Design of Micropump for Microfludic System based Diabetes Management

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Abstract:- Diabetes Mellitus (DM) is an illness created by an absence of insulin. In people, if insulin isn't given remotely, glycemia can't be managed accurately. As indicated by a few examinations, tight control of glycemia decreases the odds of building up the ulterior intricacies of this sickness. DM can incredibly diminish the patient's personal satisfaction whenever left untreated. Conventional insulin mixture procedures including a syringe and needle are illogical and upsetting. Insulin siphons are an extraordinary choice to accomplish convenience and individual solace. The siphon is exceptionally exact conveying precise amounts of insulin independent of outer conditions. Micropumps are key segments of microfluidic frameworks with applications extending from organic liquid taking care of two microelectronic cooling. This model re-enacts the instrument of a valveless micropump, which is intended to be viable at low Reynolds numbers, defeating hydrodynamic reversibility. Valveless siphons are frequently favored in microfludic frameworks since they limit the danger of stopping up and are delicate on natural material. The Fluid Structure Interaction interface is utilized to tackle for the progression of the liquid and the related twisting of the structure. Also the Global ODEs and DAEs interface is utilized to exhibit how to play out a period settled incorporation of the all-out stream all through the siphoning cycle. The design aspects architecture of the insulin pump is presented here. The simulation of the insulin micropump is done using time dependent study in comsol multiphysics software.

Keywords:- *Continous Glucouse Monitoring, Micropump, Insulin, Fluid Structure Interaction.*

I. INTRODUCTION

Diabetes mellitus is an insulin subordinate endless turmoil, which is described because of inability of the body to keep up the blood glucose levels in ordinary range. It is an immune system illness in which the beta cells of the pancreas are crushed, bringing about diminishing of insulin discharge. Inappropriate diabetes range can prompt inconveniences, for example, nerve harm, cerebrum harm, coronary illness, and stroke and vision misfortune and kidney malady and in the end demise.

Diabetes inconveniences are an overall scourge with exceptionally high restorative, monetary, social expenses. Tight control of blood glucose levels has been appeared to diminish the mortality of diabetic, and non-diabetic, emergency unit by up to half. Diabetic patients need to screen sustenance admission and day by day physical action to keep up glucose levels at a satisfactory ordinary dimension. For simplicity of the executives subjects are urged to stick to exacting schedules and diets and infusions.

Creating nation like India has more than 40 million of diabetic patients and 10-10.2% are type 1 among the diabetics. Thinking about the expense of social insurance, the sort 1 is over the top expensive infection. Advances in innovation have prompted the improvement of constant glucose observing frameworks of Continuous glucose monitoring system (CGMS) and insulin conveyance siphon treatment.

CGMS basically consists of these three: sensor unit, controller unit and injecting unit. The detection of the person's blood glucose level is done using the suitable sensing unit. After knowing the blood glucose level the controller work is to decide how much insulin has to be injected. Then it's injecting unit which has to inject insulin to the body.

The design & fabrication of the insulin pump in injecting unit for CGMS is presented in this paper which is simulated using the Comsol multiphysics 5.1 software.

II. METHODOLOGY

COMSOL multiphysics is a cross limited component investigation, solver and multiphysics reproduction programming. It permits traditional material science based UIs and coupled frameworks of fractional differential conditions. COMSOL gives an IDE and bound together work process for electrical, mechanical, liquid, and substance applications. An API for Java and LiveLink for MATLAB might be utilized to control the product remotely, and similar API is likewise utilized by means of the Method Editor.

III. MODEL

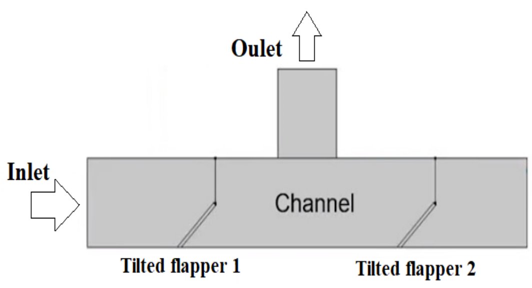

Fig 1:- Micropump model

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The micropump model encompasses of an inlet channel and an outlet point. It consists of 2 flappers in the inlet channel. Flappers are used for preventing the back flow of the injected insulin. This model is the simple geometry, but the mechanism of the insulin transportation is done using the time dependent study. To design this fine model all the geometry units are in micrometers. It is a physical mechanism responsible for generating the unidirectional flow to be visualized.

In this model the Fluid-Structure Interaction interface is used to specify the input oscillatory flow, along with the mechanical properties of the flaps. In addition, some best practice guidelines for ensuring good mesh deformation in moving-mesh problems are introduced. The deformation of the flaps, and the flow of the fluid, is calculated as a function of time for two full cycles of the pumping mechanism. This allows the physical mechanism responsible for generating the unidirectional flow to be visualized clearly. As well as visualizing flow rate and direction as a function of time throughout the pumping cycle, integration coupling components are used in conjunction with the Global ODEs and DAEs interface to calculate the net volume pumped from left to-right as a function of time. This is an example of how the functionality of one COMSOL interface can be enhanced by using a custom equation specified in a mathematics interface, and demonstrates the ease with which user defined equations can be incorporated into COMSOL models.

IV. MATERIAL

Material selection is one of the important aspects, if proper selection of the material not done then the simulated results will vary. For fabrication it should be known a factor.

A. Solid

Property	Name	Value	Unit
Young's modulus	E	3.6e5	Pa
Poisson's ratio	nu	0.499	1
Density	rho	970	Kg/m^3

Table 1:- Flapper material property

The two flappers in the channel material are selected with solid. These flappers are made of flexible solid material as it has to move or bend towards the insulin flow while it is injected to the patient body.

B. Fluid

The fluid material is chosen to all the domains except those two flappers, as the fluid has to pass through the inlet and to the channel depending on the fluid flow.

Property	Name	Value	Unit
Density	rho	1000	Kg/m^3
Dynamic viscosity	mu	0.001	Pa.s

Table 2:- Fluid Property

V. PHYSICS

The methodology of the micropump mechanism is simulated in comsol multiphysics software. The chosen physics for the simulation of the geometry are fluid structure interaction and global derivatives.

Fluid mechanics is the foundation for the picked material science liquid structure connection. Fluid Mechanics is the science that manages conduct of liquids very still (liquid statics) or in movement (liquid elements) and the communication of liquids with solids or different liquids at the limits and though Fluid-Structure Interaction multiphysics interface can show wonders where a liquid and a deformable strong influence one another. The interface models both the liquid space and the strong area (structure) and incorporates a predefined condition for the cooperation at the liquid strong limits.

Linear Elastic Material feature is applied to the two tilted flaps, and then the Fluid-Solid Interface Boundary feature is automatically assigned to the boundaries between the flaps and the fluid in the channel. An Inlet boundary feature is applied to the top of the vertical chamber. This specifies the inflow velocity, via a user input expression, to vary sinusoidally in time with a period of 1sec. An Outlet boundary feature is applied to the left and right boundaries of the channel. Two boundary integration coupling components, named intopL() and intopR() for the left and right outlets respectively, are also applied to these outlet boundaries. These are used to compute the flow rate out of each outlet. This is achieved using some user defined variables in the definitions node within Component 1. The flow rate from each outlet is calculated by integrating the depended variable u_fluid, which is the horizontal component of the fluid velocity, and multiplying by the out-of-plane length scale of 10 µm. The net flow rate out of the channel, UoutNet, is then calculated from the difference between the flow from the left and right outlets, such that positive values correspond to a net flow in the left-to-right direction.

A Global ODEs and DAEs interface is added to compute the integrated net flow as a function of time. This is achieved using a Global Equation which integrates UoutNet with respect to time to obtain Vpump. This step is necessary as UoutNet gives the instantaneous net flow rate as a function in time, however a more useful metric for evaluating a pump is the total volume pumped throughout an entire pumping cycle. Note that the timeint() operator can also be used to visualize the time integration of a variable. However, use of timeint() is not as accurate as directly solving for an integrated quantitiy, as the timeint() operator only uses the timesteps which are saved in the solution but solving directly uses every timestep taken by the solver.

VI. SIMULATION STEPS

A. 2D space dimension

Two-dimensional space is a geometric setting in which two qualities are required to decide the situation of a component.

B. Physics – fluid flow – Fluid-Structure Interaction (FSI)

Utilizing the FSI multiphysics interface can show marvels where a liquid and a deformable strong influence one another. The interface models both the liquid space and the strong area (structure) and incorporates a predefined condition for the association at the liquid strong limits. An ALE plan is utilized for fusing the geometrical changes of the liquid area.

The liquid can be either compressible or incompressible. The stream routine can be laminar or tempestuous (if the CFD Module is accessible). The strong space has indistinguishable choices from in a Solid Mechanics interface, including contact conditions and furthermore nonlinear materials if the Nonlinear Structural Materials Module or Geomechanics Module is accessible.

C. Mathematics ODE & DAE interfaces

The Global ODEs and DAEs interface is utilized to include worldwide space-free conditions that can speak to extra states. The conditions can be ODEs, mathematical conditions, and DAEs.

D. Time dependent study

The Time Dependent examination is utilized when field factors change after some time.

E. Add parameters

- Reynolds number: The Reynolds number, alluded to as Re, is utilized to decide if the liquid stream is laminar or fierce. It is one of the principle controlling parameters in every single thick stream where a numerical model is chosen by pre-determined Reynolds number.

- Coefficient to change Reynolds number

F. Design & build the geometry

The insulin micropump is designed in simulated with all the dimensions in micrometers.

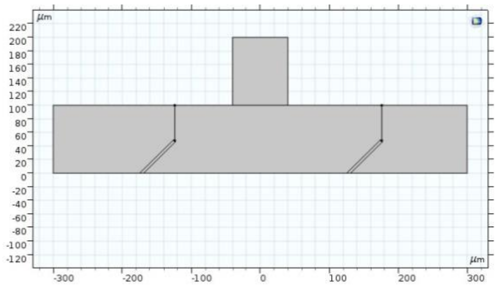

Fig 2:- Build model

G. Material selection

For the fabrication of the insulin pump designed material is important aspect. For the taken Poisson's ratio and Young's modulus property – silicon rubber can be used.

H. Meshing

The work is a gathering of components which serve to separation the CAD model into littler basic pieces - each piece (or component) can be thought of as a touch of spring with a three-dimensional spring condition, and the accumulation of components speaks to a structure. Complete micropump mesh consists of 3544 domain elements and 358 boundary elements.

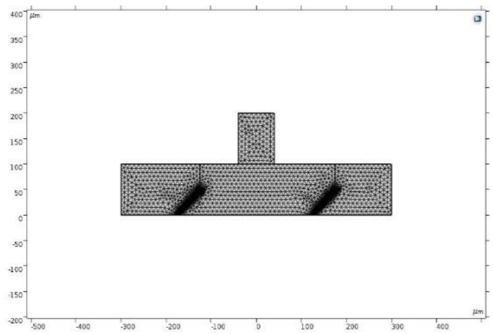

Fig 3:- Meshed model

I. Compute and analyze the results

VII. RESULTS

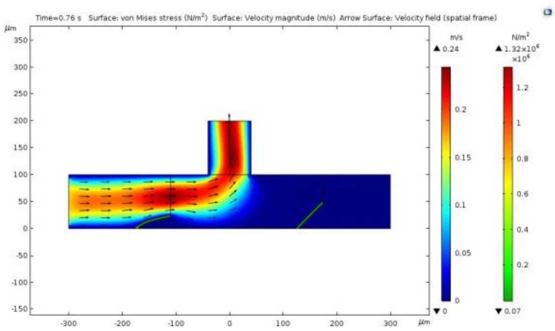

Fig 4:- Flow of insulin

The visualizing flow rate and direction as function of time throughout the pumping cycle, integration coupling components are used in conjunction with the Global ODEs and DAEs interface to calculate the net volume of insulin passing from inlet to outlet in function of time.

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During the flow, when insulin is injected to the channel the flapper 1 is bent in the flow direction. The solution of this mechanism takes place from 0.52sec to 1sec approx. to complete the one dosage injecting to a diabetic patient body. The velocity magnitude is 0.24 m/s and velocity field is in the range of 104 to $1.5*10^4$.

VIII. CONCLUSION

The after effect of this conduct is that there is a net stream rate from left to directly inside the channel. This has numerous conceivable applications in microfluidic frameworks. For instance, this insulin pump could be utilized to convey liquid from a bead repository associated with the vertical outlet into a microfluidic pathway associated with the left hand inlet. On the other hand, this micro pump could be utilized to make a flowing framework where a liquid is siphoned around a persistent circle to cool a microelectronic framework.

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