V-groove shaped micro channel for lab On Chip applications using COMSOL Multiphysics

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Abstract— *MEMS is abbreviated as micro electro mechanical systems. It is defined as miniaturized mechanical and electromechanical elements. Micro channels have been identified to be one of the important elements to transfer fluid within a miniature area for Lab on Chip applications. By utilizing the COMSOL MUTLIPHYSICS software, the micro channel was designed and analysis equipment with a specific amount of fluid. Controlling pressure is an accurate way to introduce a set quantity of fluid at a certain velocity to some piece of equipment.*

Keywords--micro channel, modelling, simulation, velocity, pressure, COMSOL MULTIPHYSICS

I. INTRODUCTION

The manipulation of fluid flow in micro-channel (infuser) with small dimension of micrometres has emerged as a distinct new field. Micro channels have been used as an element to transport fluid. In addition to connecting different chemical chambers, micro channels are also used for delivering of reactant, physical particle separation, fluidic control, chemical mixing, and computer chips cooling.

In this paper we have designed an infuser, a device that feeds a reactor or analysis equipment with a specific amount of fluid. Controlling pressure will set a quantity of fluid at a certain velocity to some piece of equipment. Modelling this process in the time domain can lead to a reduction of the infusing pressure, micro channel design, and time control. This model demonstrates two useful tools. In COMSOL Multiphysics modelling. The ability to define a time-dependent boundary condition and easily sweep meshes into 3D to save memory.
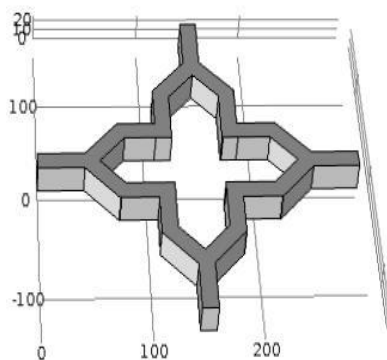

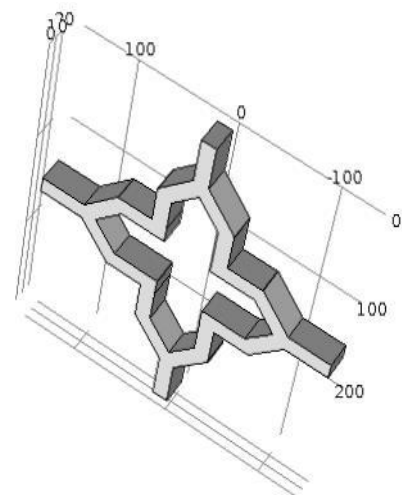Fig. 1 V-groove shaped infuser.(top view of the designed model)

fig. 2 V-groove shaped infuser.(front view of the designed model)

II. MODEL DESIGN

In our design we have constructed the geometry and set few conditions for the flow in V-groove micro channel as shown in fig 1 and fig 2. The differential pressure at the three inlets relative to the outlet pressure is time-controlled so that the inlet flow passes from one to the next in a smooth way. At any particular instant, one of the inlet flows dominates, although flow could be significant from more than one inlet. The pressure at the outlet is set to zero.

Fig 1: A V-groove shaped infuser with three inlets and one outlet. The model sets up a varying pressure differential at each inlet in the time domain in such a way that the dominant inlet flow alternates among them.

Fluid flow through a micro-channel exhibits a number of characteristic features, the most important of which is laminar flow. The velocity profile of the flow has a parabolic shape with the fastest velocity in the middle of the channel and decreasing velocity towards the channel vertical and horizontal walls as shown in Fig. 3. Cross currents are not perpendicular to the direction of flow of fluids. In laminar flow, the motion of the particles of the fluid is very orderly with particles close to a solid surface moving in straight lines parallel to that surface. Laminar flow is a flow regime characterized by low momentum convection and high momentum diffusion. Laminar flow of fluid as shown in fig 3.
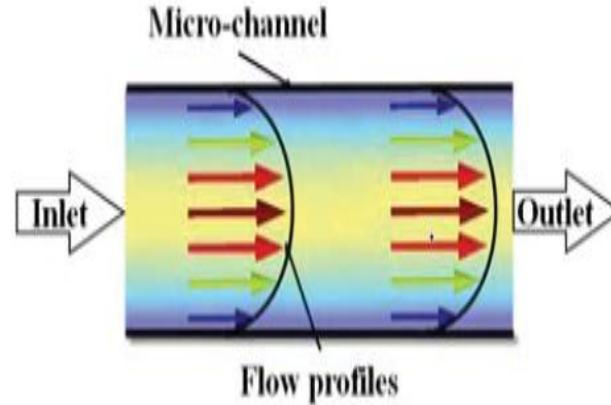

Fig. 3 laminar flow of fluid

The designed model only fluid flow whose velocity is of a magnitude that suggests laminar behaviour. This implies that you can get a numerical solution of the full momentum balance and continuity equations for incompressible flow with a reasonable number of elements.

The equations you must solve are the Navier-Stokes equations in the time domain

$$\rho \frac{\partial u}{\partial t} - \nabla.\mu \left(\nabla U + (\nabla U)^T \right) + \rho\, U \nabla U + \nabla P = 0$$

$$\nabla.U = 0$$

Where ρ denotes density (kg/m3), **u** is the velocity (m/s), μ denotes dynamic viscosity (Pa·s), and *p* equals pressure (Pa).

The fluid in this case is water, with the corresponding density and viscosity values. The boundary conditions for the outlet and the inlets assume a set pressure; they also assume vanishing viscous stress: Outlet, Inlets.

$[\nabla.\mu \left(\nabla U + (\nabla U)^T \right)].n=0$, $P=P_i$

Make sure that the pressure at the outlet to zero; at the inlets, use the time-dependent expressions

pi = 50 + 10 $\sin(\pi t + \alpha)$ Pa

Where *t* is time (s), and *k* is a value between zero and one. This simplified example sets the phase α to 0, $\pi/4$, $\pi/2$, 3π /4, or 3π, depending on the inlet boundary. Apply the no slip condition to all other boundaries; it states that the velocity is zero in the *x*, *y*, and *z* directions at the wall. **u** = (0 0 0).

III. MATERIALS

In COMSOL MULTIPHYSICS provides blank material feature where you can create your own customised materials by adding to your model, assign it to the necessary parts of your model geometry, describe how material behaves through specifying material properties. Use constant, parameter or write an equation to define the value of each material property. Enter parameter details as shown in table I, pressure at three inlets as shown in table II and table III.

TABLE I: Parameter Details

Name	Expression	Value	Description
p0	50[Pa]	Pa	Pressure offset
p1	10[Pa]	Pa	Pressure amplitude
Omega	pi[rad/s]	3.1416 rad/s	Angular velocity
T	0	0	Dummy variable

TABLE III: Expressions for pressure at 3 inlets

Name	Expression	Unit	Description
p_in_rm	p0+p1*sin(omega*t)	Pa	Pressure, rightmost inlet
p_in_c	p0+p1*sin(omega*t+pi/2)	Pa	Pressure, central inlet
p_in_lm	p0+p1*sin(omega*t+pi)	Pa	Pressure, leftmost inlet

TABLE III: expressions for water

Property	Value	Unit	Name
Density	1000	Kg/m^3	Rho
Dynamic viscosity	1e-3	Pa	Mu

IV. MESH

Automatic and semi-automatic meshing tools are available in COMSOL Multiphysics, including free tetrahedral meshing and swept meshing. The default algorithm is automatic tetrahedral meshing for physics defined in solids, and a combination of tetrahedral and boundary-layer meshing for fluids. You could get the full control over the steps sequence of operations used for creating the mesh by defining a mesh sequence
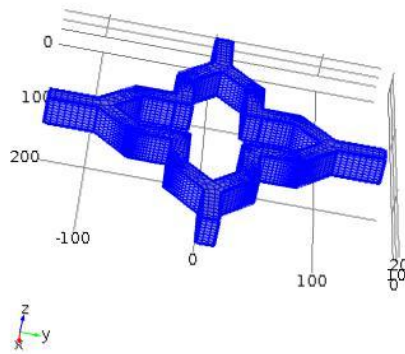

Fig 4 Mesh of the designed model

A mesh sequence process allows for the mix of prismatic, tetrahedral or hexahedral elements and could be made parametrically driven. Mesh obtained from designed model as shown in fig 4.
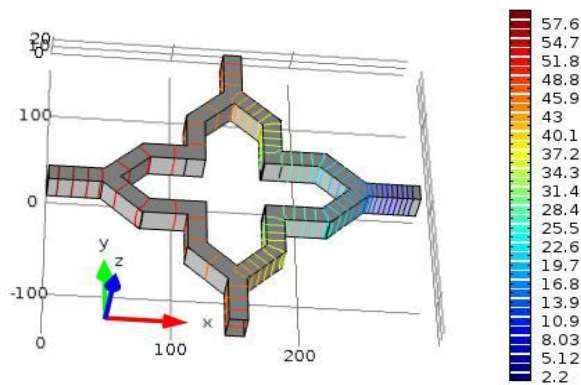
V. RESULTS

Fig. 5 Pressure drop during the fluid flow in V-groove shaped micro-channel.

Pressure drop during the fluid flow in V-groove shaped micro-channel with a maximum pressure of 57.6 Pa and minimum of 2.2 Pa. Pressure is less at outlet as shown in fig 5.
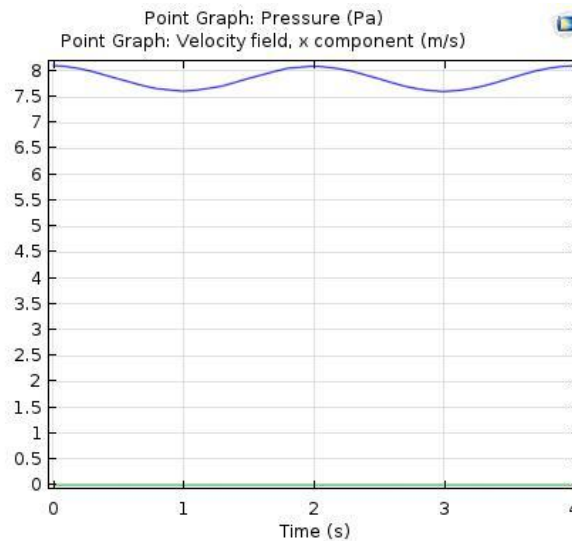

Fig. 6 pressure graph of the V-groove shaped micro channel.

Velocity in the X direction and pressure at a point near the outlet. As shown in fig 6 pressure values is constant between 7.5 to 8.
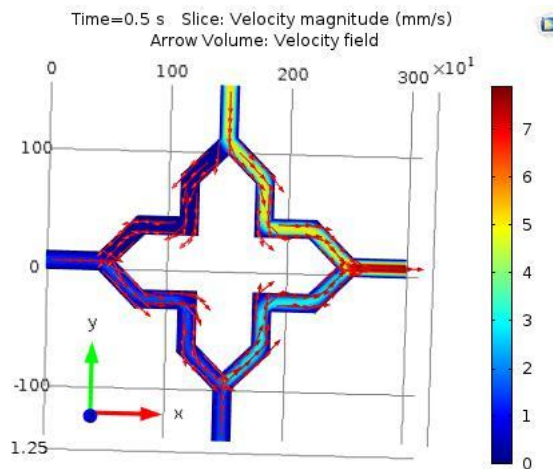

Fig. 7 shows the animation view of the velocity field of the V-groove shaped micro channel.

Velocity field as a combined slice and arrow plot through the middle of the geometry at $t = 0.5$ s. Setting up and observing this plot as an animation gives an informative qualitative description of the process as shown in fig 7.
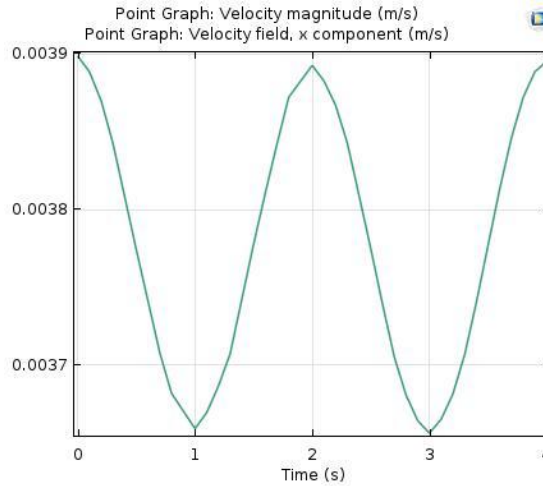
Fig. 8 velocity graph of the V-groove shaped micro channel.

Fig 8 shows the velocity in the *x* direction and the pressure in a point near the outlet as functions of time. Velocity values between 0 to 0.0039 m/s.
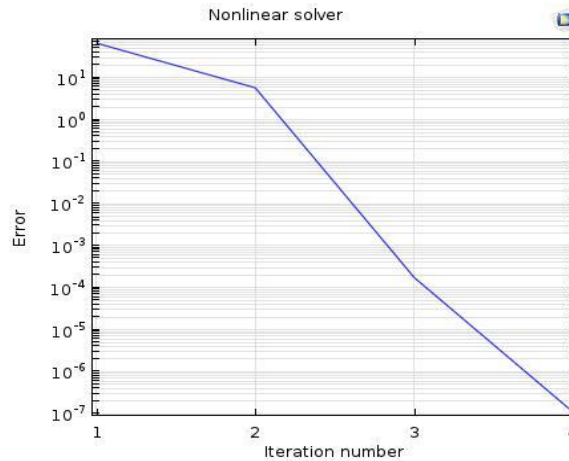

Fig. 9 shows the convergence plot of the V-groove shaped micro channel

Convergence means arriving at a solution that is close to the exact solution within some pre-specified error tolerance or other convergence criterion. Error rate decreases as the iteration number increases as shown in convergence plot of the designed model in fig 9.

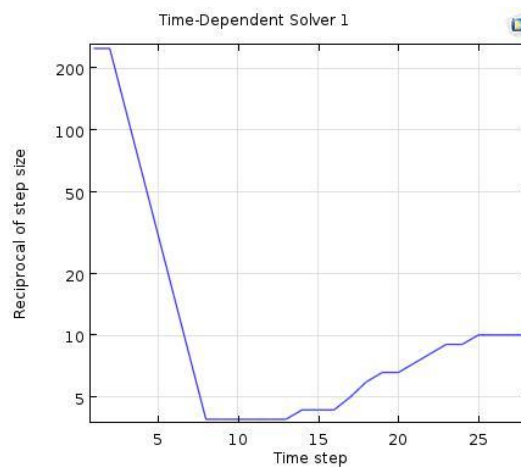Error rate is 10 for 1st iteration and error rate decreased to 10e-7 for 4th iteration.

Fig. 10 shows the time dependant solver of the V-groove shaped micro channel.

Definition of solver converges means that it has found a solution to the system of equations at a specific time instant. If the time step size is too big, or otherwise unsuitable, the next step can also converge but the solution will be

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inaccurate. COMSOL checks for that type of convergence as well in time-dependent problems and modifies the time step if needed. Time dependant solver of the designed model as shown in fig 10.

VI. CONCLUSION

The design and simulation of V-groove micro channel with 3 inlets and 1 outlet is simulated and results being verified. These micro channels are used for Lab on Chip applications to allow the fluids to floe along with buffers. The mechanism and the structure of the micro channel play an important role in the fluid flow and velocity of the fluid.

As from the simulations we can conclude that the right most inlet is not offering minimum flow velocity as compared to the top and bottom inlet. in our design the inlet channels in the V-groove micro infuser are pumping the fluid at a pressure of maximum 57.6 Pa and a minimum value of 2.2 Pa. Henceforth is an optimum design for the micro infuser for a Lab On Chip applications.

REFERENCES

[1] Norasyikin Selamat, Muhammad Syafiq Bin Rahim, Abang Annuar Ehsan "Effect of Microchannel Sizes on 3D Hydrodynamic Focusing of a Microflow Cytometer"IEEE vol 16,pg no-109-112,2016.

[2] Bhagyashri Gharge,Vaishali Upadhye,Dhananjay Bodas "Design and Simulation of Microcantilevers for Detection of Pathogens"vol 15,pg no249-252,2015.

[3] Nadir Belgroune,Abdelkader Hassein-Bey "Modeling and FEM Simulation Using Fluid Structures Interaction of Flexible Micro-Bridge Bending Within PDMS Micro-Channel" IEEE vol 14,pg no-495-498, 2014.

[4] Chung-Hao Kang, Shih-Hsiang Tai1, Sheng-Chung Chen1, David T.W. Lin1,"Optimization of the Micro Channel Ladder Shape Heat Sink" IEEE vol 13,pg-no389-392,2013.