ROTATIONAL SEPARATION OF NON SPHERICAL BIOPARTICLES USING COMSOL MULTIPHYSICS

Prepared by -

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MICROFLUIDICS

1. Microfluidics deals with the behaviour, precise, control and manipulation of fluids that are geometrically constrained to small tube, capillary penetration governs the movement.
2. By controlling and manipulating liquids at low volume (micro-nano scale), microfluidics has achieved many practical applications such as multiplexing,automation, and high throughput screening.
3. A microfluidic device comprises of a chip etched on a material commonly (glass,polymer such as PDMS(PolyDimethylSiloxane),silicon).
4. Comsol microfluidics model allows us to know the working of a microfluidic device.
5. Lab-on-a-chip (LOC) technology is a concept in which several preparative or analytical processes are integrated onto a single chip that fits in a human hand.

Microfluidic separation method:

1. There are two separation methods-
    - Active
    - Passive

2. Active method comprise of external force. This includes DEP(Dielectrophoresis), Electrophoresis, etc.

3. Passive method rely on carefully designed channel geometry & internal force to sort different particles. This comprises the use of pillars, weirs, hydrodynamic filtration(HDF), etc. DLD(deterministic lateral displacement) comes under passive method.

Deterministic Lateral Displacement (DLD)

1. These are the structures used to separate particles based on size in a continuous flow. DLD is a hydrodynamic, microfluidic technology.

2. DLD is a passive method which means this completely relies on design of the channel geometry, internal force to sort different particles.

3. The parameters taken into consideration are : Size, Shape, Deformity, Complexity, Density.

4. The separation mechanism in DLD works as, if the center of particle is out with the width of the 1st streamline, then gets displaced into other streamline when coming to agreement to a post or can say when negotiating to a post.

5. Such a particle passes the posts as it has a larger Dc(critical diameter) and particles with smaller Dc remain centered along the 1st streamline and follow the defined route.

PRINCIPLE

When 2 differently sized particles follow the same streamline, these enter the constrictions & negotiate a post.

Assumption - The particles do not alter streamline and do not interact with one another.

Streamline It is the number of flow paths allowed between two pillars. Here, it has been denoted by (N).

Critical Diameter(Dc)

1. Critical diameter (D) is directly proportional to the no. of streamlines defined by the observer. So, the formula for Dc is given by -

$$D_c = 1.4*G*(N)^{(-0.48)} \quad \textbf{OR} \quad D_c = 1.4*G*(E)^{(0.48)}$$

where, G = Gap between two columns of pillars

N = Number of streamlines

E= 1/N

2. Considering the number of streamlines between the column of two pillars N=5 ,G= 10 µm with this the critical diameter comes out to be Dc=6.46µm. Similarly, when the value of N =10 the Dc= 4.63.

3. Hence, as the value of N is increased, the critical diameter decreases. This affects the particle flow through the gap between the column of two pillars, the particle with smaller diameter than the defined D_c will remain in first streamline as its hydrodynamic center is not out with the width of 1st streamline.

4. The one with a larger D_c value, is displaced to the next streamline due to hydrodynamic centre out of the defined boundary of streamline and this action is continuous, termed as displacement mode.

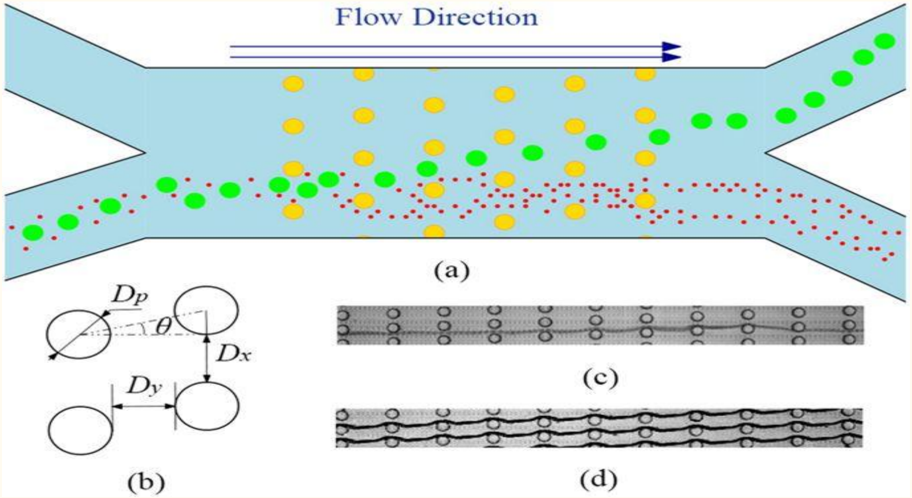
5. Particles larger than the D_c value gets displaced in accordance with the displacement angle (Θ) theta, and is termed as lateral row shifting. And, for particles smaller than D_c have a straight course through the device.

Significance of gradient shift (ϴ)

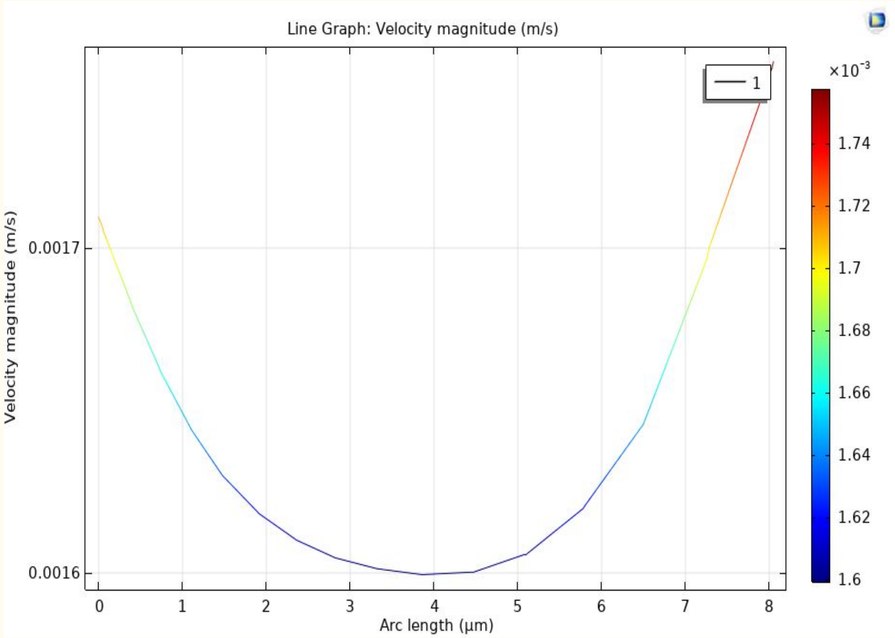
1. The gradient shift and N are inversely proportional. The relation is given by;

$$\tan(\theta) = 1/N$$

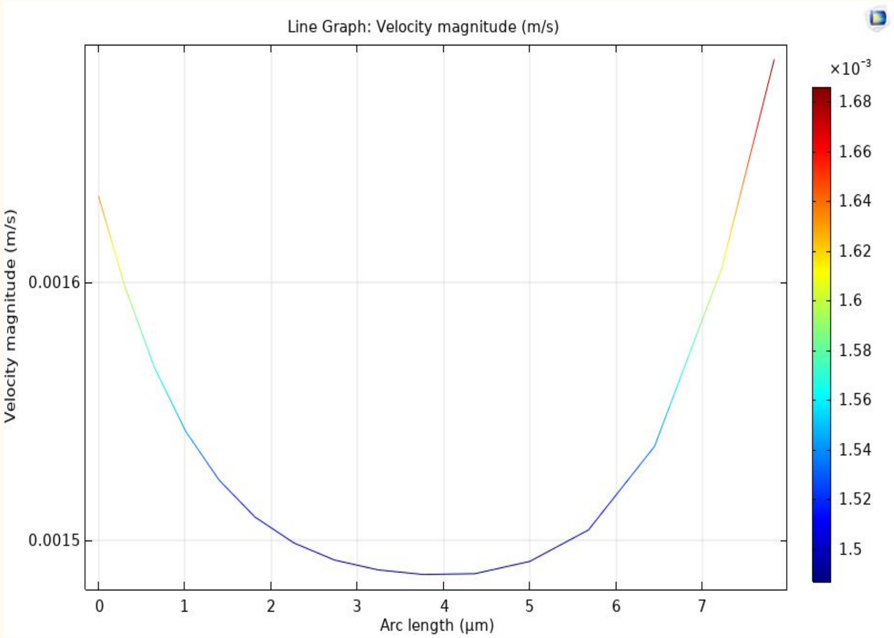
2. With the help of this we can actually shift the successive column of pillars which in turn provides an asymmetric flow lane distribution in DLD devices.



RESULTS

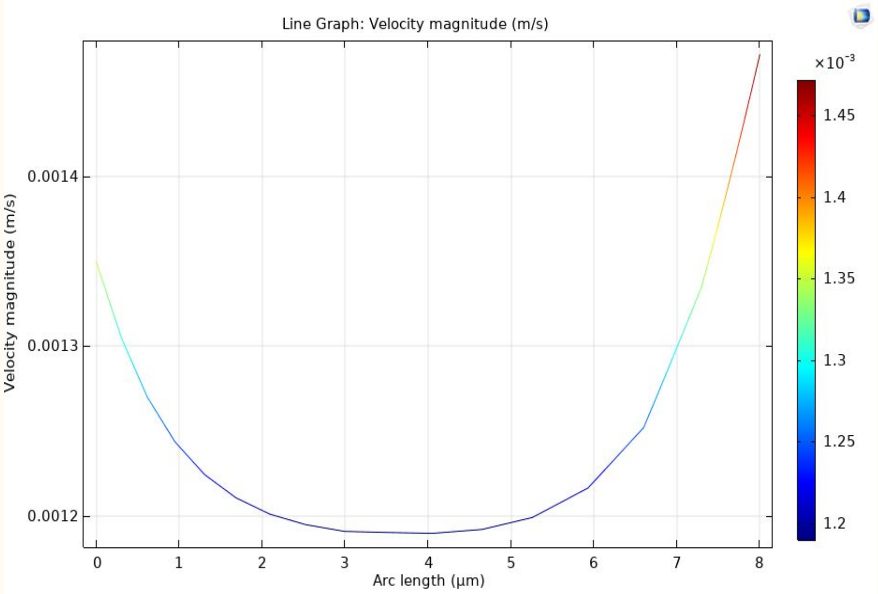


N=5

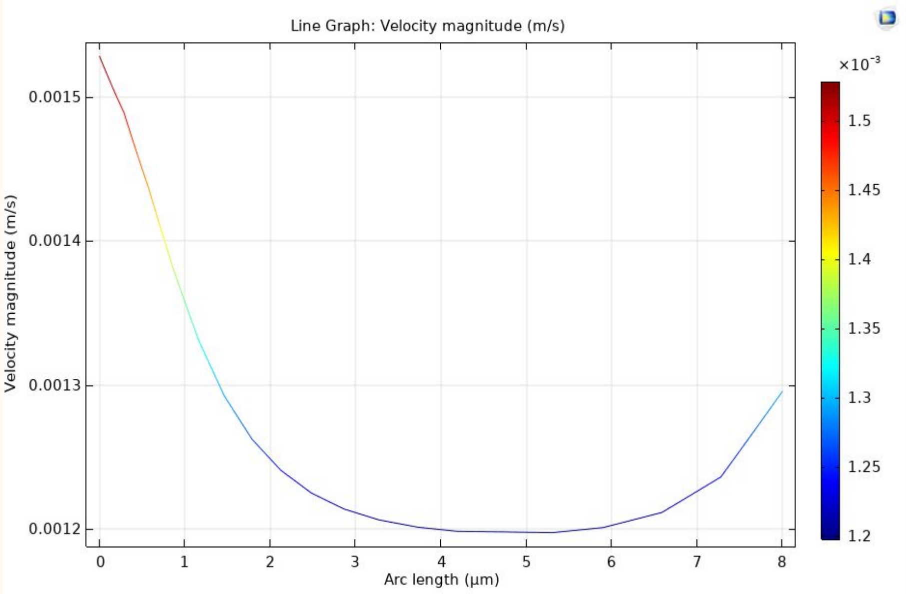


N=10

Hexagonal Pillars
Velocity Magnitude vs Arc Length Plots

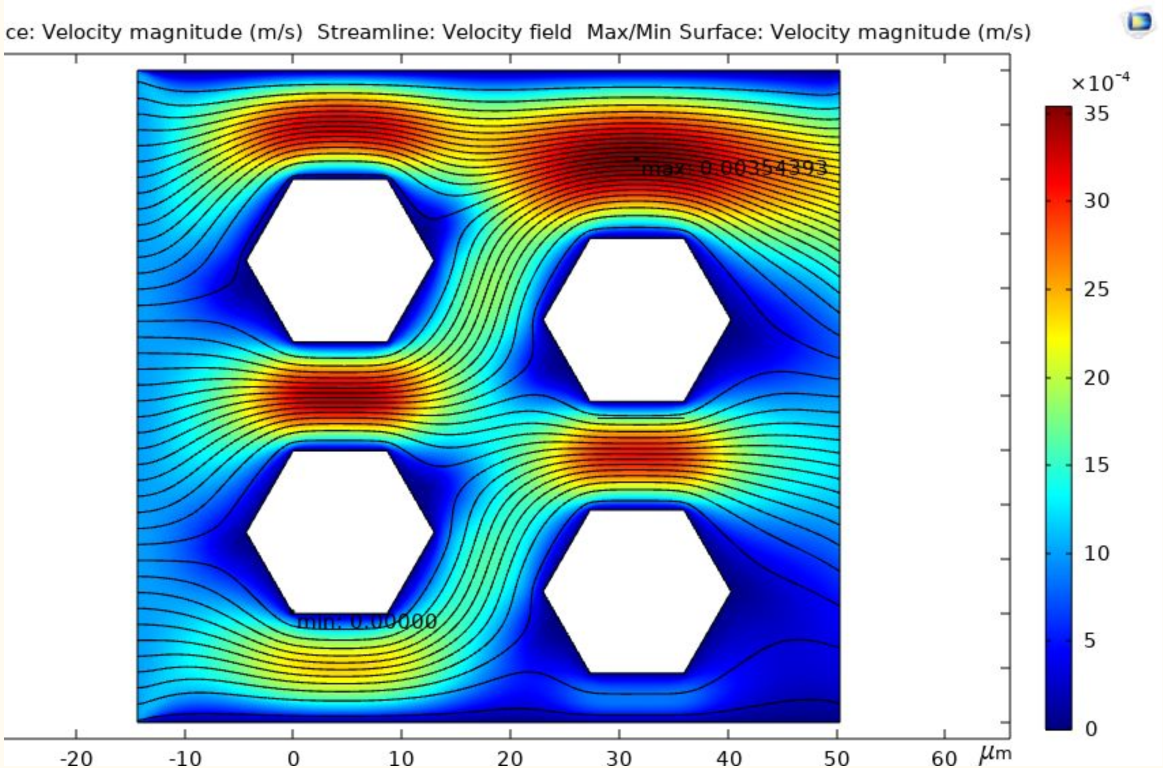


N=15



N=20

Hexagonal Pillars
Velocity Magnitude vs Arc Length Plots



N=5

Inlet Velocity = 0.001 m/sec

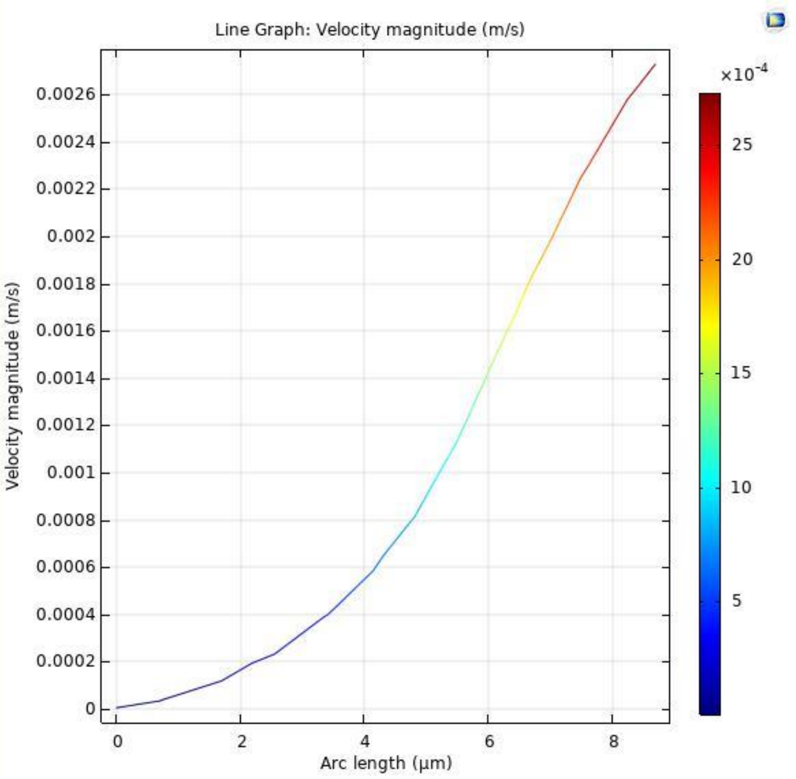
Outlet Pressure = 101325 pa

Density of Streamline = 25

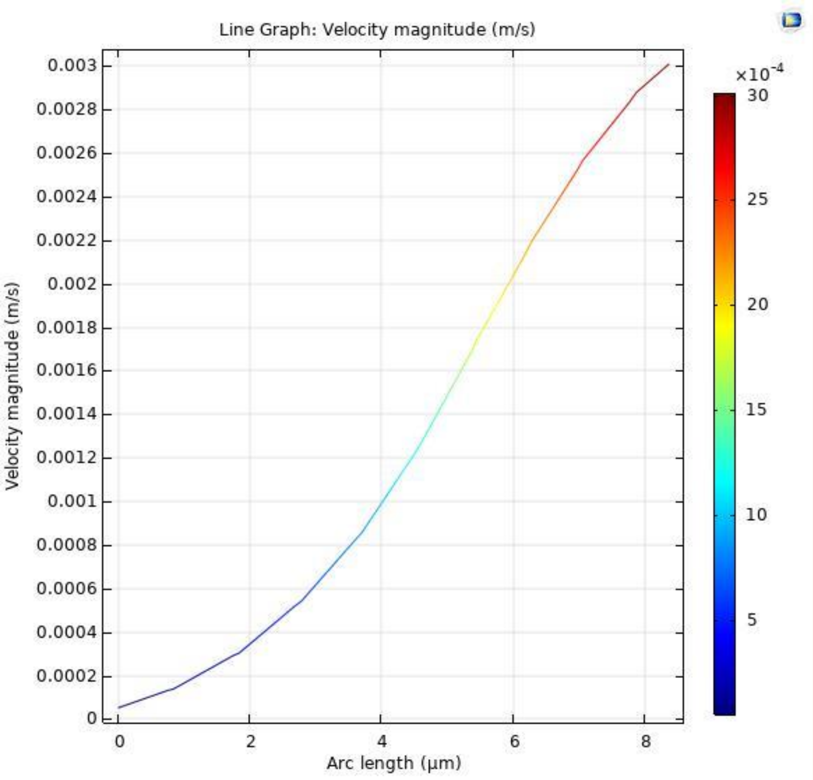
Gradient (**θ**) = 11.309°

Y-Axis Shift= - 5.464101µm

N=5

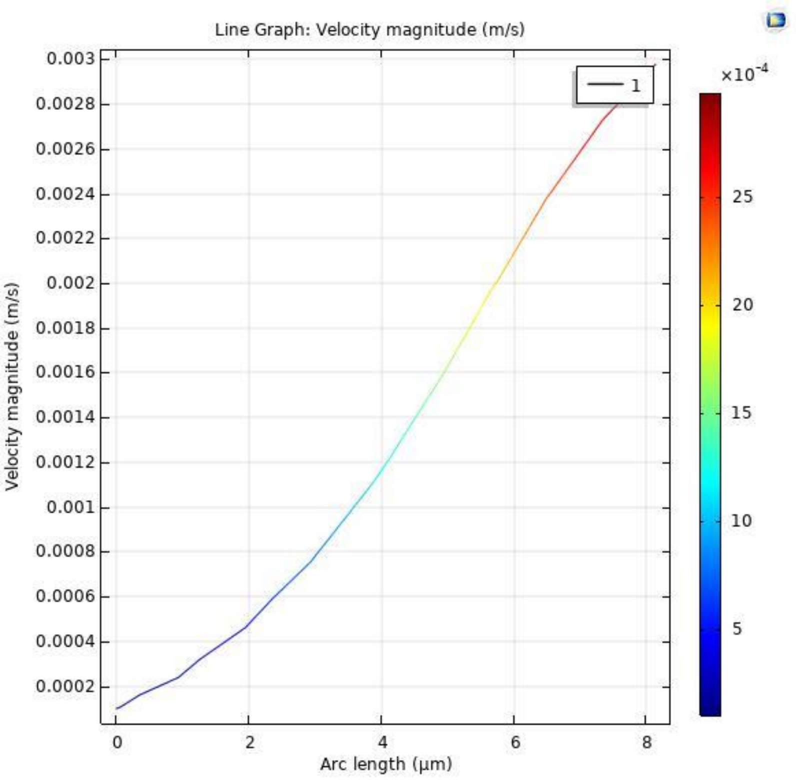


N=10

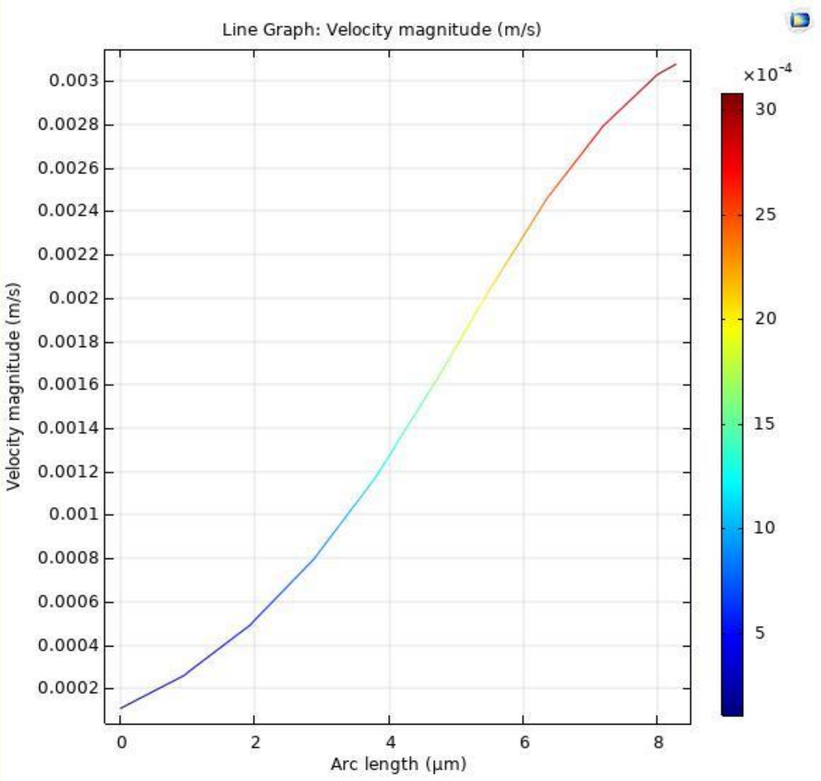


I - Shaped Pillars with Triangular Cutout
Velocity Magnitude vs Arc Length Plots

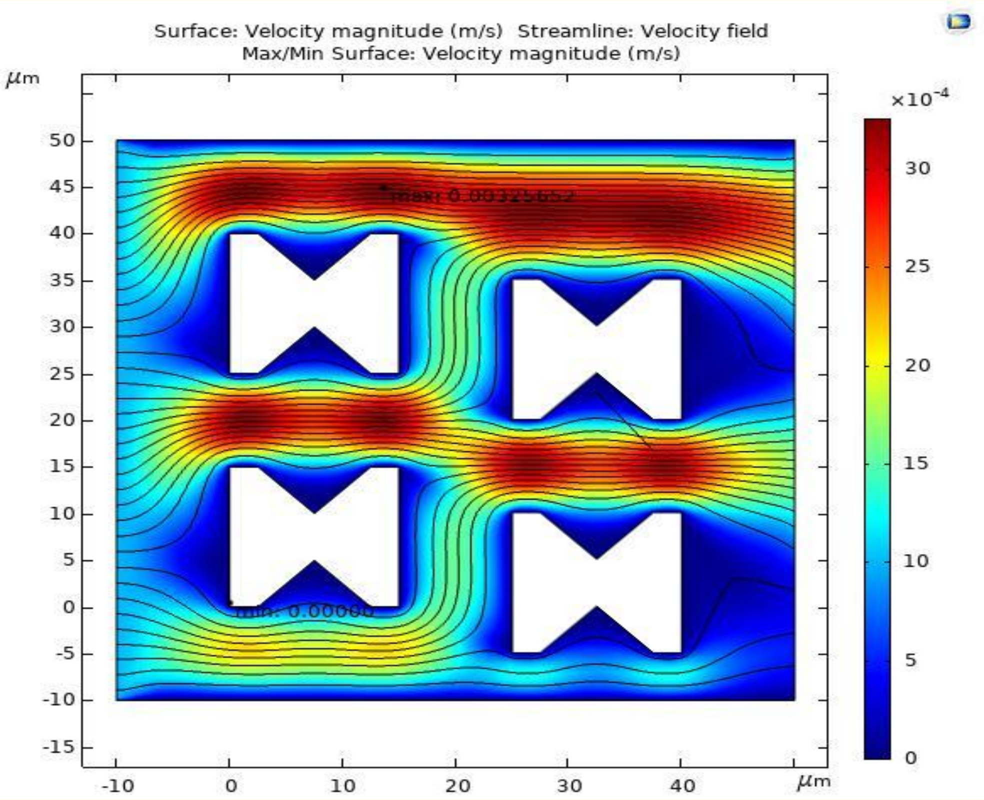
N=15



N=20



I - Shaped Pillars with Triangular Cutout
Velocity Magnitude vs Arc Length Plots



N=5

Inlet Velocity= 0.001 m/sec

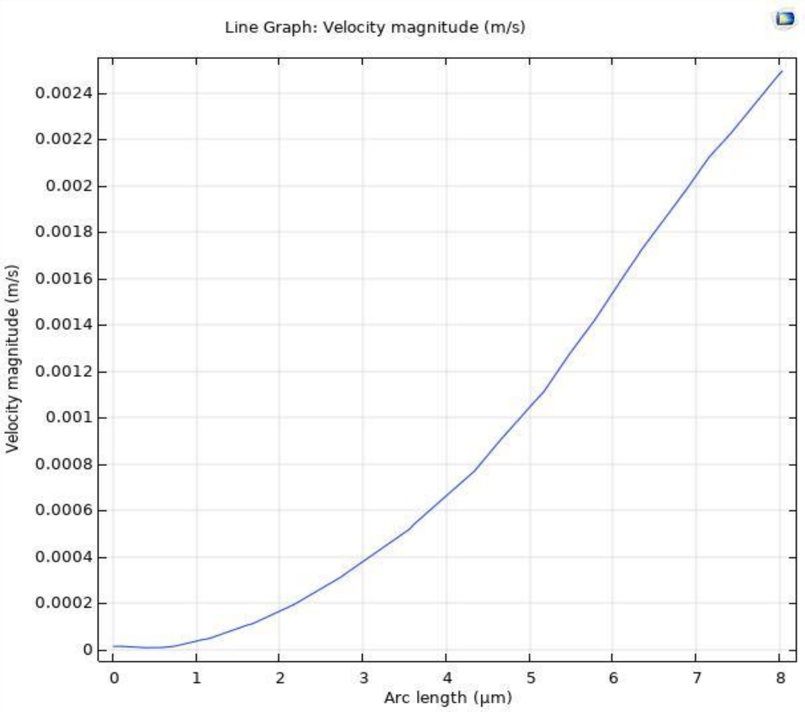
Outlet Pressure = 101325 pa

Density of Streamline = 20

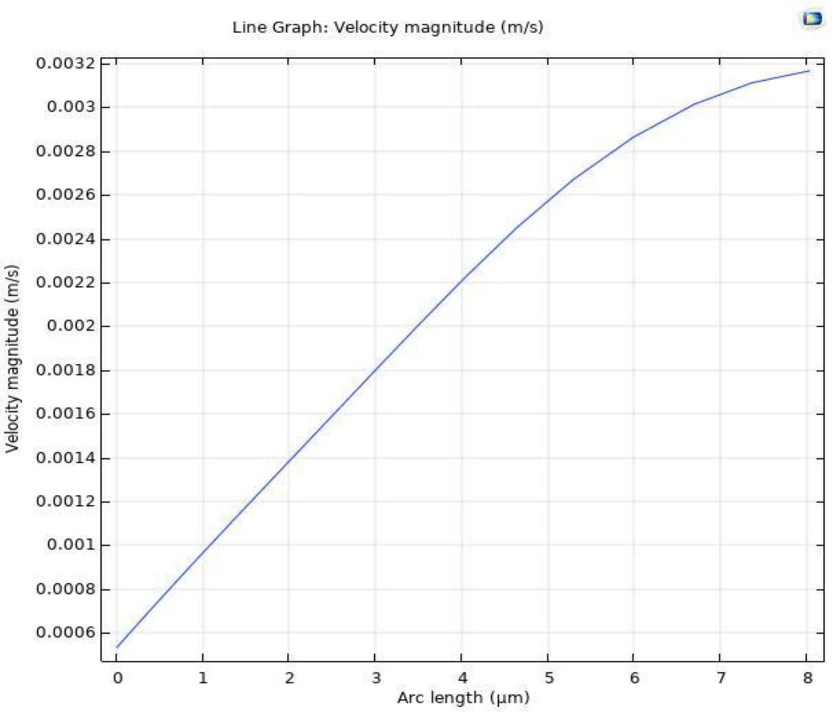
Gradient(θ) = 11.309°

Y-Axis Shift = -4.903μm

$$N = 5$$

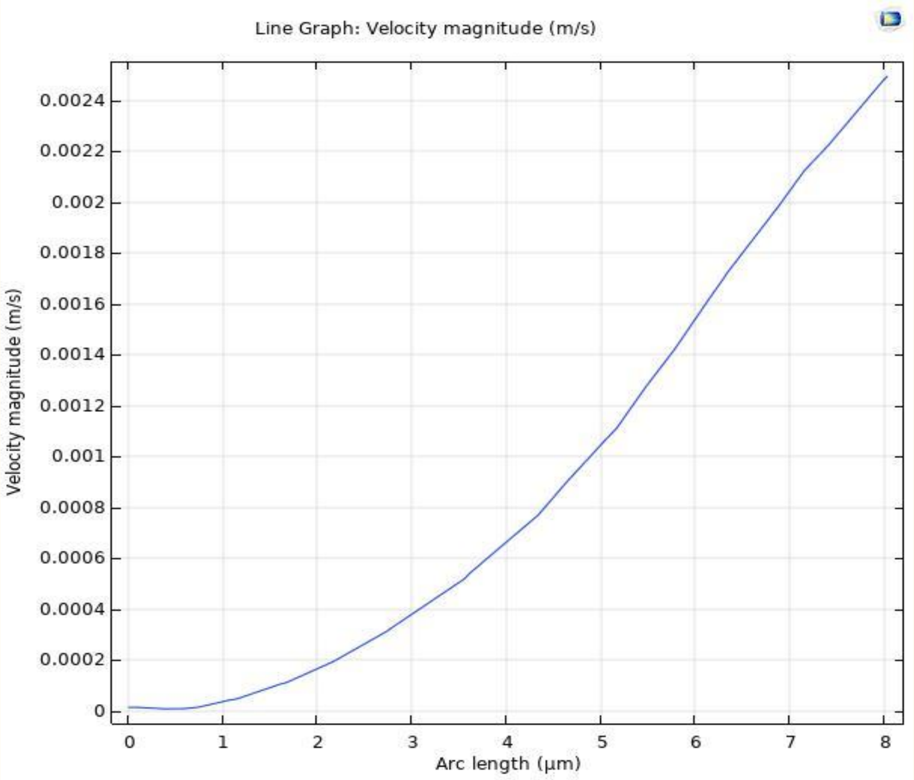


$$N = 10$$



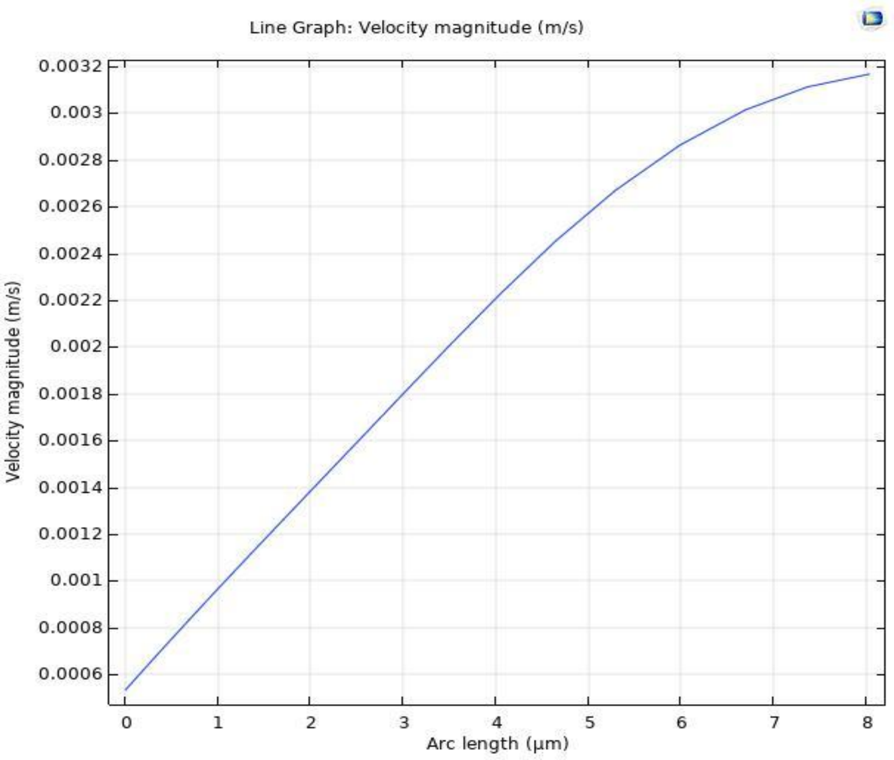
N - Shaped Pillars
Velocity Magnitude vs Arc Length

N = 15



Line Graph: Velocity magnitude (m/s)
0.0024
0.0022
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
Velocity magnitude (m/s)
0 1 2 3 4 5 6 7 8
Arc length (µm)

N = 20



Line Graph: Velocity magnitude (m/s)
0.0032
0.003
0.0028
0.0026
0.0024
0.0022
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
Velocity magnitude (m/s)
0 1 2 3 4 5 6 7 8
Arc length (µm)

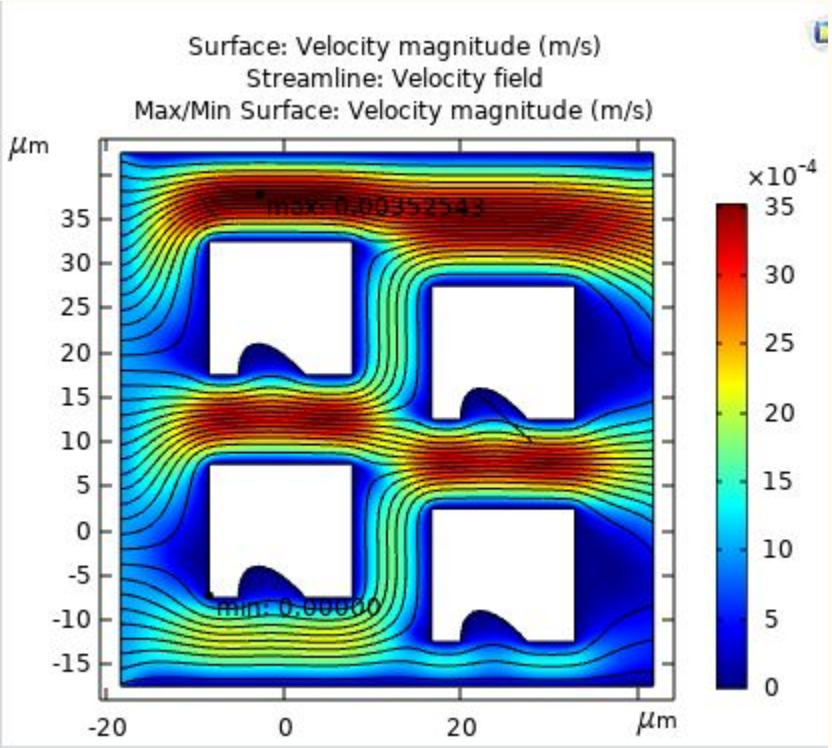
Inlet Velocity = 0.001 m/sec

Outlet Pressure = 101325 pa

Density of Streamline = 20

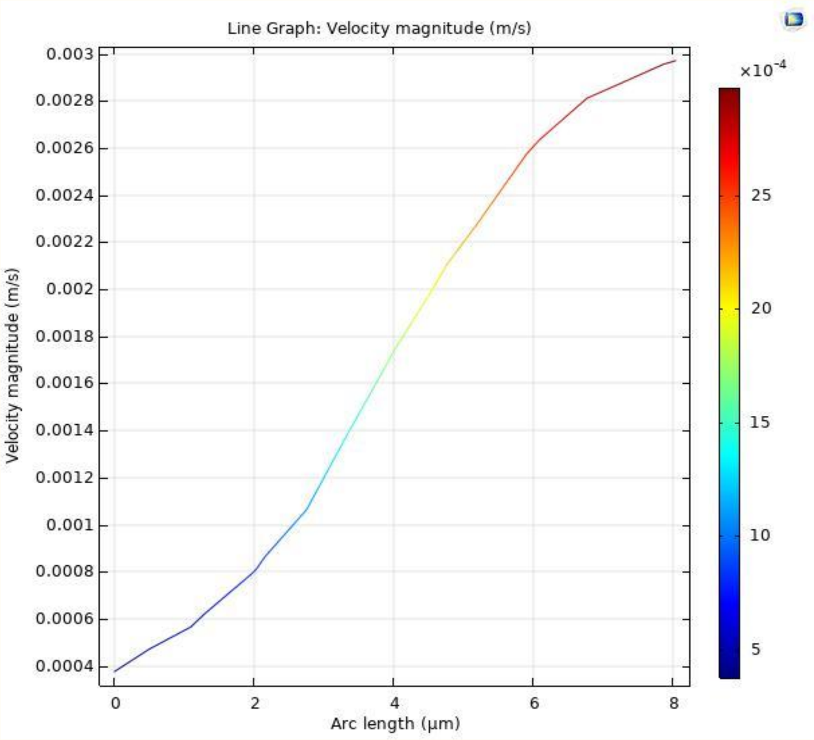
Gradient (θ) = 11.309°

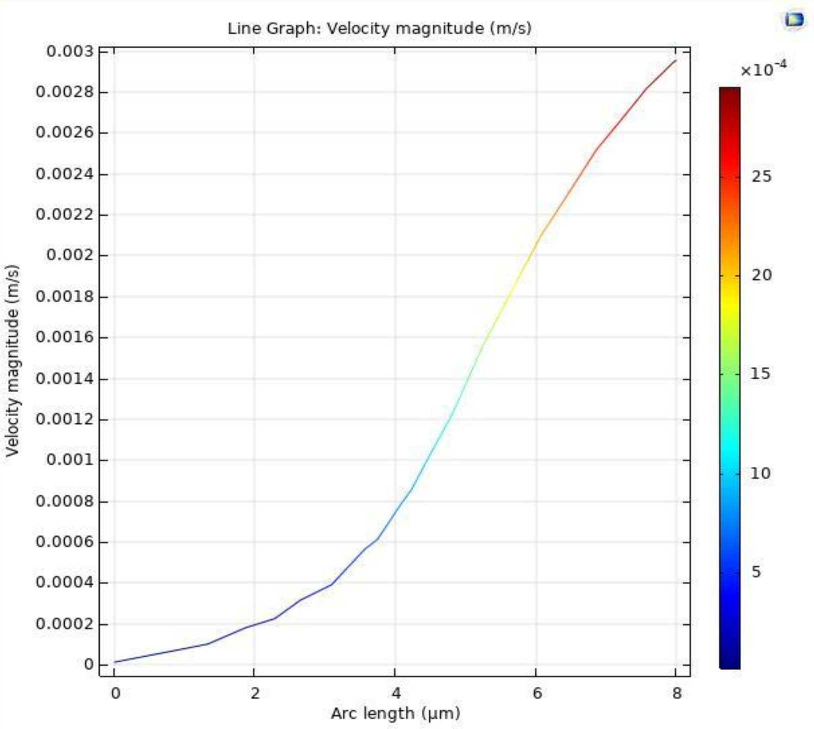
Y-Axis Shift = -4.903μm



N=5

$N = 5$ $N=10$

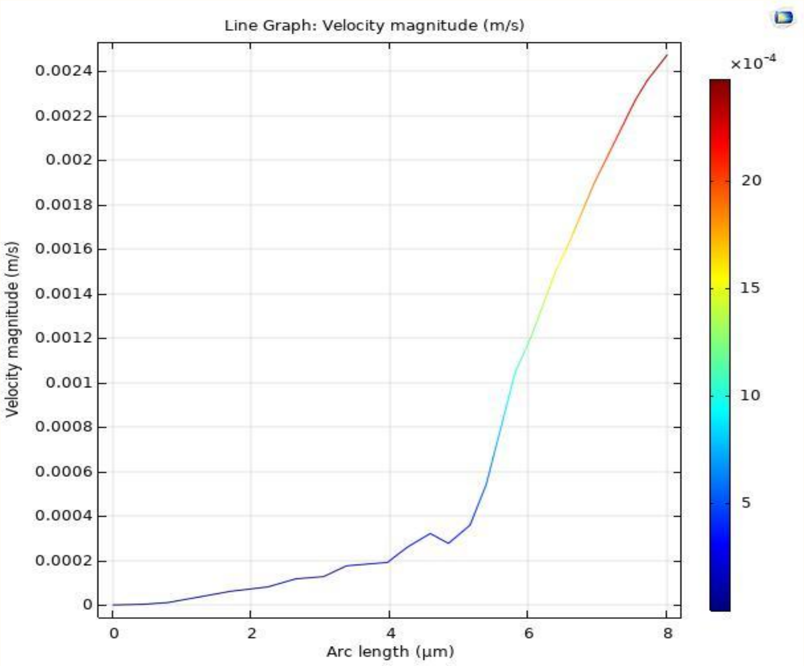


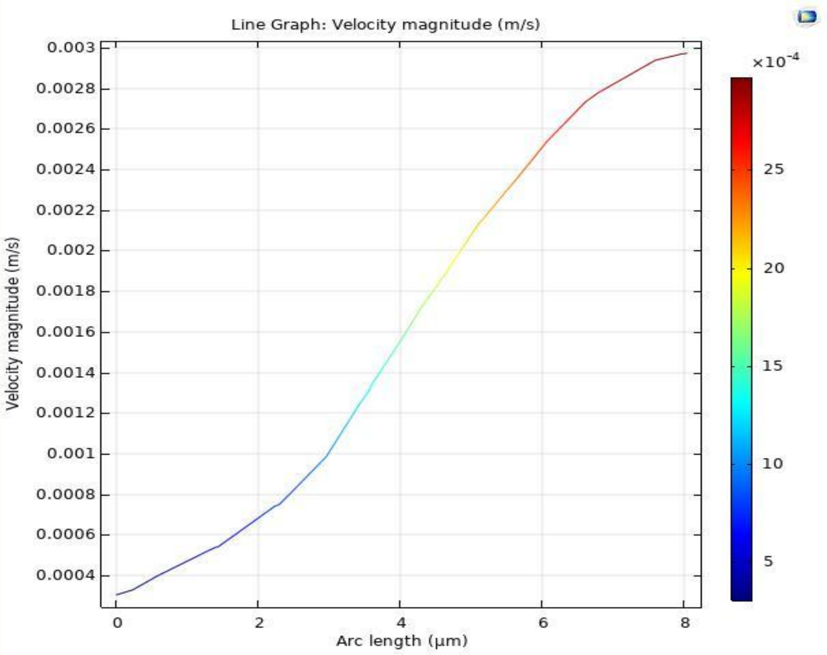


I - Shaped Pillars with Circular Cutout
(Velocity Magnitude vs Arc Length Plots)

N = 15

N = 20


Line Graph: Velocity magnitude (m/s)
Velocity magnitude (m/s)
0.0024
0.0022
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
0
2
4
6
8
Arc length (µm)
×10⁻⁴
20
15
10
5


Line Graph: Velocity magnitude (m/s)
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0.003
0.0028
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0.0022
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0
2
4
6
8
Arc length (µm)
×10⁻⁴
25
20
15
10
5

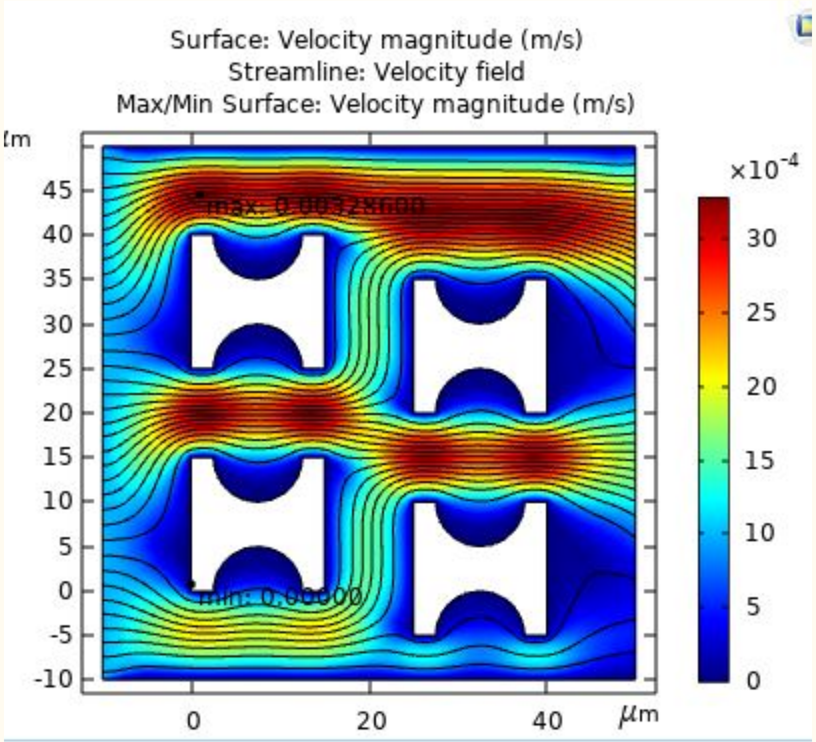
Inlet Velocity = 0.001 m/sec

Outlet Pressure = 101325 pa

Density Of Streamline = 25

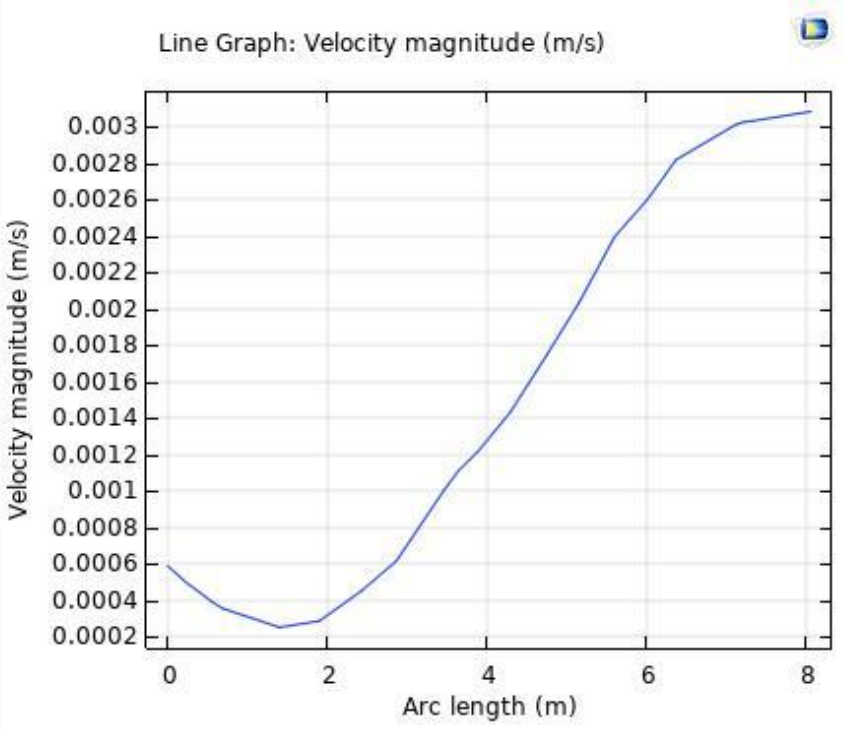
Gradient (θ) = 11.309°

Y-Axis Shift = -4.90

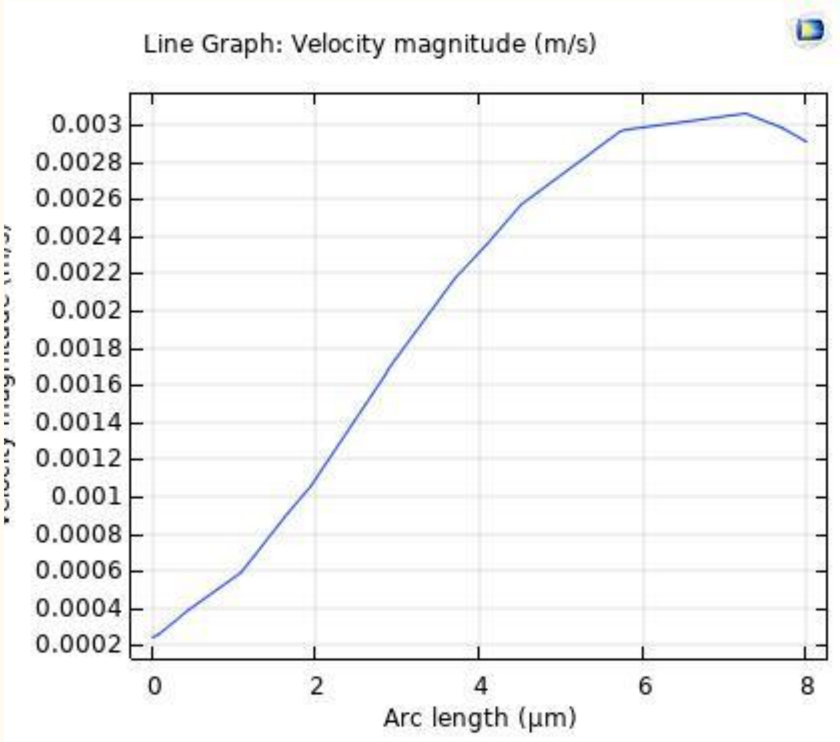


N = 5

N = 5

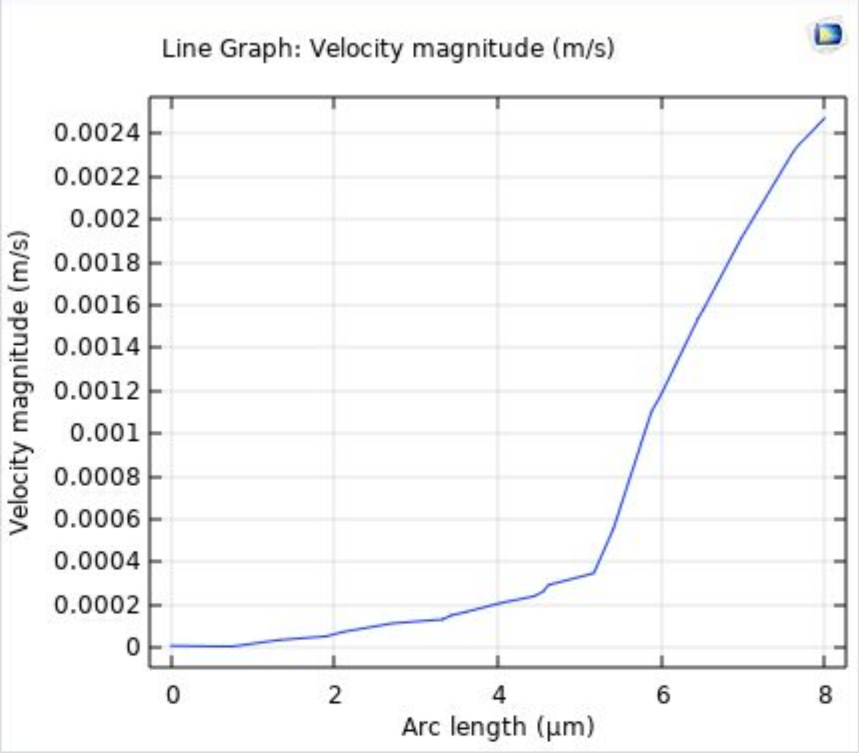


N = 10



I-Shaped Pillars (Inverted N)
Velocity Magnitude vs Arc Length

N = 15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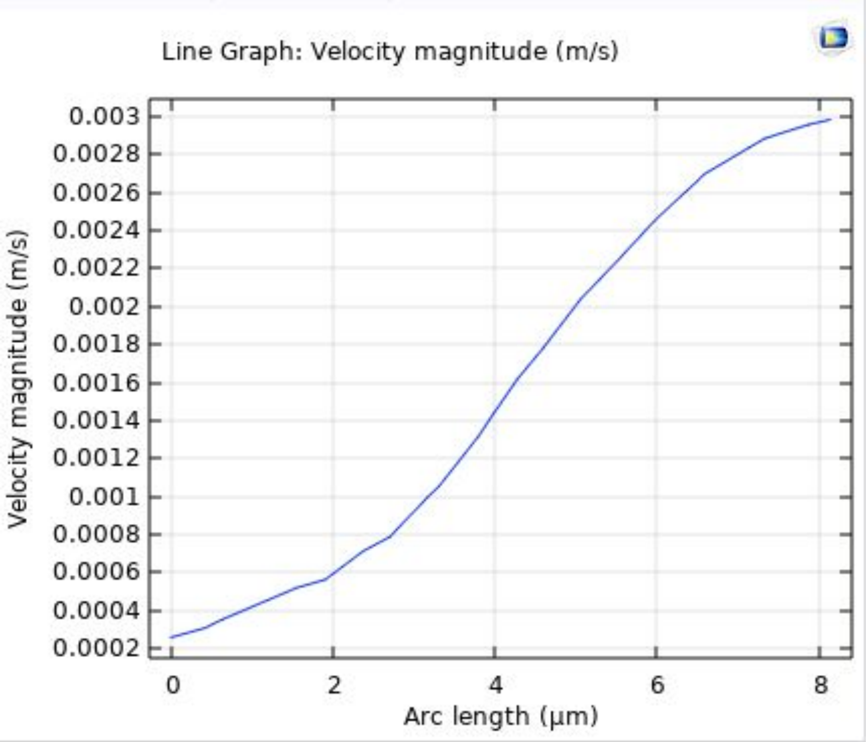
0.0022
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
0
2
4
6
8
Arc length (µm)

N = 20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0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
2
4
6
8
Arc length (µm)

Inlet Velocity = 0.001 m/sec

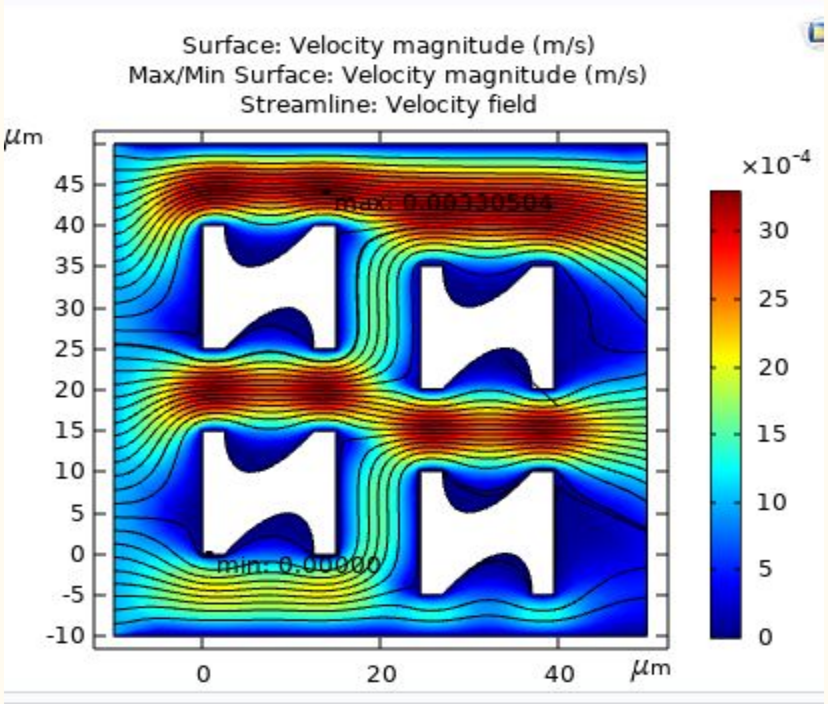
Outlet Pressure = 101325 pa

Density of Streamline = 25

Gradient (θ) = 11.309°

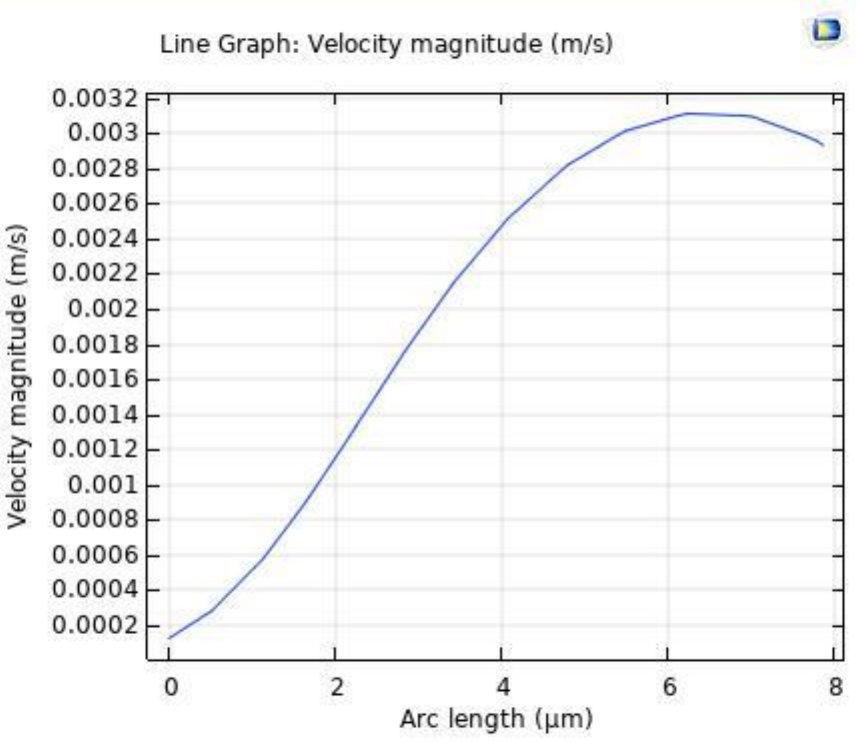
Y-Axis Shift = -4.903μm

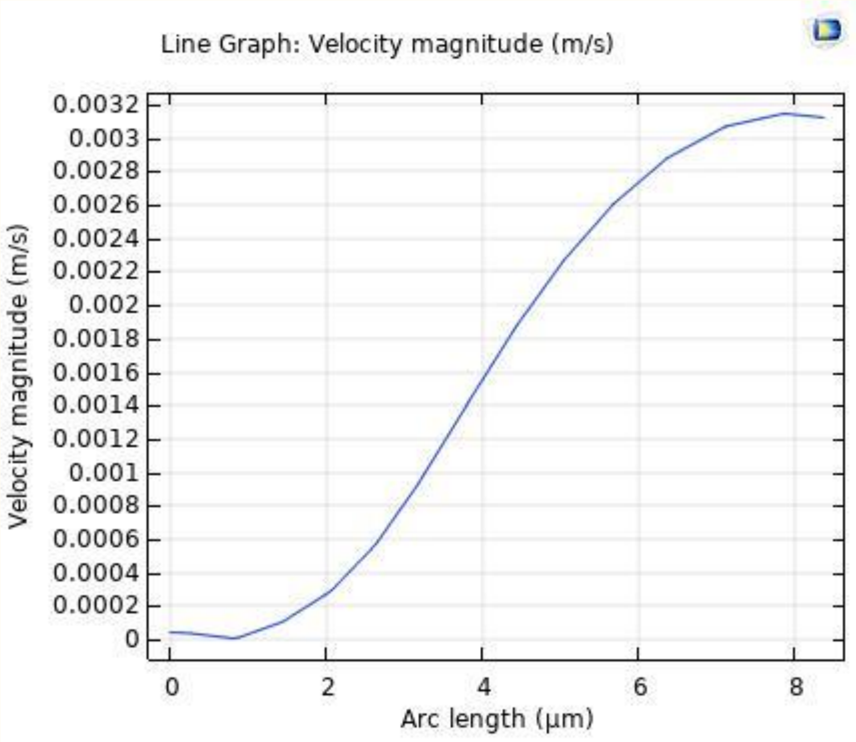
N=5



N = 5

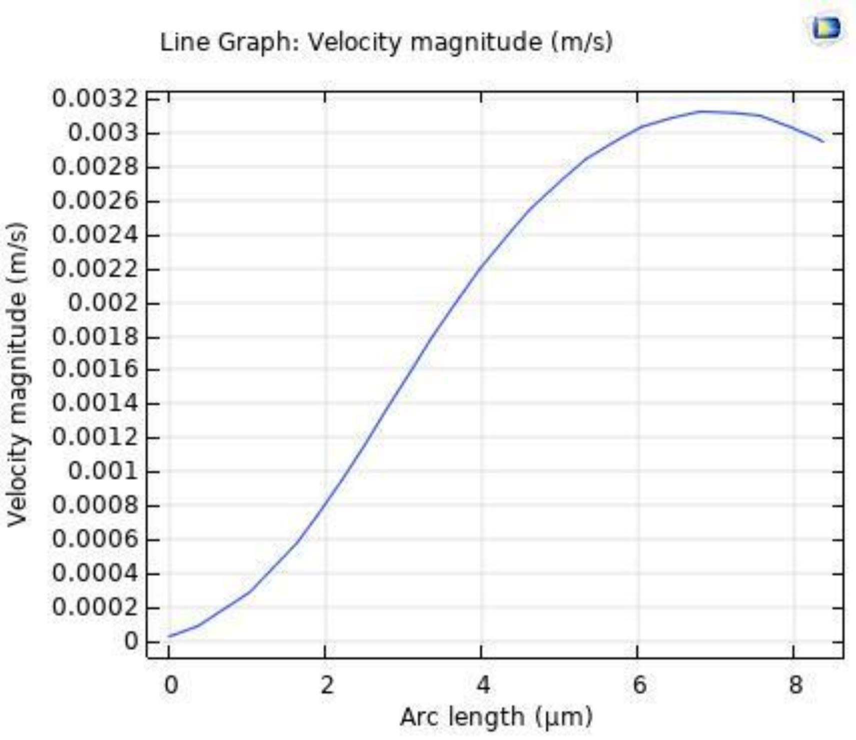
N = 10





H- Shaped Pillars with Elliptical Cutout
Velocity Magnitude vs Arc Length

N = 15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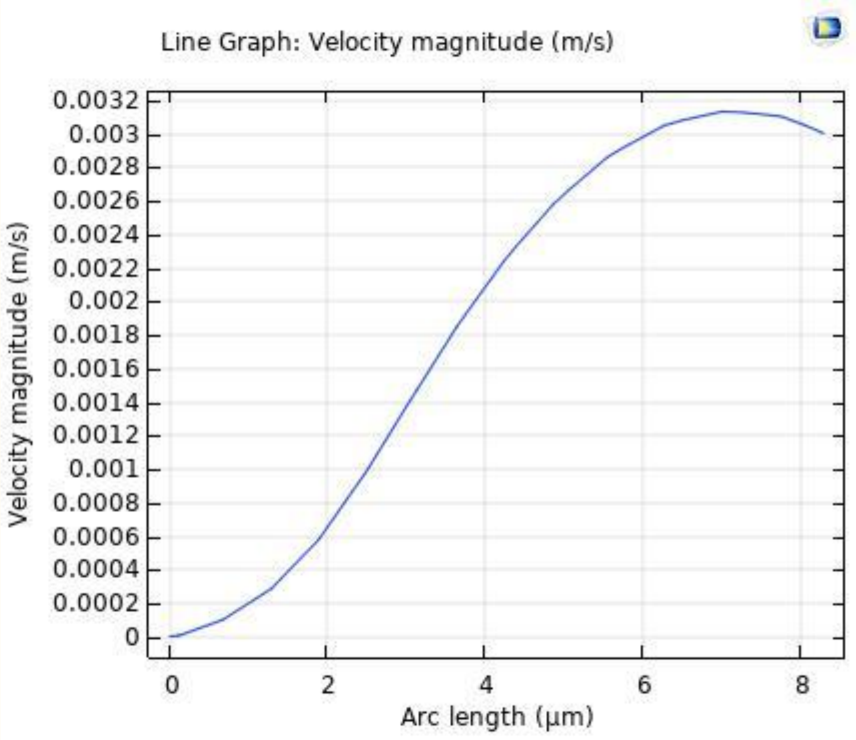
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
0
2
4
6
8
Arc length (µm)

N = 20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0.0024
0.0022
0.002
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
0
2
4
6
8
Arc length (µm)

Inlet Velocity = 0.001 m/sec

Outlet Pressure = 101325 pa

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