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Fluidic simulation for blood flow in five curved Spiral Microchannel

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ABSTRACT

This study presents ANSYS FLUENT and Fuzzy Logic MATLAB simulation for the study of blood flow in five curved spiral shaped tortuous vein. The dimensions of spiral microchannel used in simulation are 30 mm long and 2 mm in radius. ANSYS simulation has given 0.26 µL/s flow rate with velocity 0.02055 m/s while FUZZY simulation has given 0.29 µL/s with velocity 0.02647 m/s. The results from both simulation and previous results found in a close settlement at the same Reynolds number and pressure. This study is very important for examining the blood flow rate with blood velocity. This simulated research is helpful in finding the cure for diseases.
Keywords: MEMS, Microfluidics, Microchannels, ANSYS FLUENT, Fuzzy Logic

INTRODUCTION

Microfluidics is relatively a novel branch of micro-electromechanical system (MEMS) which has prepared extensive progress in the last twenty years (Thakur *et al.,* 2016). This improvement focused on growing responsiveness for the analysis of laminar blood flow in microchannels (Ragheb *et al*., 1999, Hansen 2008). The usage of microchannels in all natural and biomedical structures is widespread (Oloffs *et al.,* 1994). A noticeable and an innovative category of microchannel is the spiral microchannel with their numerous biomedical applications (Mihov & Katerska 2010). The filtration and parting of micro-particles is significant for many fields like micro/nano engineering, medical and liquid flow investigation (Hennessey *et al.,* 2017, Kübler & Reczuch 2017). Spiral microchannels have been functioned for Deoxyribonucleic Acid (DNA) on a compact disc (Peng *et al.,* 2007). It has been investigated that the parting of micro-particles with liquid rate of flow (0.3 micro liter per second) by the use of “differential migrations and dean flow” (Bhagat *et al.*, 2008). Dielectro-phoresis systems have been investigated for the separation of numerous particles (Zhu & Xuan 2011). Cell partings have been investigated with rate of flow (3milli Liter per minute) through spiral channels (Nivedita, *et al.,* 2013). Spiral channels have been investigated for quadrangular with trapezoidal samples on the basis of mass and examined the parting with rate of flow (0.5 milli Liter per minute) (Guan, *et al*., 2013). Spiral channels have been investigated on extraordinary speedy blood plasma parting (Rafeie, *et al.,* 2016). Binary spiral microchannel has been examined and found the increased flow rate for the dual droplet trains with the rise in Reynolds number (Xue *et al*., 2016). Afzal *et al*., 2017 and 2018 use Fuzzy and ANSYS simulation for the study of varicose veins. Some tortuous veins are like spiral channels (Afzal *et al*., 2017 and 2018). Many more researchers have found ANSYS and Fuzzy simulation useful for their studies (Tayyaba *et al*., 2016 and 2017) (Afzal *et al*., 2018). Spiral microchannel has been used for cell parting and biomedicine applications (Liu *et al.*, 2019). The transfer of heat was enhanced with the flow rate in spiral microchannels. Though, the flow rate of hot water had a slight effect on the performance of spiral microchannel. It presented a decent consistency and operation constancy for a bigger heat transfer (Ling *et al*., 2019). The accumulative development in ANSYS, Fuzzy simulation and micro-fabrication predicts that spiral microchannels will play a leading role in research and commercialization of medical diagnostics. Therefore, in this study, the authors have simulated

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first time a five turn spiral microchannel for the blood flow rate through ANSYS FLUENT and Fuzzy Logic MATLAB.

ANSYS FLUENT Simulation for five curved spiral microchannel

Spiral microchannel of five turns is simulated with ANSYS FLUENT. The dimensions of this channel was 30 mm long and 2mm in radius. This spiral model consisted of inlet, wall, fluid region and outlet. For precision of results, the meshing of the channel has been completed. Elements (25760) and nodes (30426) with tetrahedron technique were built in meshing analysis. Results have shown below (figure 1) in the contours. As stated by results converse relation of pressure and velocity obtained. It can be perfectly said from the next figure1 that the pressure at input was increased and have lower speed and at the output was lower with high speed.

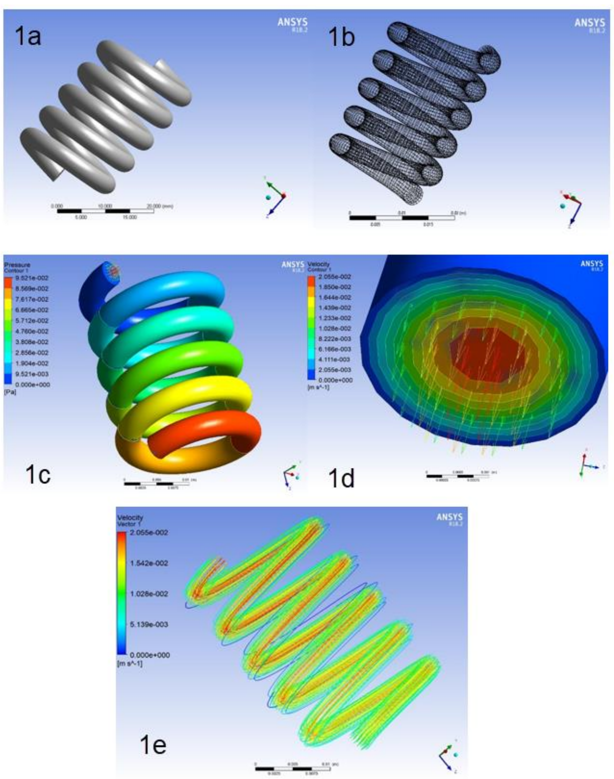


Fig. 1a, b, c, d, and e: (a) design modeler (b) mesh (c) Contour of pressure; (d) Contour of velocity and (e) Contour of streamline view.

The following graphs obtained through ANSYS FLUENT 18.2 between Reynolds number and pressure drop and the other one is between Reynolds number and the flow rate. Direct relation is shown by both graphs here in figure 2(a, b). At Reynolds number 44.11, the flow rate increased up to 1.41%. At Reynolds number 264.68, the flow rate increased up to 11.27%. At Reynolds number 441.01, the flow rate increased up to a maximum of 18.31%. This means that flow rate increased gradually at a steady rate. The details of increasing flow rate are shown in bar graph in the figure 2(b).

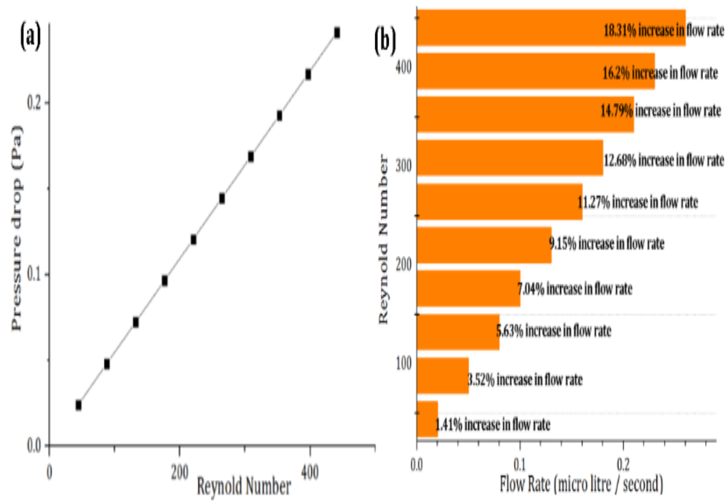


Fig. 2a & b: (a) graph between Reynolds number and pressure drop, (b) bar graph between Reynolds number and flow rate.

According to simulation, at 95 mPa, channel radius 2 mm, channel length 30 mm the flow rate has the value 0.26 (µL/s). The velocity is calculated by the software is 0.0255 (m/s).

FUZZY Logic Simulation for five curved spiral microchannel

For building a Fuzzy controller (5CSMCFC), it has three inputs (Pressure in kilo Pascal, Channel radius in mm and Channel length in mm) with only one output and i.e. flow rate (µL/s). 5CSMCFC is shown in the figure 3 below.

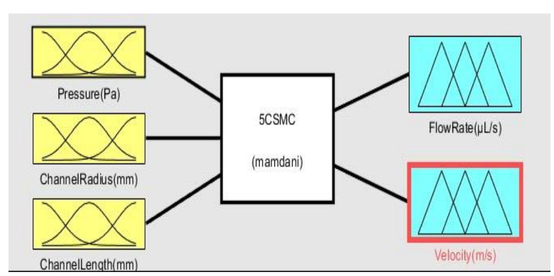
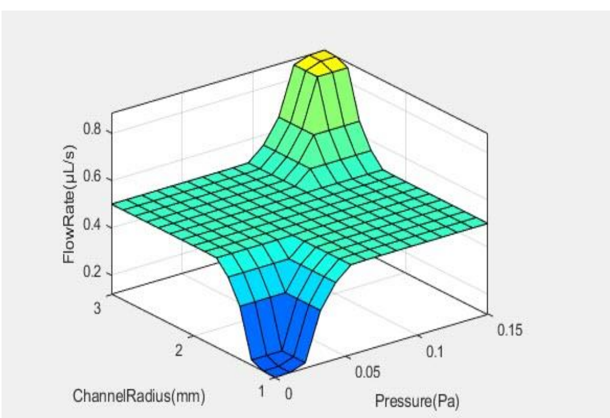


Fig. 3: 5CSMCFC

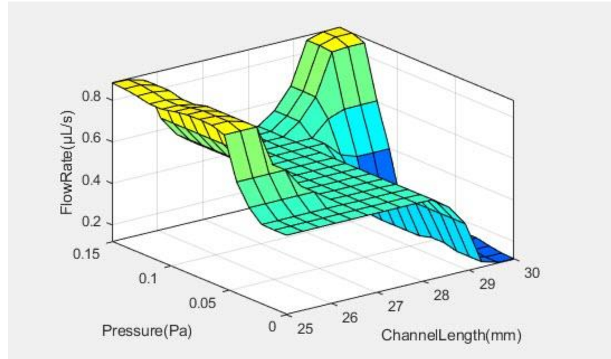
All membership functions have different ranges. This 5CSMCFC has twenty-seven rules built on “if and then statement”. According to simulation, at 95 mPa, channel radius 2 mm, channel length 30 mm the flow rate has the value 0.29 (μL/s). The velocity is calculated by the software is 0.02647 (m/s).

Fig. 4: Rule Viewer for 5CSMCFC

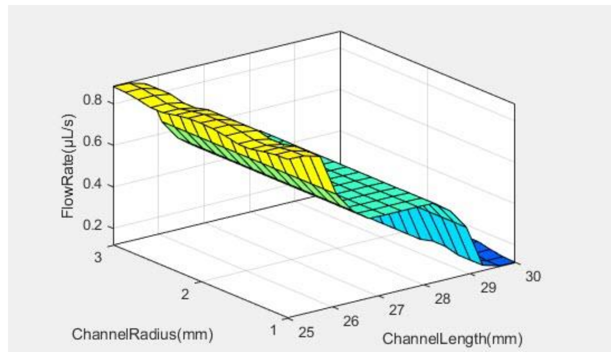
The 3D-graphs of flow rate with channel length, channel radius and pressure is shown in the following figure 5a,5b and 5c.



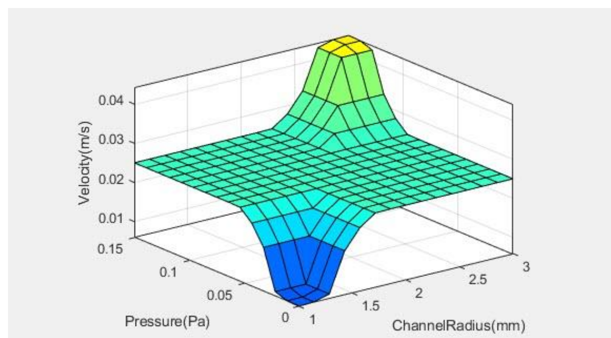
5a



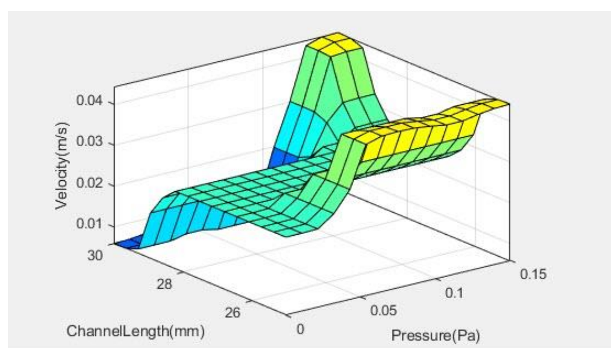
5b



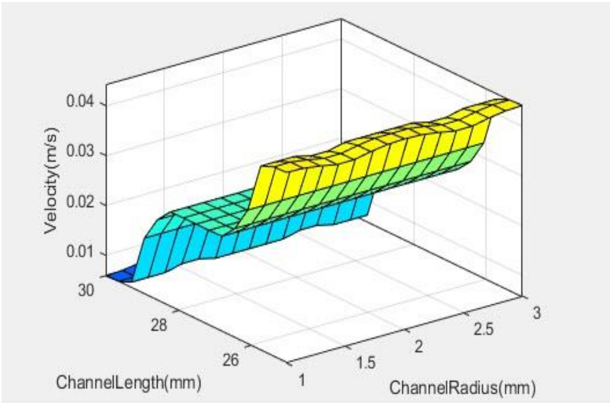
5c



5d



5e



5f

Fig. 5a, b, c, d, e, & f: 3D graphs of Fuzzy simulation, 5a (flow rate vs pressure and channel radius), 5b (flow rate vs pressure and channel length) and 5c (flow rate vs channel length and channel radius), 5d (velocity pressure and channel radius), 5e (velocity vs pressure and channel length) and 5f (velocity vs channel length and channel radius).

RESULT

Bhagat *et al*. (2008) has been shown the flow rate 0.3 µL/s for spiral microchannel (Bhagat, *et al,.* 2008). Gossett *et al*., (2010) has been shown the flow rate 1.6 µL/s for spiral microchannel (Heck *et al.,* 2017). Here, in this paper, according to ANSYS simulation, the flow rate is calculated 0.26 µL/s with velocity 0.02055 m/s at Reynolds number 441.01 with 95 mPa pressure at inlet for five turns spiral microchannel. For Fuzzy simulation, at 95 mPa pressure the flow rate was obtained 0.29 µL/s with velocity 0.02647 m/s at the same Reynolds number. Both simulation perform well and give results in a close agreement with each other and previous studies.

CONCLUSION

Qualitative approach exhibits a significant role with computer simulation. Modeling and investigation of multifaceted systems involve in qualitative approaches. ANSYS fluent offers a wide-ranging set of computational fluid dynamics (CFD) for demonstrating blood flow with other connected somatic phenomena. It suggests unmatched blood flow examination abilities. Natural human thinking abilities exhibit in qualitative and language expressions. The simulationists doing qualitative simulation must depend on an explicit formalism based on mathematics. Fuzzy simulation, specifically, is advantageous when statistics are inaccessible generally due to cost issues. Fuzzy Simulation is an active tool for assessing system characteristics. Fuzzy simulation is logical with intrinsic indecisions. Both software has the ability to give accurate results. Here, in this study the flow rate with velocity (ANSYS (0.26 µL/s, 0,02055 m/s) and FUZZY (0.29 µL/s, 0.02647 m/s)) have been examined successfully at the same Reynolds number and pressure. These simulations give accurate results without experimenting. This study will help in understanding the blood flow in various veins and arteries in human body for proper treatments of diseases.

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