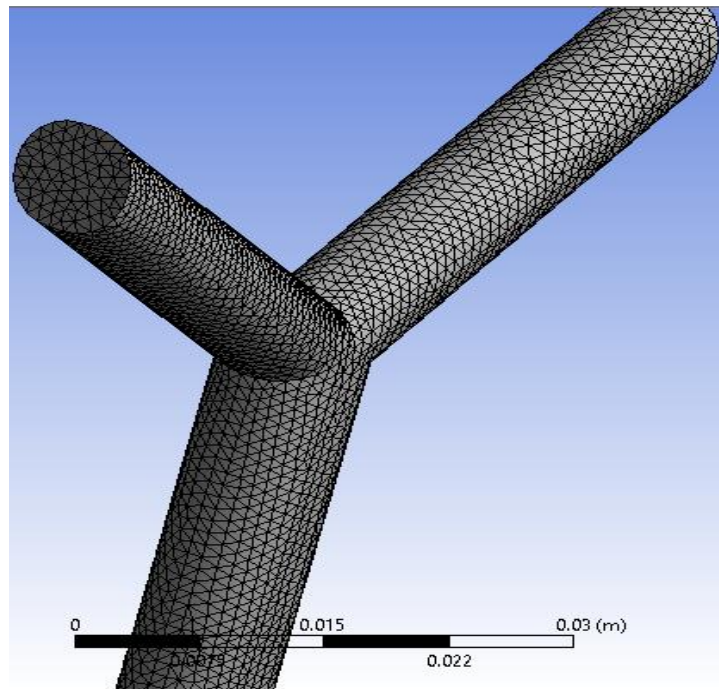


Figure 2: Meshed geometry.

In the fluid domain, two fluids of varied viscosity have been used for each inlet. The fluid temperature is set as 290K and 325K for inlet 1 and inlet 2 respectively. As blood is high temperature as compared to other fluid, the inlet having the blood is set at a temperature 325K and for the anticoagulant the temperature is set at 290K.

Results and Discussion

Streamline fluid flow has been shown in figure 3. As the viscosity of the fluids blood and anticoagulant is different at both inlets, the velocity at which the fluid flow at both inlets is extremely different which can be seen in figure 3. As the blood flow is quite high as compare to the anti-coagulant, the velocity at the inlet where the blood enter is high as compare to the inlet from where the anti-coagulant enters. The velocity at the inlet with blood is 5.118 ms^{-1} and at the inlet with anticoagulant is 1.279 ms^{-1} as shown in figure 3.

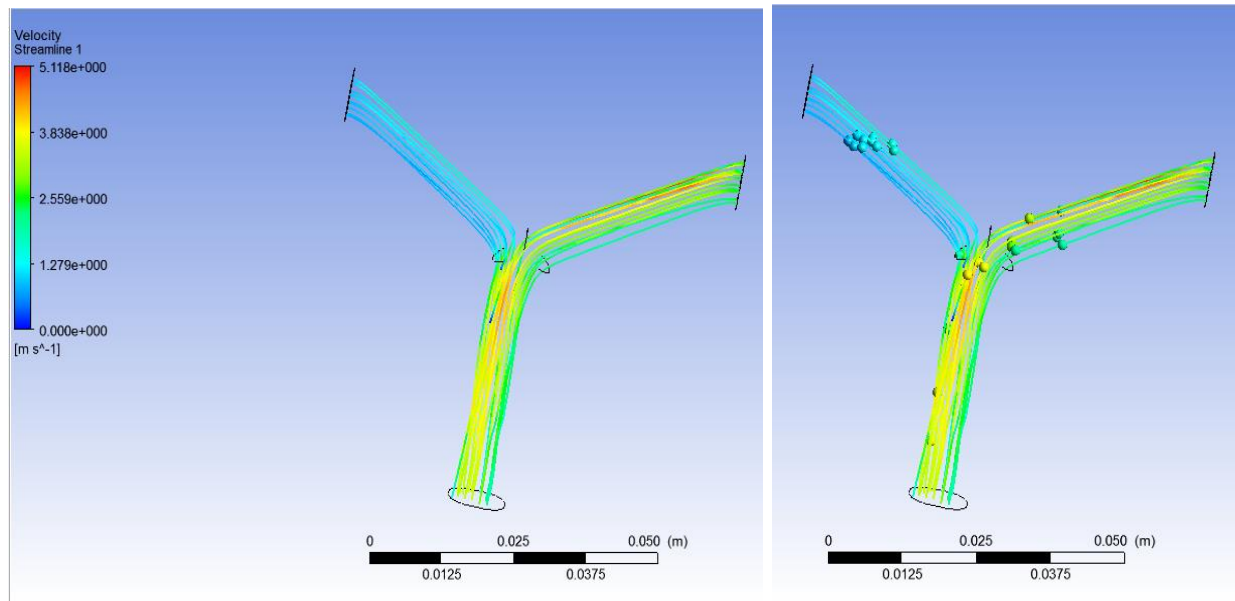


Figure 1: Velocity streamline for micro mixture fluid flow

The contour plots in figure 4 illustrate the velocity contour of the simulation. It can be seen that the blood entering from the vein has high velocity as compared to the fluid for anticoagulant. However, the velocity of the blood decreases when the two fluid meet at the inlet and moves towards the output. This clearly shows that the fluid mixing results in a change in velocity in the fluid when both the fluids meet. Figure 4 clearly shows that the maximum velocity of blood in inlet 1 is 4.963 ms^{-1} and maximum velocity for anticoagulant in inlet 2 is 1.551 ms^{-1} . The outlet velocity decreases and it shows a maximum value of 4.653 ms^{-1} .

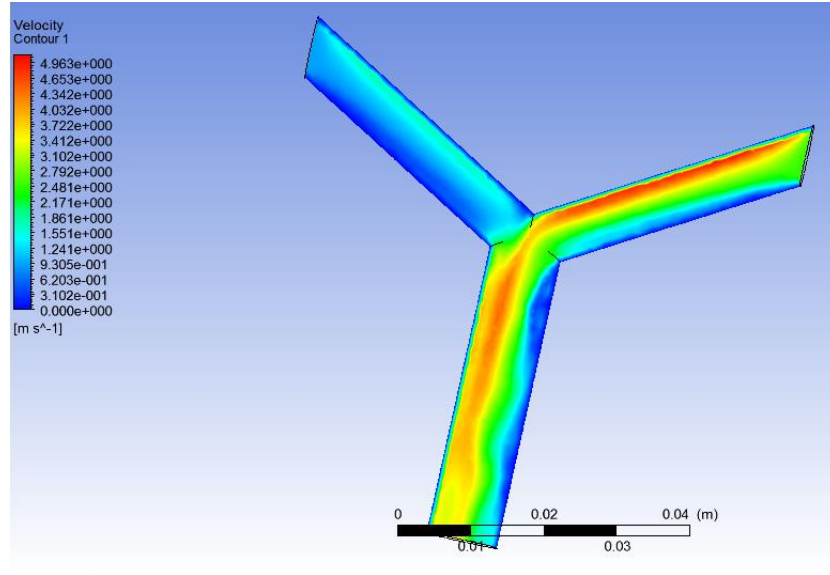


Figure 2: Velocity contour for the inlet and outlet of the proposed design of micromixer

Figure 5 shows the velocity vector for the inlet and outlet of the proposed design. The velocity vector is maximum with a value of 5.118 ms^{-1} for inlet with blood and 1.271 ms^{-1} for anticoagulant. However, the mixing in the outlet decreases as shown in figure 5. The mixing of the fluid is thus clear from the velocity vector as shown in figure 5.

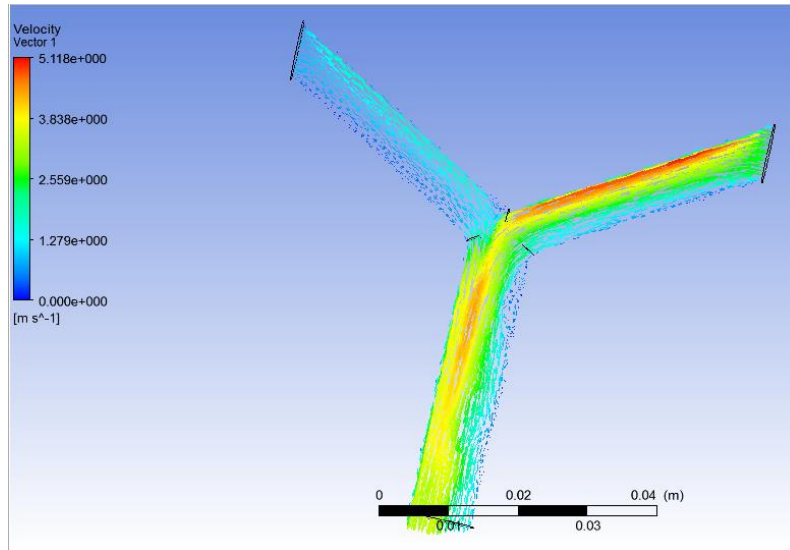


Figure 3: Velocity Vector for the inlet and outlet of the proposed design micromixer

The temperature contour is shown in figure 6. The temperature of the blood through inlet 1 is maximum before mixing having a value of 325K and the anticoagulant from inlet 2 have a temperature of 290K. Figure 6 clearly shows at the conjunction of outlet and inlet, the temperature of both the inlet fluid merges and a shift in temperature has been observed in the outlet. This shows that the addition of anticoagulant will significantly reduce the temperature of the blood.

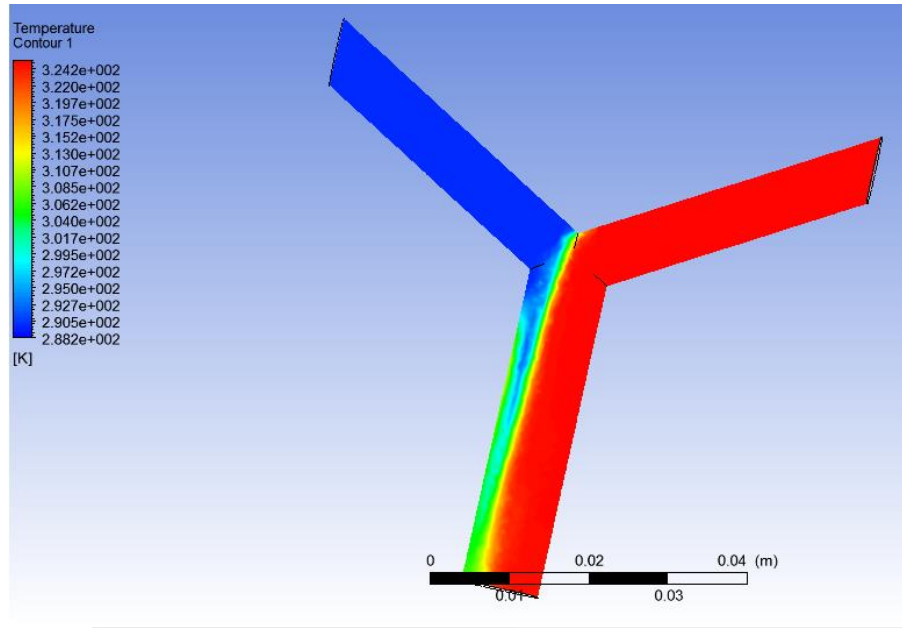


Figure 4: Temperature Contour for the inlet and outlet of the proposed design of micromixer

Figure 7 shows the pressure contour of the inlet and outlet of the proposed design of the micromixer. The pressure of the fluid at the inlet 1 and inlet 2 are higher having a value of 2.47×10^3 Pa and 5.84×10^3 Pa respectively. Since the pressure at inlet was high, fluid flow decreased coming toward the outlet.

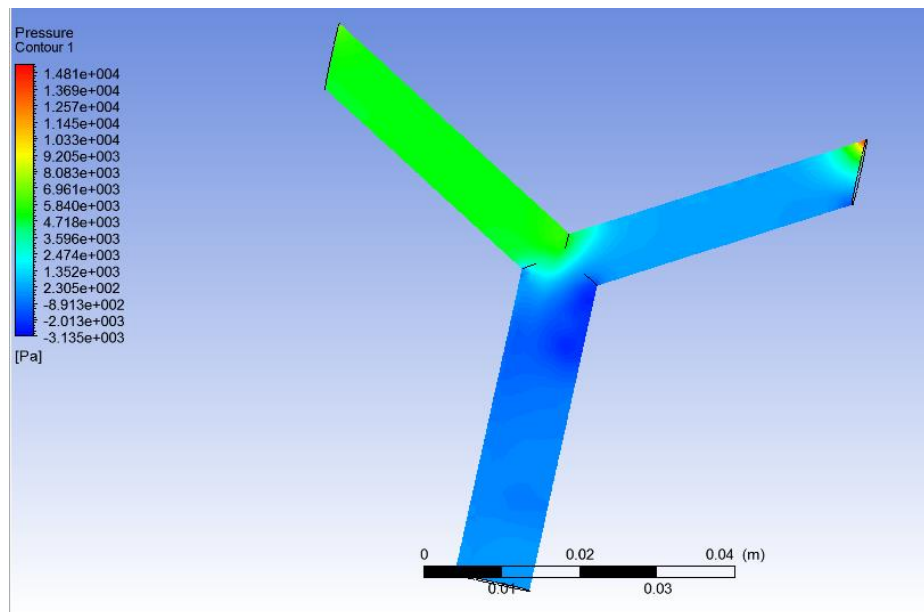


Figure 5: Pressure Contour for the inlet and outlet of the proposed design of micromixer

Conclusion

This work provides a simulation based on Fluid flow (fluent) simulations in ANSYS to analyze the effect of various parameters during the micromixing of the blood and anticoagulant for reducing the hyperviscosity syndrome. The micromixer geometry is created in ANSYS with two inlets, one containing the blood and other containing the anti-coagulant to reduce the viscosity of the blood. The two-fluid mix at the outlet and the velocity, pressure and temperature of the outlet is analyzed. The results show that at the outlet, the velocity of the blood decreases with the addition of the anticoagulant. Furthermore, the temperature of the blood also decreases however, fluid flow decreased coming toward the outlet since the pressure at inlet was high. The result depicts that basic parameters can largely affect the passive micromixers resulting in better mixing of the fluid owning the change in their velocity, pressure and temperature profiles.

Author's Contribution: F.Q, Conceived the idea; M.A, S.M, designed the simulated work in ANSYS; M.A., F.Q., did the interpretation of data; S.M did the data analysis; M.A., S.M., wrote the basic draft, S.M., did the language and grammatical edits or Critical revision.

Funding: The publication of this article was funded by no one.

Conflicts of Interest: The authors declare no conflict of interest.

Acknowledgement: The authors would like to thank the Nano-Electronics lab, Department of Physics (Electronics), GC University Lahore for assistance with providing facility to access the ANSYS software.

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