DESIGN AND SIMULATION OF VALVELESS PIEZOELECTRIC MICROPUMP

Presented

by

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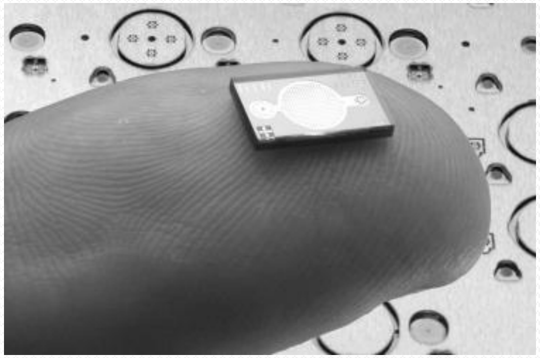
AGENDA

- *INTRODUCTION*
- *DESCRIPTION OF WORK*
- *SIMULATION RESULTS*
- *PROPOSED WORK*
- *CONCLUSIONS AND SCOPE FOR FUTURE WORK*
- *ACKNOWLEDGMENT*
- *REFERENCES*

INTRODUCTION

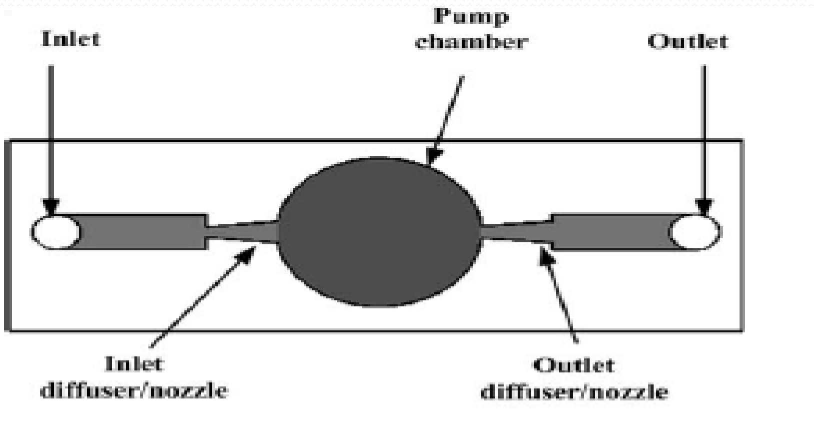
- Micro pump is a miniaturized pumping device fabricated by micromachining technologies.
- Micro pump are divided into two categories
  a) Mechanical Micro pump
  b) Non mechanical Micro pump
- The three main aspects of mechanical micro pumps are actuation mechanism, pumping mechanism, valves.



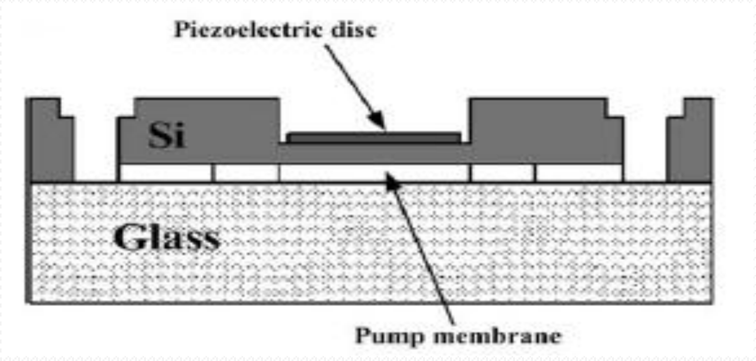
Valve less piezoelectric micro pump

- Valve less piezoelectric micro pump consists of

1. Actuator unit
2. Two diffuser/nozzle element
3. Inlet and outlet channel
4. Pump chamber
5. Diaphragm/ Pump membrane
6. Power supply module



Top view of Micropump



Side view of Micropump

ACTUATOR UNIT

- Actuator is necessary to operate the diaphragm of the micropump.
- The actuator is made of a piezoelectric disc with the dimension of Φ6mm × 0.15mm thick and a silicon membrane with the dimension of Φ6mm× 0.1mm thick.

Inlet & outlet channel

Two short brass pipes are fixed to the pump inlet & outlet cavity of micro pump

Pump chamber

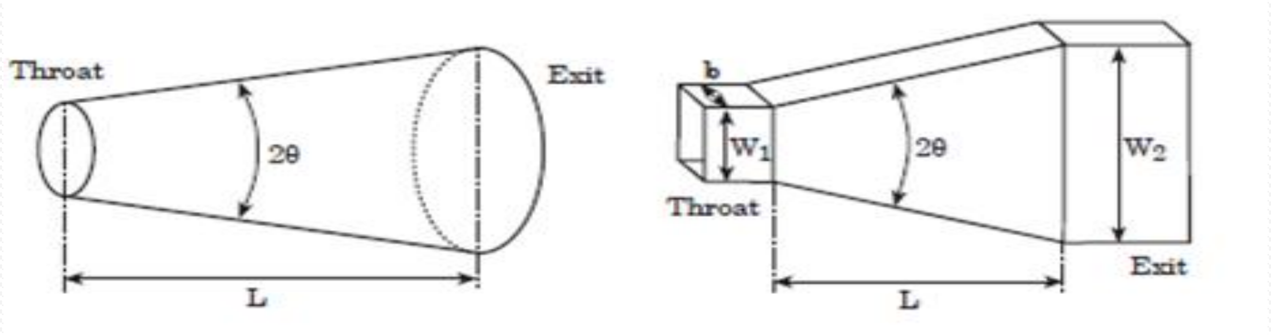
Pump chamber made up of silicon & covered by glass substrate.

Diaphragm

- The diaphragm closes the cavity of pump chamber and it is bonded with the centre disk of the actuator.
- Circular diaphragm made up of silicon 0.1mm thickness & 6mm diameter is chosen.

DIFFUSER/NOZZLE ELEMENT

- Diffuser is a duct with gradually expanding cross section and nozzle is a duct with gradually converging cross section.
- Diffuser are of two types :- conical and flat-walled diffusers.
- The choice of diffuser type depends mainly on the fabrication process.



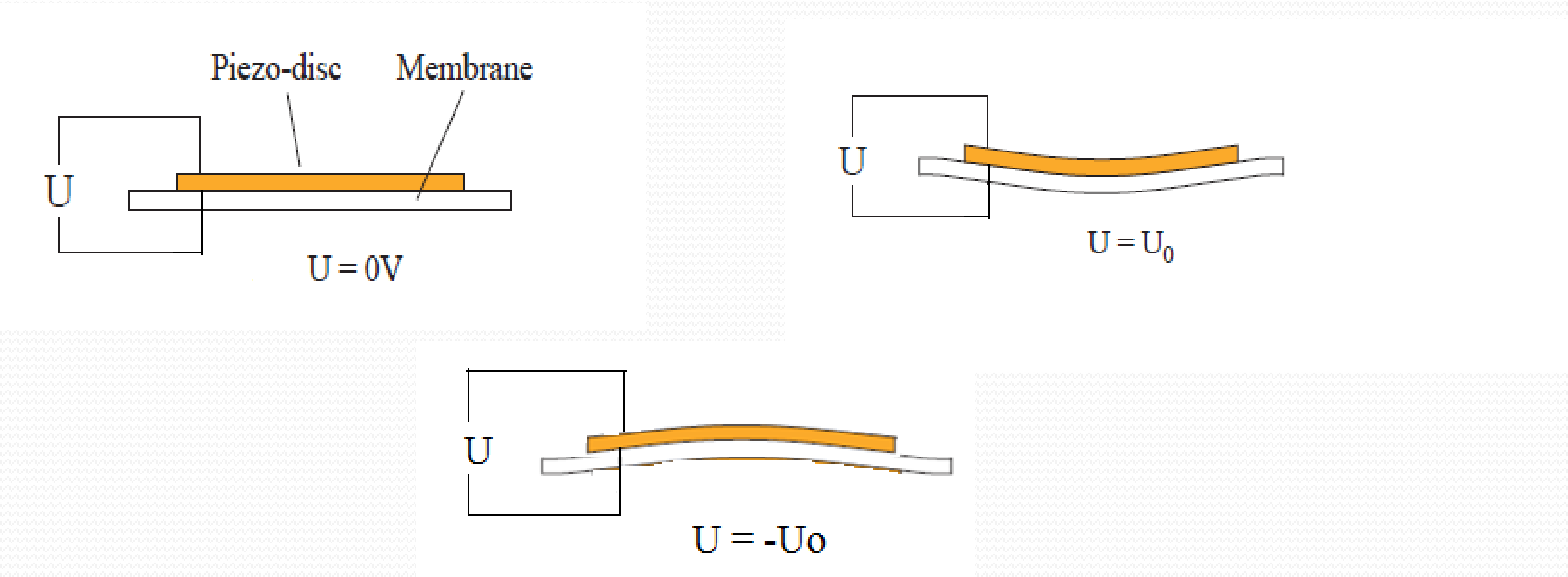
Conical diffuser

Flat walled diffuser

- The basic dimension parameters of the diffuser element involve the divergence angle θ, the diffuser length L and the width of the narrowest part W_1.

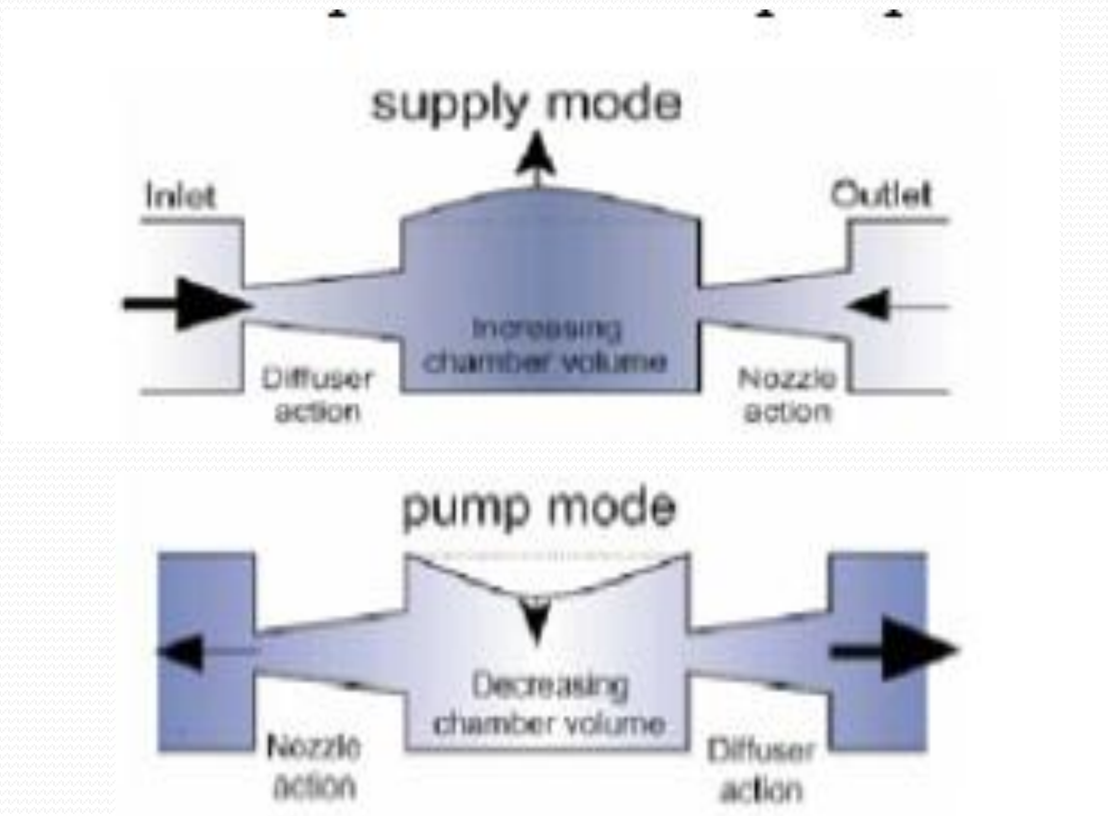
Power supply module

- The displacement of PZT actuator is directly proportional to applied electric field.
- An alternating voltage of 50V (0 to peak) is utilized.



Bending of a piezoelectric disc glued on a membrane

WORKING PRINCIPLE VALVE LESS PIEZOELECTRIC MICRO PUMP

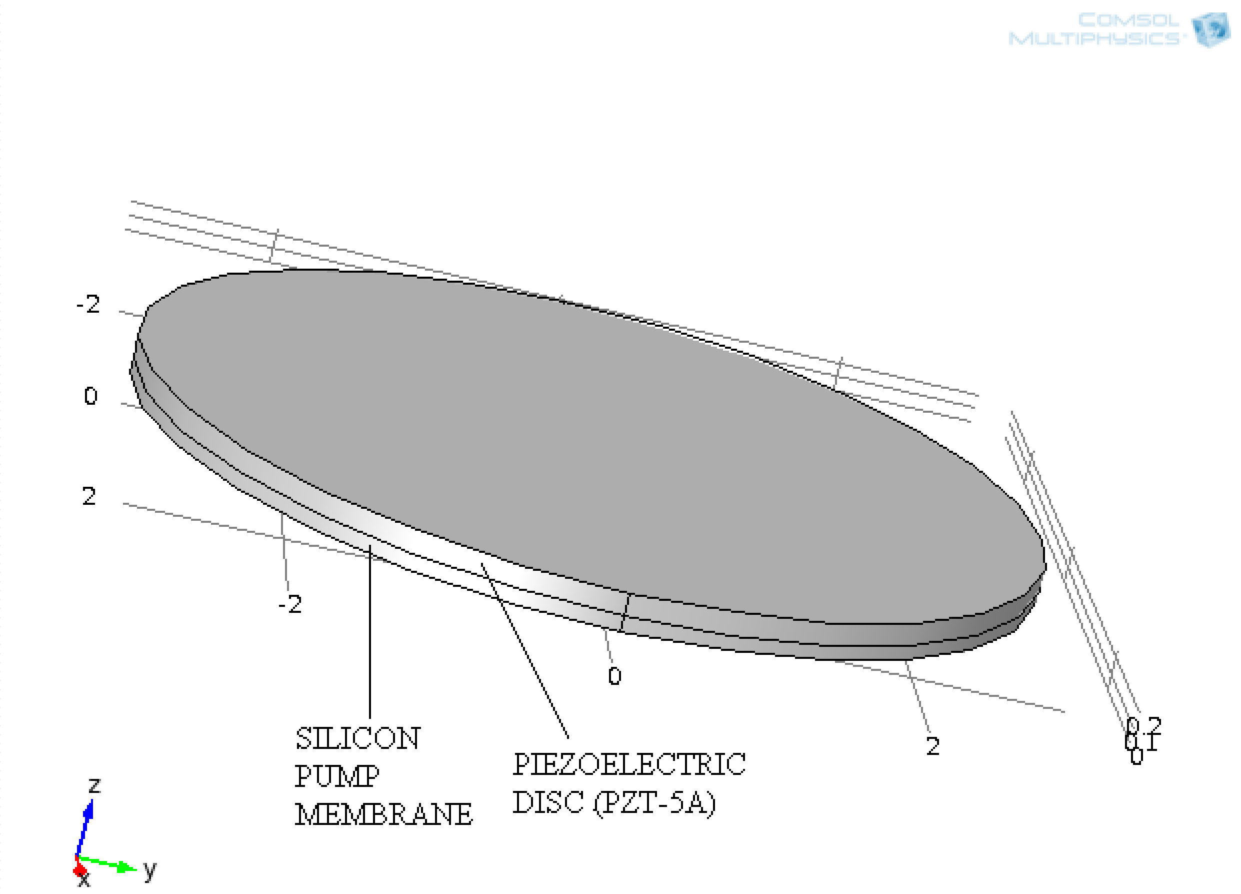


SIMULATION RESULTS

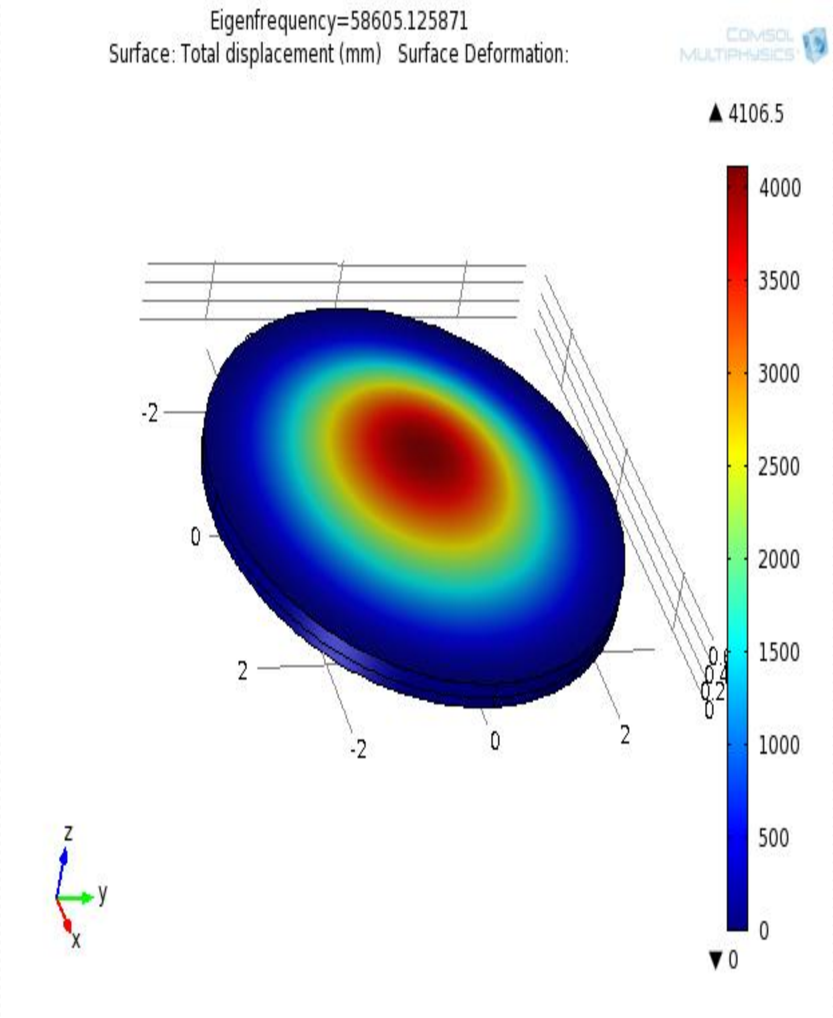
Simulations are carried out for two couplings in the micropump design:-

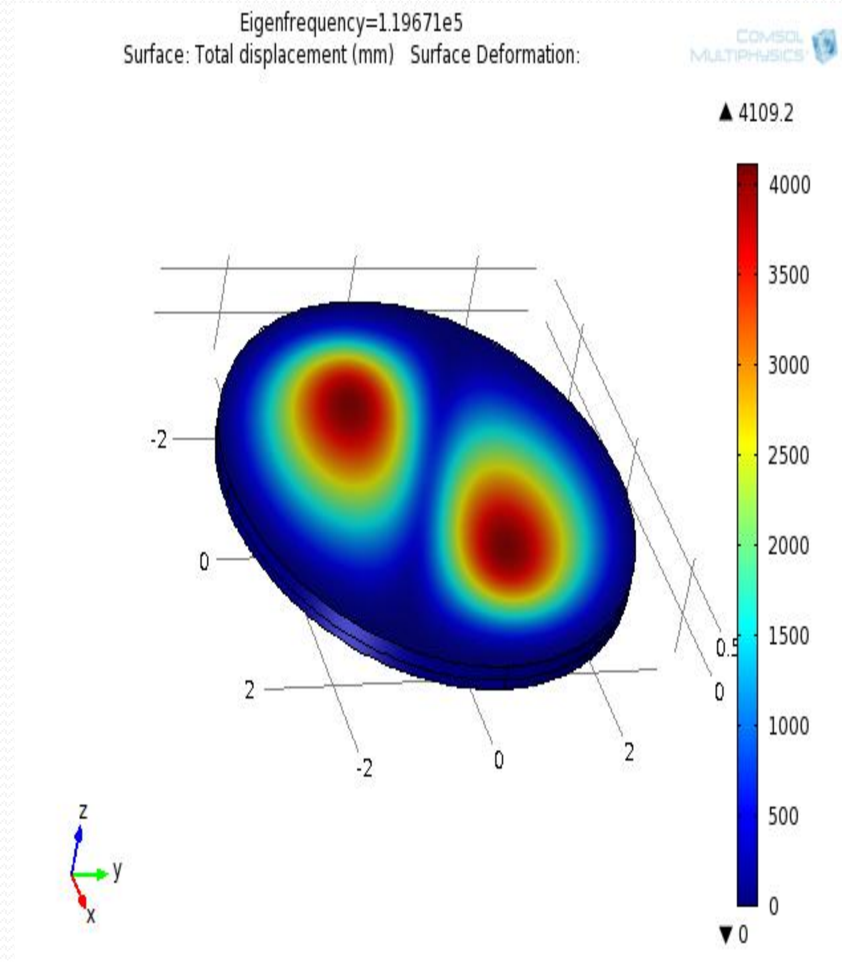
- The electromechanical coupling of piezoelectric actuator.
- The fluid-structure coupling between the fluid and walls of Nozzle/diffuser elements.

ACTUATOR STRUCTURE



EIGEN FREQUENCY ANALYSIS





MAXIMUM DEFLECTION OF THE PUMP MEMBRANE

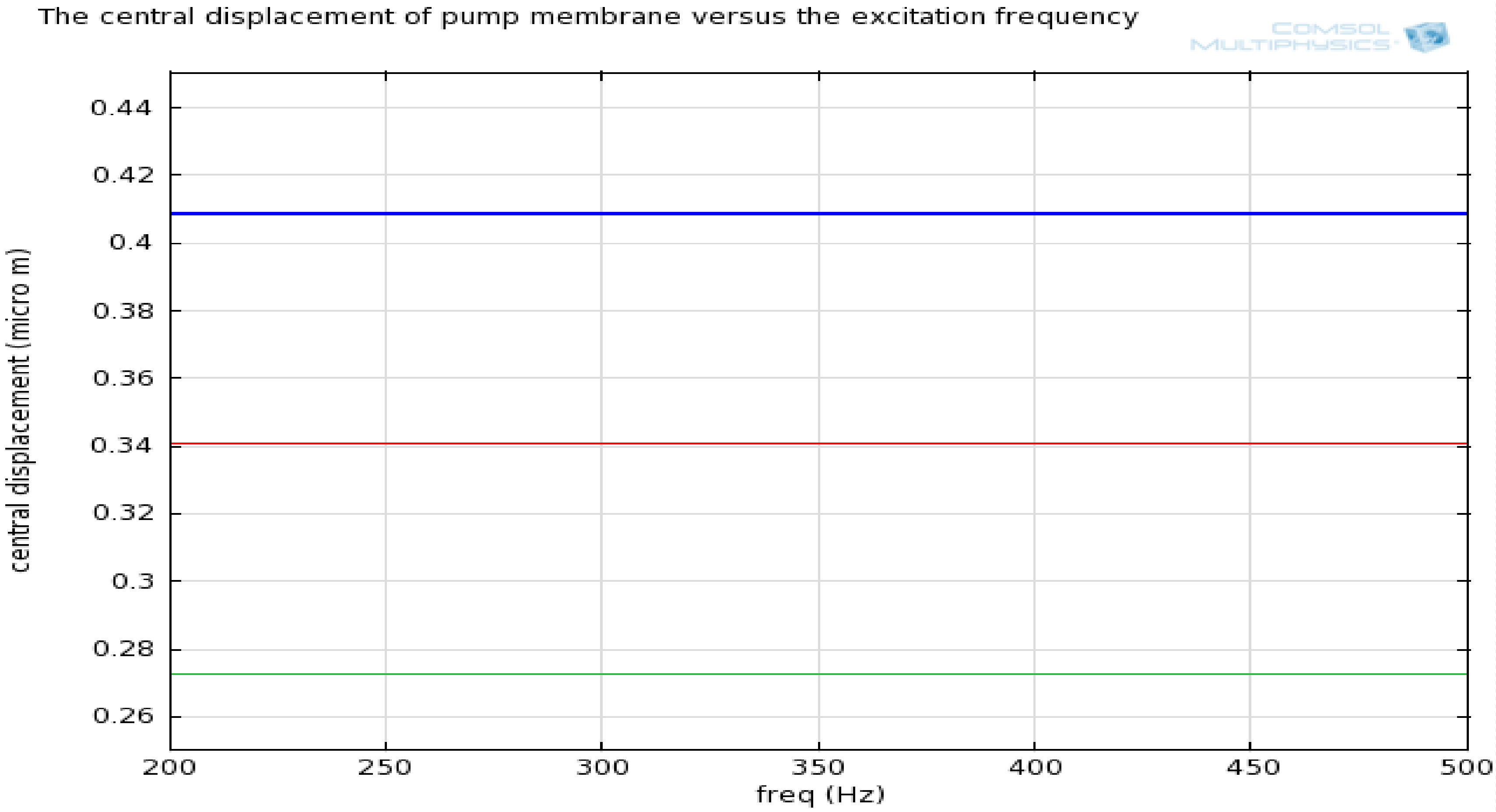
- The Piezoelectric Actuator model is imported into *Piezoelectric Device* module to analyze its behavior when a voltage is applied on the surface of the PZT-5A disc.
- The Piezoelectric Actuator is excited at the working voltage of 50V (0 to peak) and the excitation frequency much lesser than the natural frequency. The maximum deflection obtained is 0.176μm at the centre of pump membrane.

FREQUENCY DOMAIN ANALYSIS

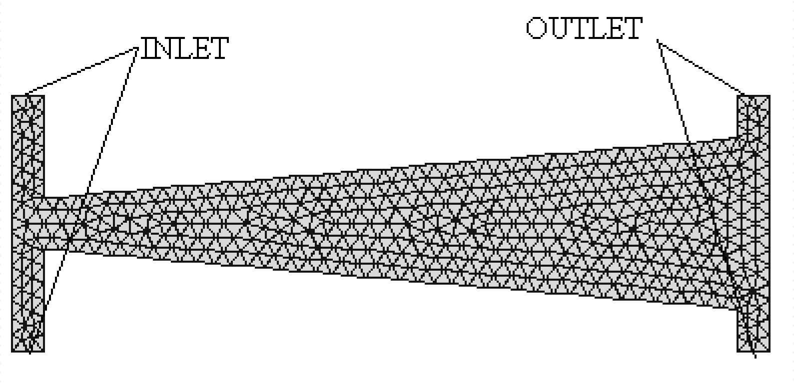
U = 80 V

U = 100

U = 120 V



DIFFUSER / NOZZLE STRUCTURE

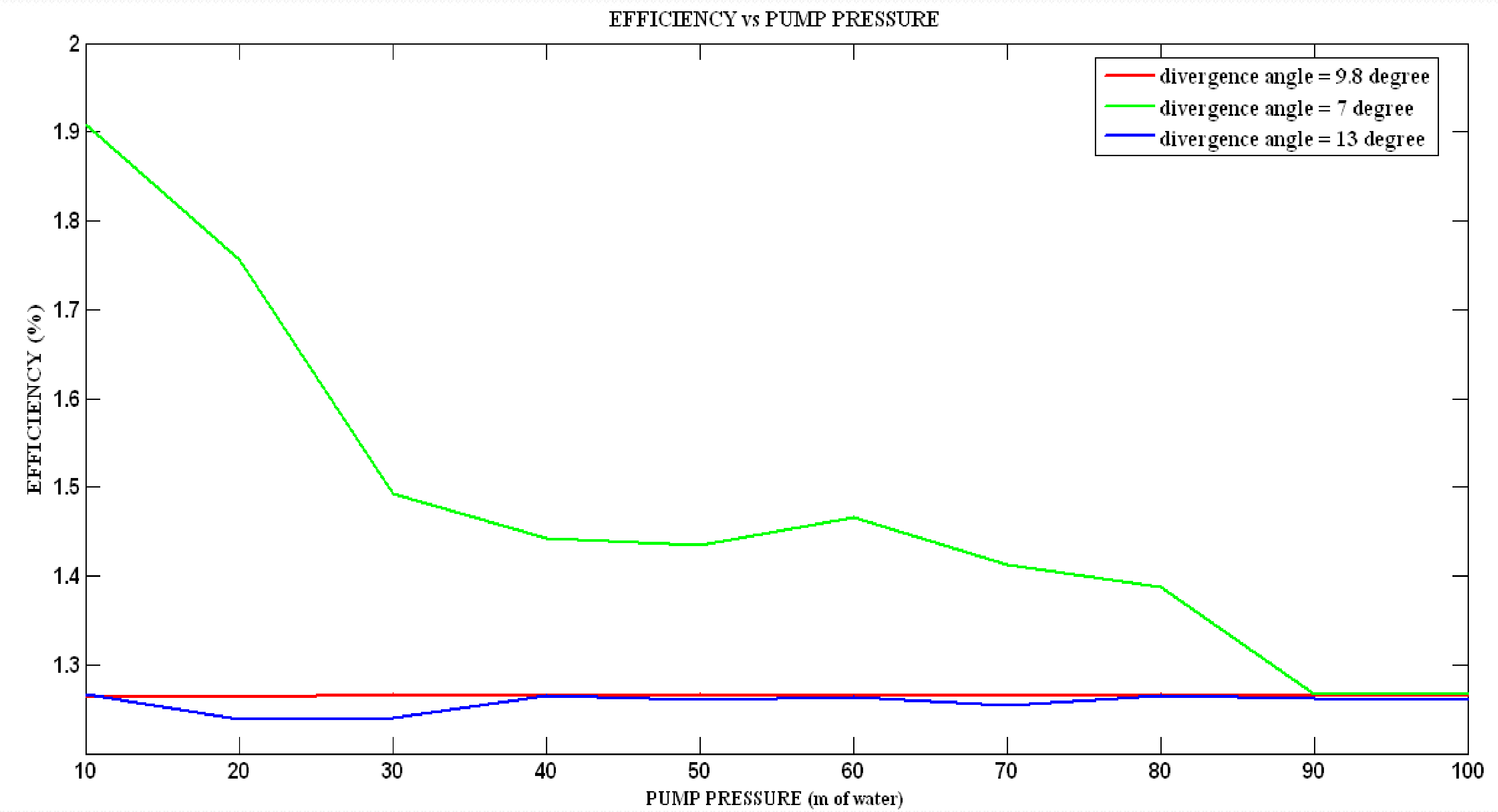


Diffuser model simulated

Dimensions of Diffuser elements

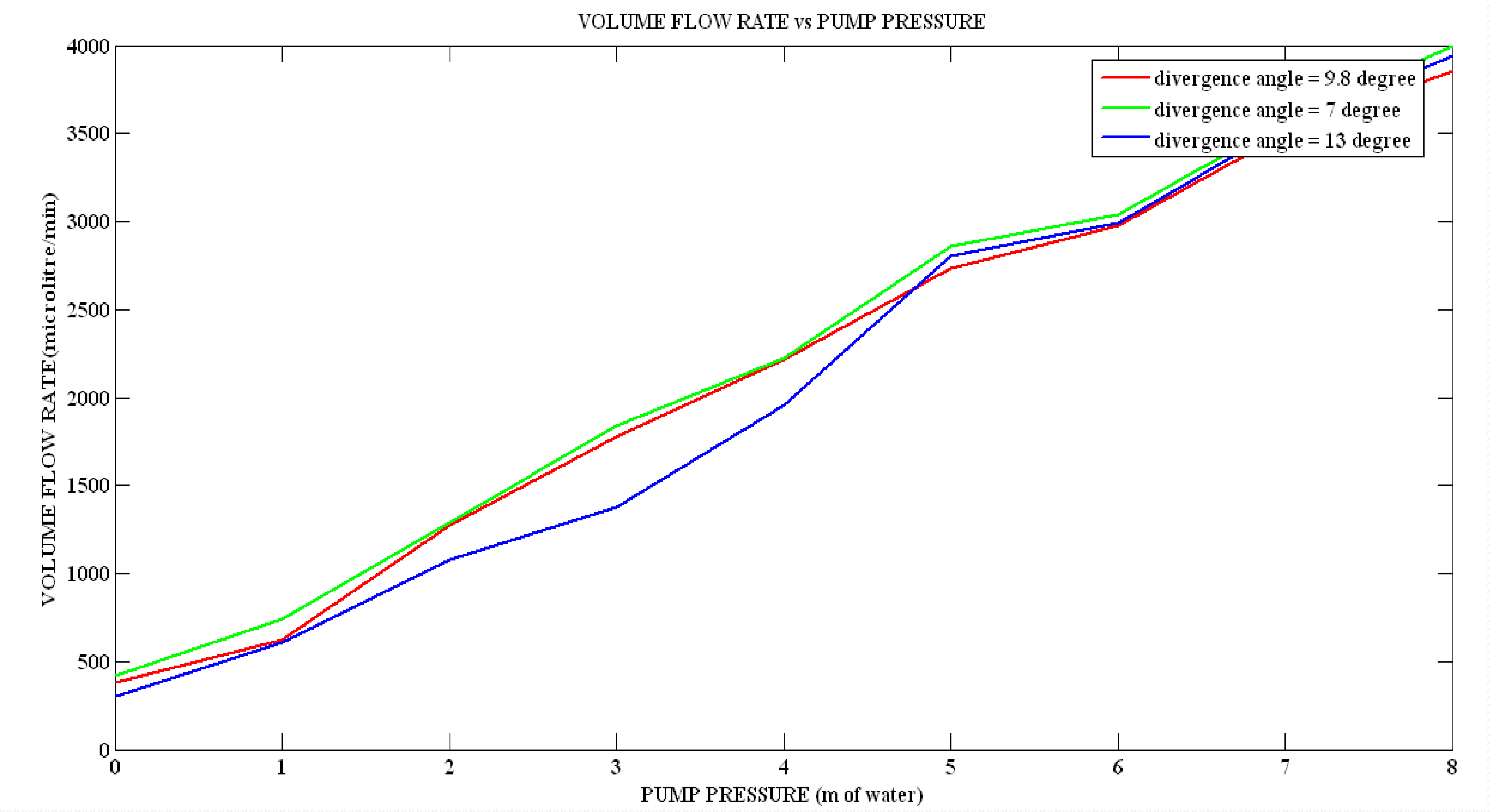
NOTATION	W_1 [μm]	L [μm]	$\alpha = 2\theta$
3a	80	1093	9.8^0
3b	80	1440	9.8^0
3c	80	1093	7.0^0
3d	80	1093	13^0

STATIONARY ANALYSIS



Diffuser element efficiency ratio versus pump pressure for different divergence angles

Contd…



Diffuser element volume Flow rate versus pump pressure for different divergence angles

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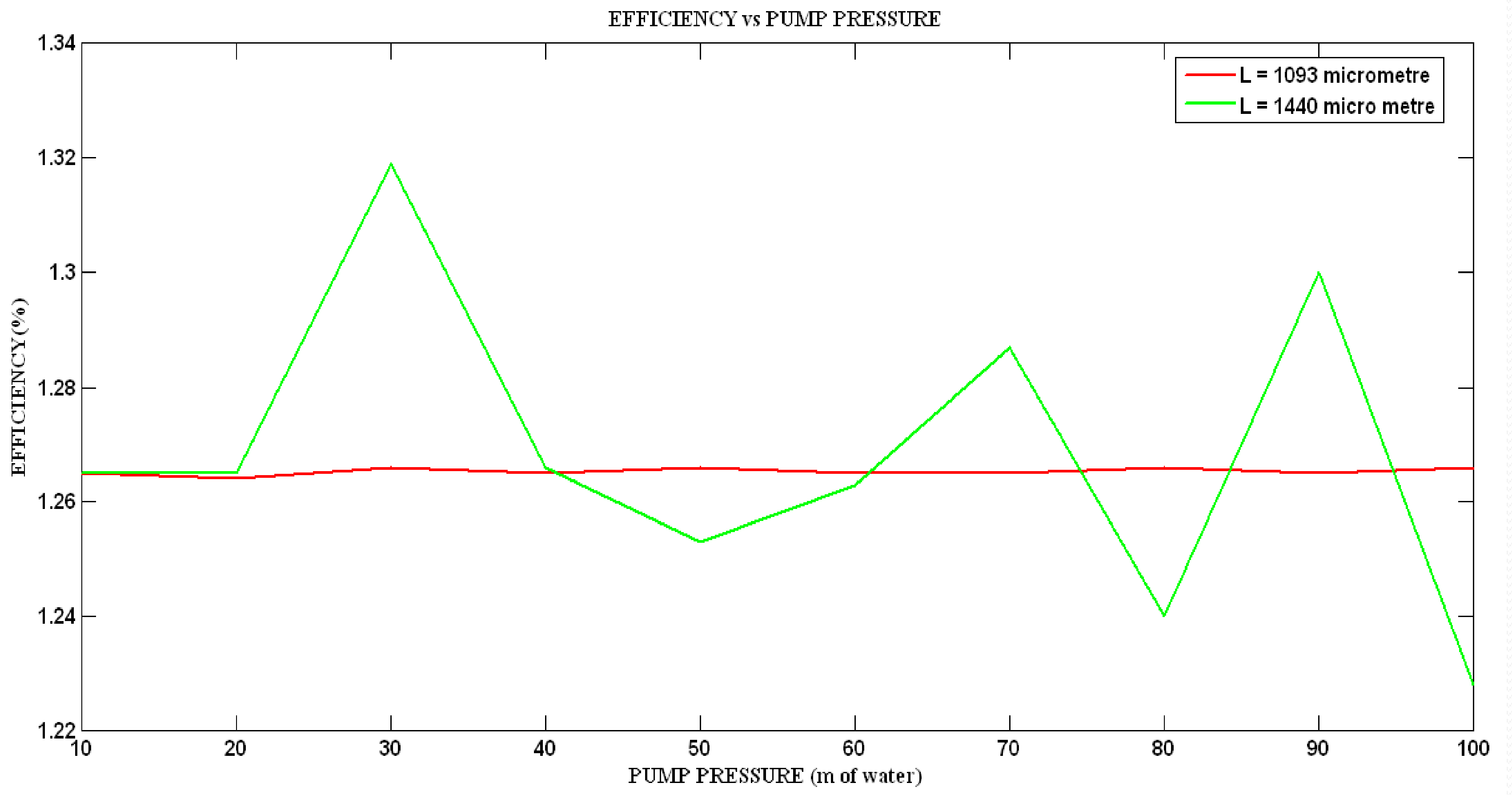

Diffuser element efficiency ratio versus pump pressure for different diffuser lengths

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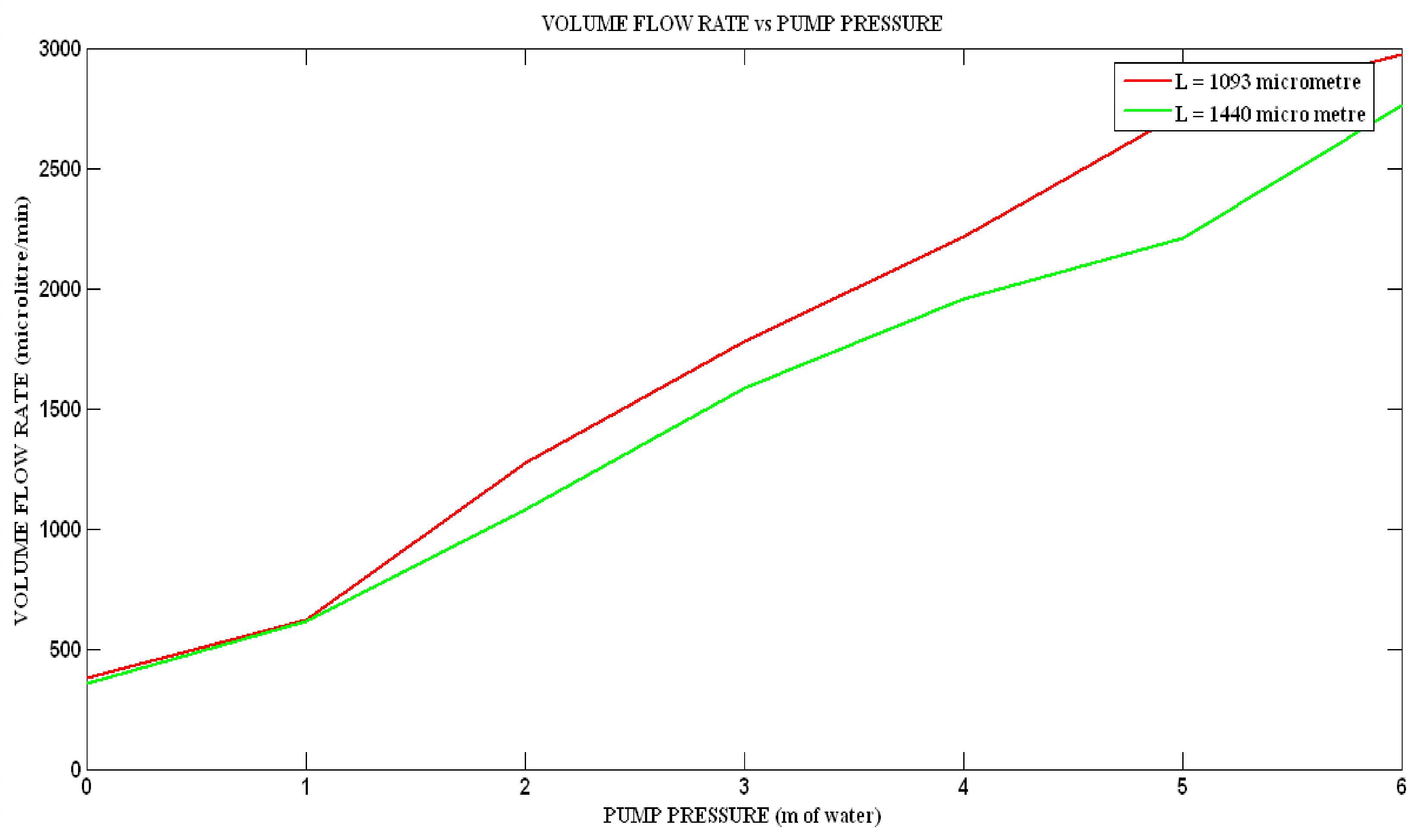
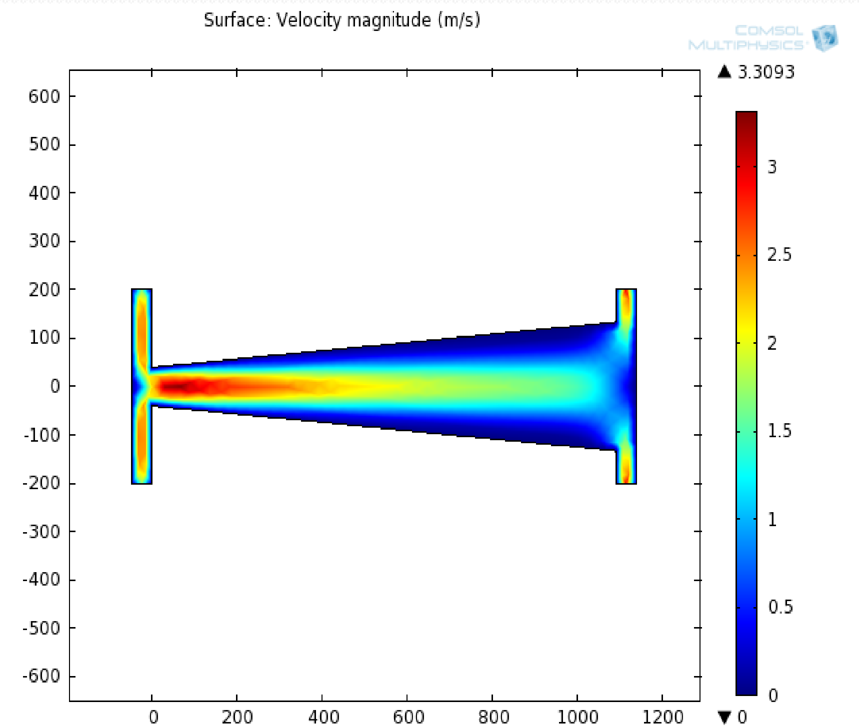
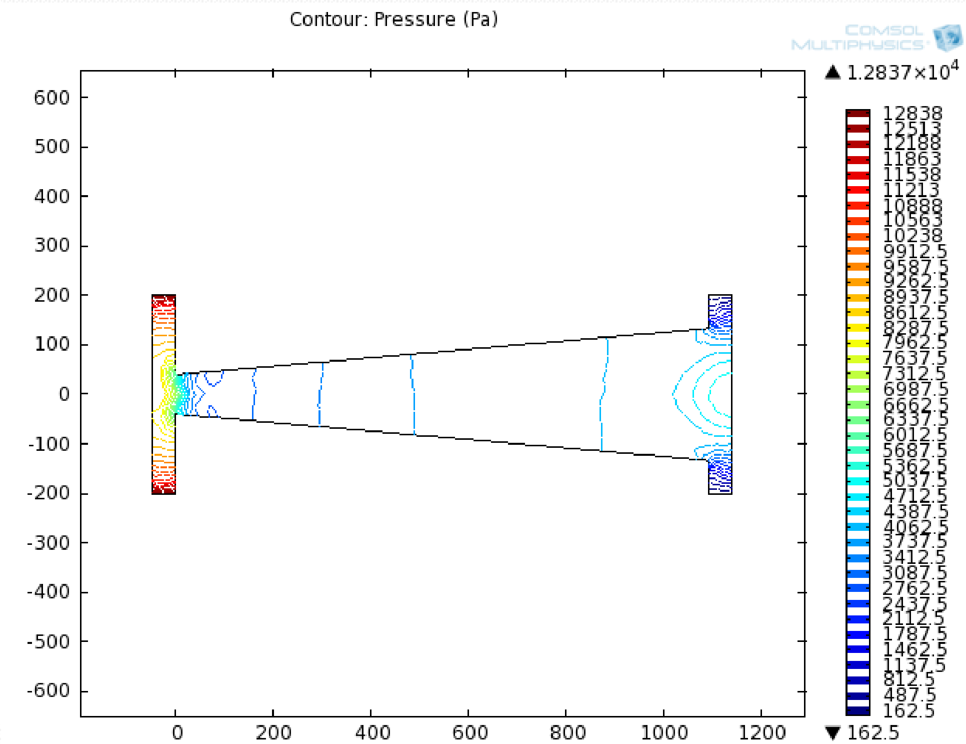


Diffuser element volume flow rate versus pump pressure for different diffuser lengths

FLOW PATTERNS OF DIFFUSER ELEMENT

Diverging – wall direction





Velocity vector plot with entering pressure 13kPa and 0Pa backpressure at outlet

Contour plot for the pressure distribution for the same load

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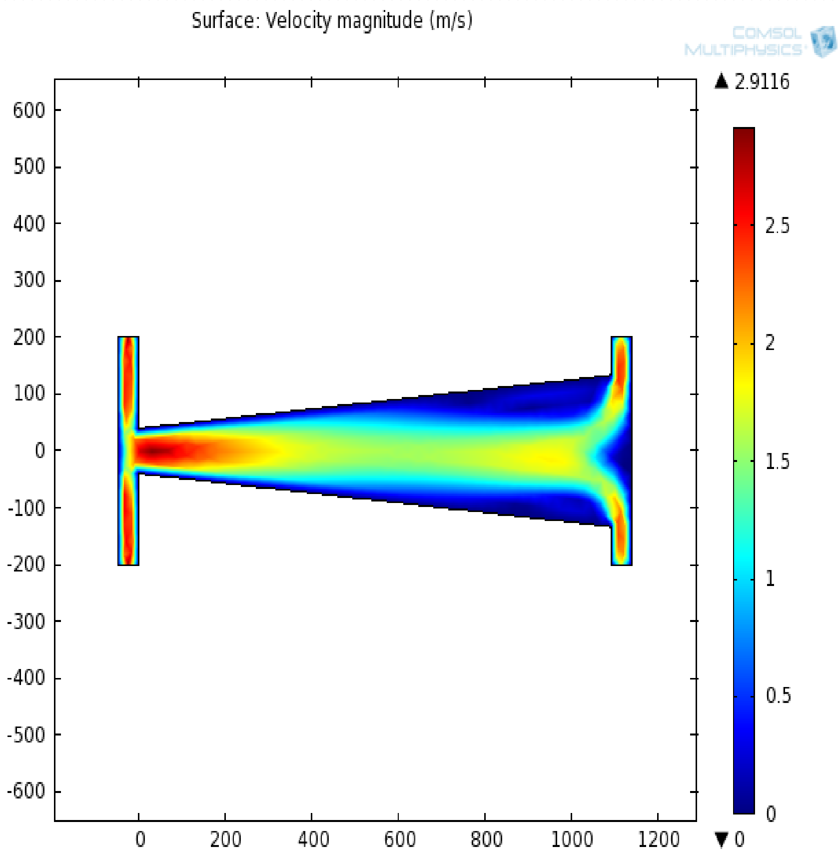
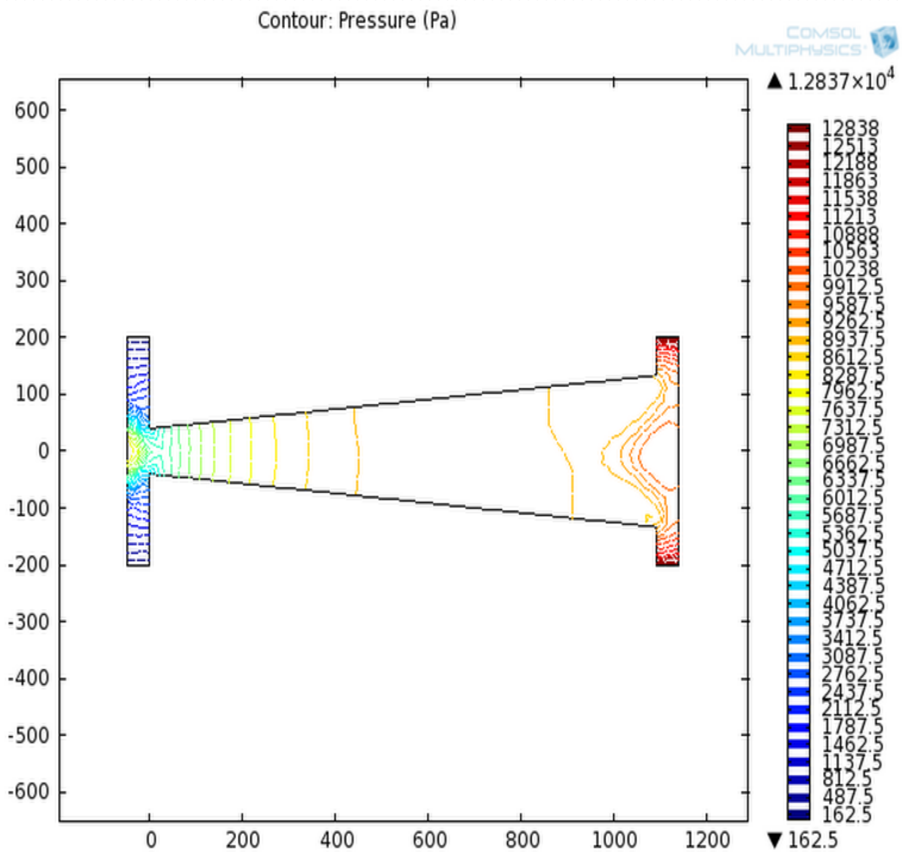
Converging – wall direction



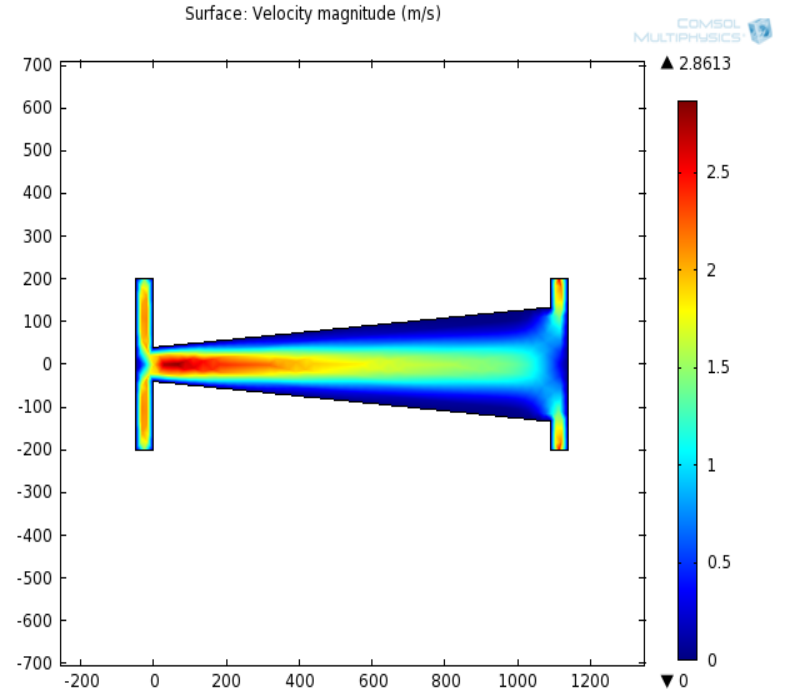


Velocity vector plot with entering pressure 13kPa and 0Pa backpressure at outlet

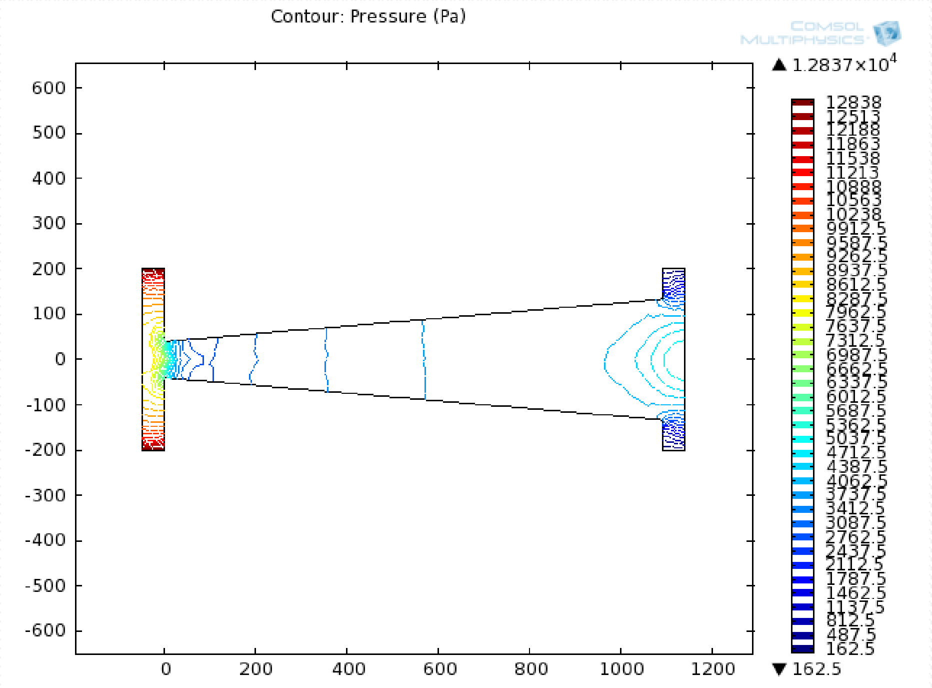
Contour plot for the pressure distribution for the same load

PROPOSED WORK

Simulations are performed for diffuser element with dimension (3a), with the diverging-wall direction as positive direction using Gentamicin as a working fluid.

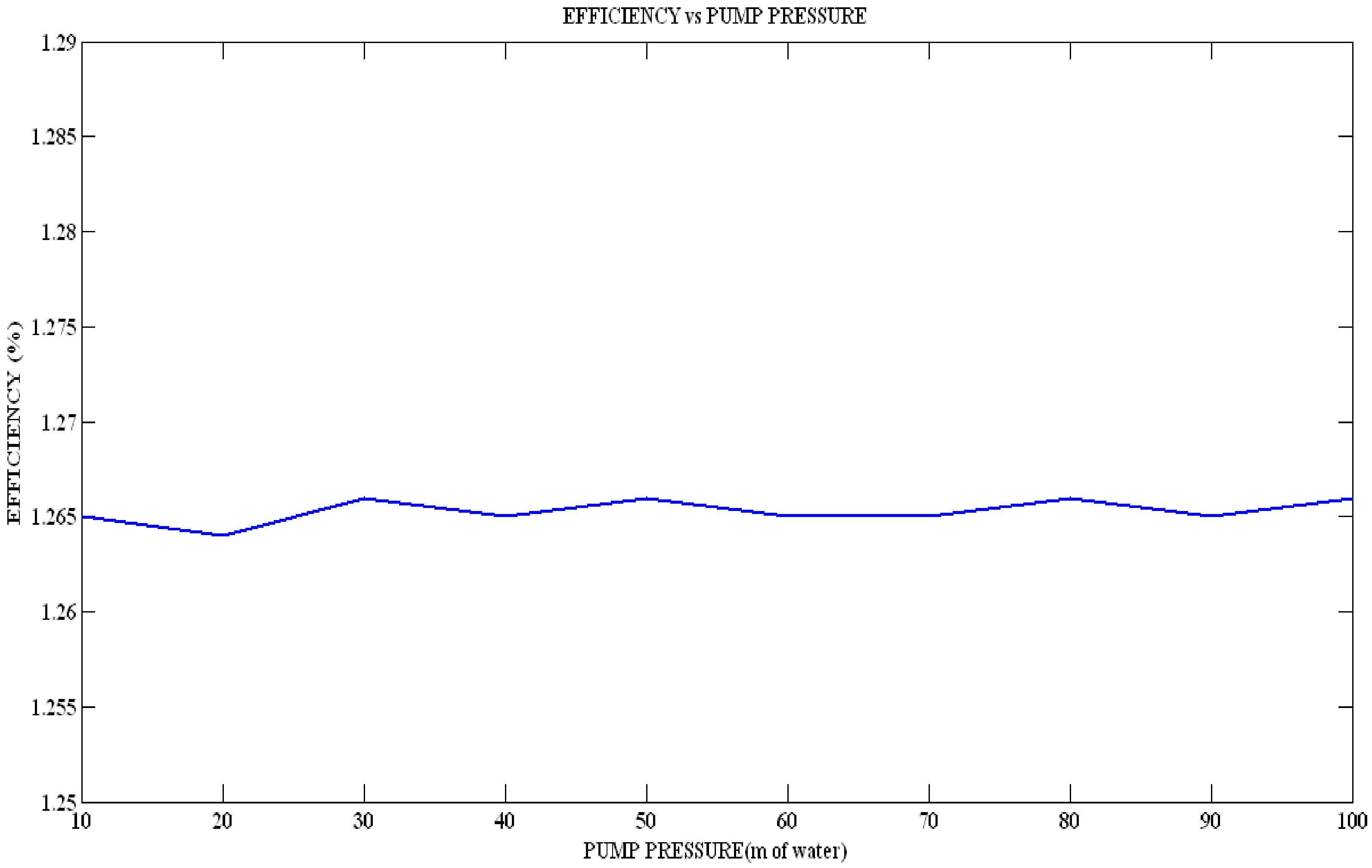


Velocity vector plot with entering pressure 13kPa and 0Pa backpressure at outlet

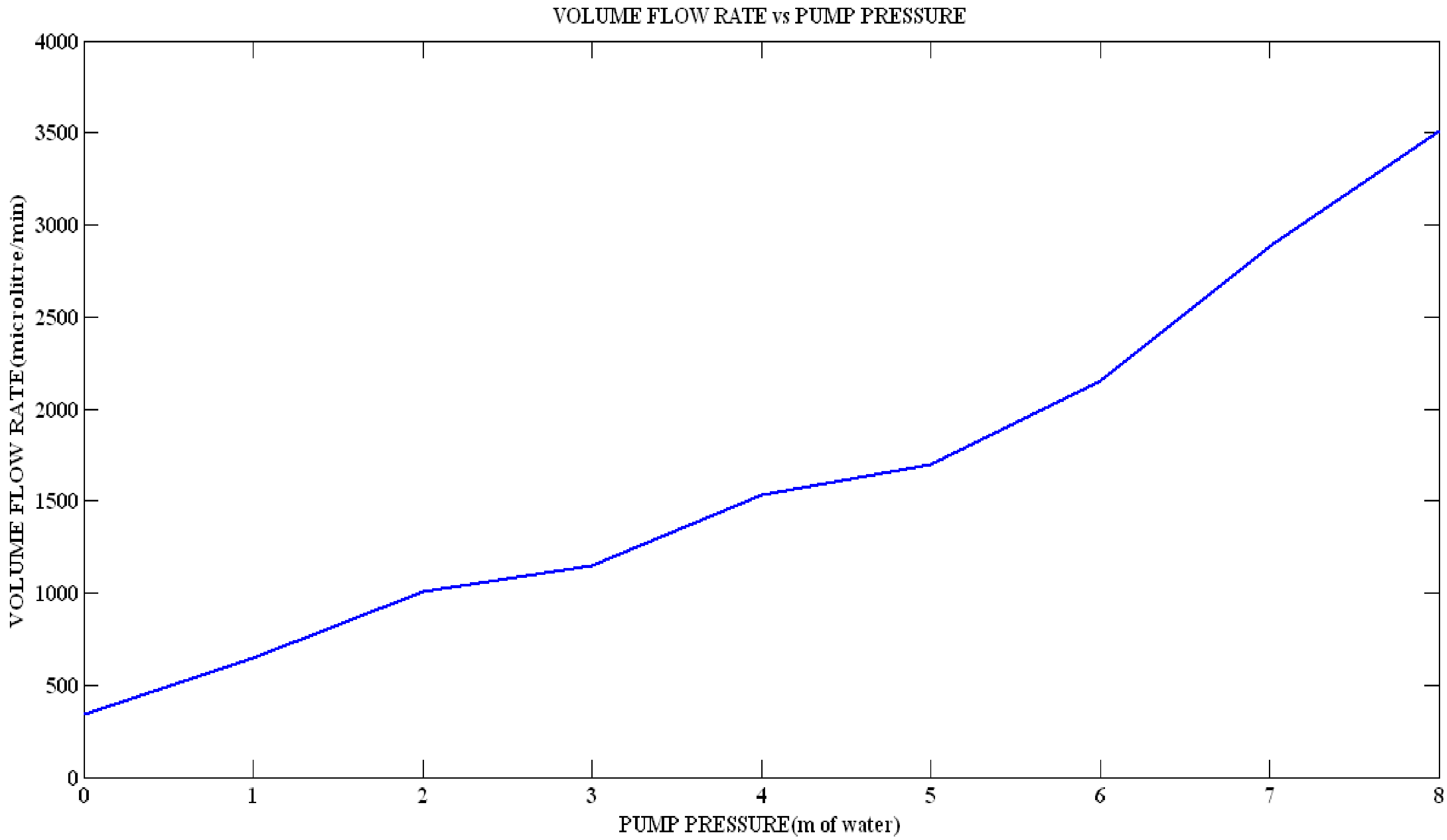


Contour plot for the pressure distribution for the same load

STATIONARY ANALYSIS



Diffuser element efficiency ratio versus pump pressure



Diffuser element volume flow rate versus pump pressure

CONCLUSIONS AND SCOPE FOR FUTURE WORK

- The simulation was performed for 3D membrane using Comsol package and results conclude that deflection of actuator is linear with applied potential over PZT material of the membrane.
- On the other hand a 2D diffuser/nozzle element for gentamicin intravenous administration was simulated for the laminar flow to check the rate of change of flow from expansion towards the contraction and vice versa.

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- COMSOL India.

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THANK YOU