Undergraduate Research Symposium

Enhancing miscible fluid mixing using Golden ratio spiral Microchannel

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Introduction:

- Mixing of fluids has numerous applications.
- It is crucial in maintaining a homogenous environment for chemical and biological experimentation.
- Particularly with micro channels, it is used in lab-on-a-chip applications.[2]
- Every chemical reaction among various components on the chip are governed by understanding the physics behind mixing.
- Mixing of miscible fluids using a T-shaped microchannel has been a standard.[1]
- W.R. Dean's works on the fluid behavior in curved channels revolutionized mixing.[2]
- The anomalous behavior of the golden ratio[4] spiral microchannel and the physics behind it is analyzed.

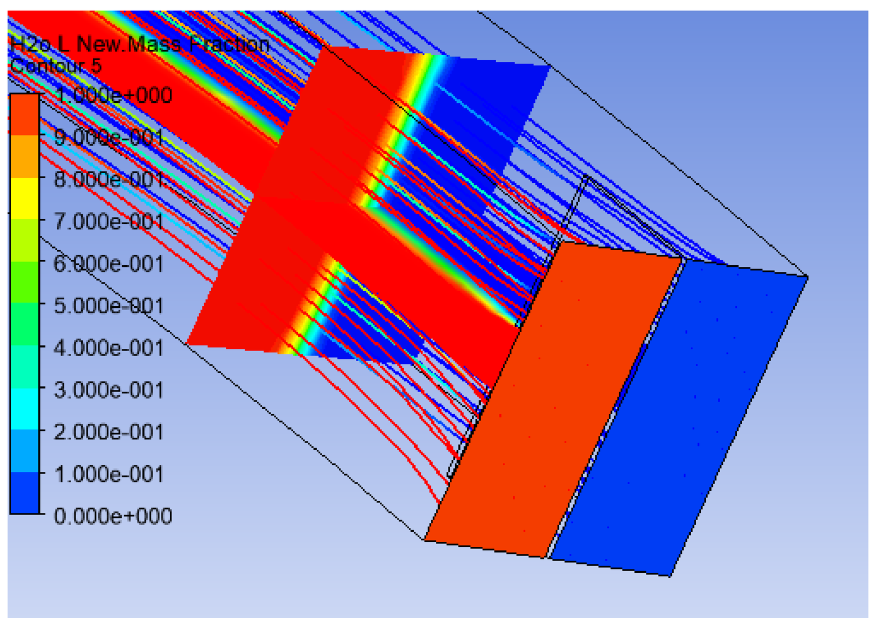


Figure 1. *Mixing at the inlet position*

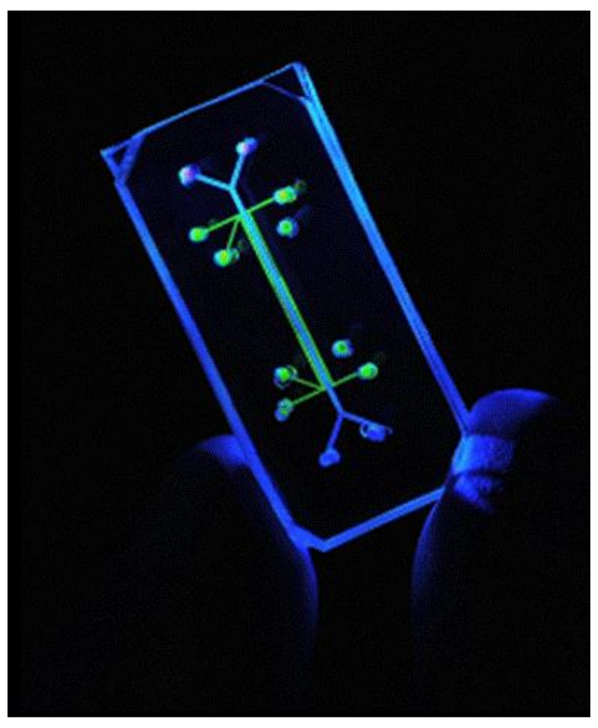


Figure 2. *Lungs on chip [5]*

Literature:

- The effect of miniaturization of dimension to a micrometer scale increases the ratio of surface area relative to fluid volume. This enhances mixing as well as the heat transfer between the fluids.[2]
- The inertial forces enable the inter and intra molecular diffusion, which upon formulation results in the species transport equation.[1][3]
- The introduction of curvature in the microchannel path leads to the generation of a net shear force along the axial plane.[1][2][3]
- Balancing this force, keeping the conservation of mass in mind results in the formation of vortices knows as Dean's vortices in the fluid.
- These vortices enhance the mixing properties, by introducing a localized swirling motion. This was previously absent in the straight microchannel.

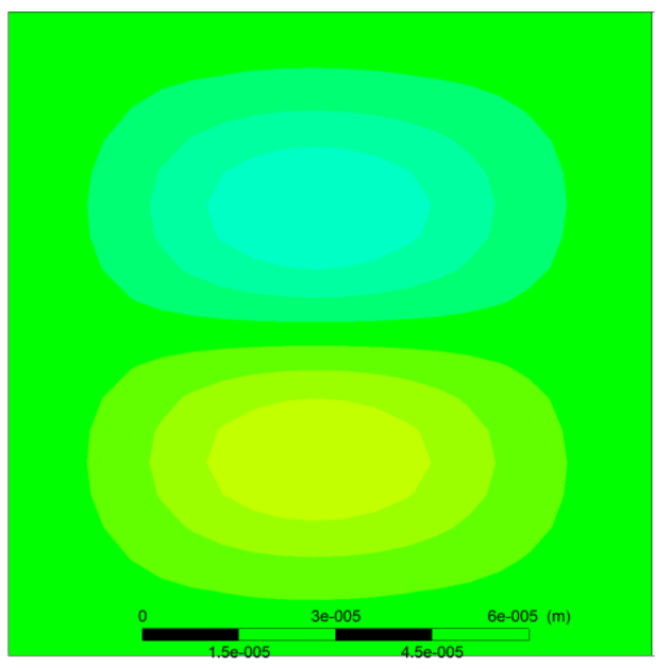


Figure 3. *Primary dean vortices (Archimedean spiral, Re : 40)*

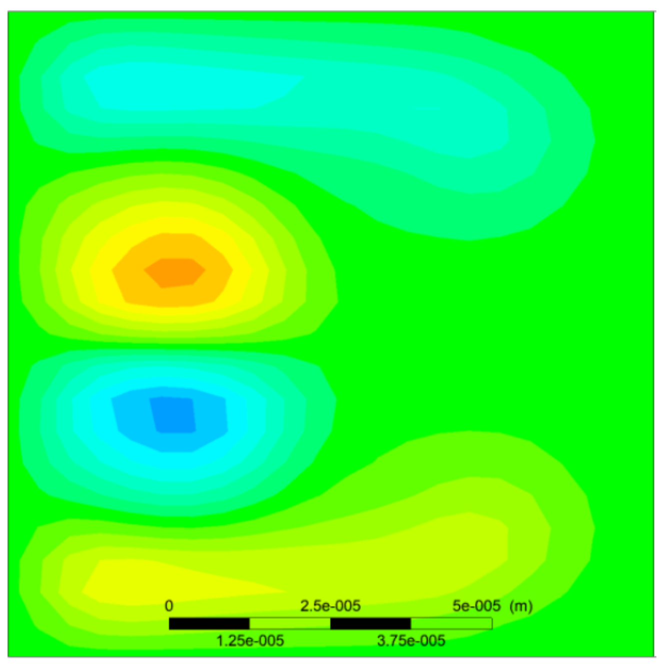


Figure 4. *Secondary dean vortices (Archimedean spiral, Re : 1000)*

Methods:

- In order to obtain a comparative on the various curved microchannel geometries, a study was done on various spiral geometries.
- Archimedean, Hyperbolic and golden ratio spirals were utilized.
- The governing equations along with the STE were solved in FLUENT.
- A grid Independence test was carried ensure the accuracy of the solutions.
- The contours and data exportation was done from POST. MATLAB was utilized to calculate the mixing efficiency.

Results:

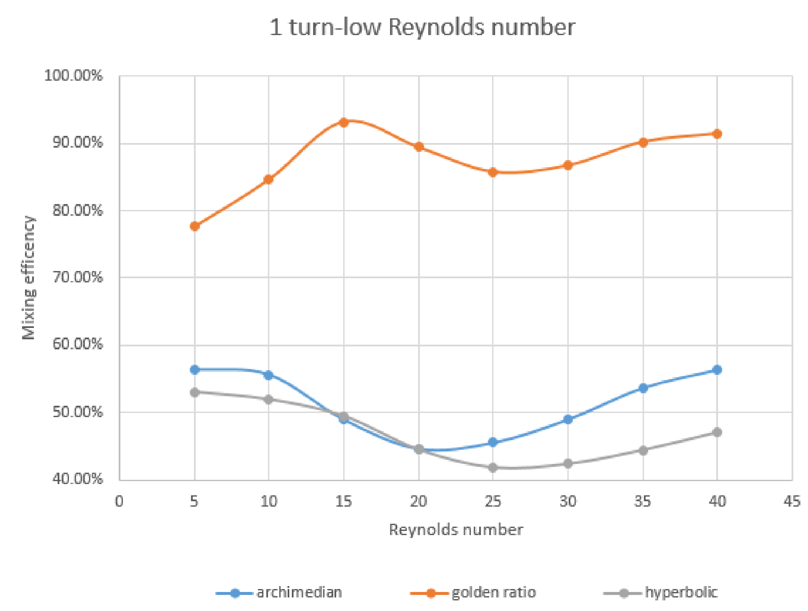


Figure 5. *Mixing efficiency over Reynolds number*

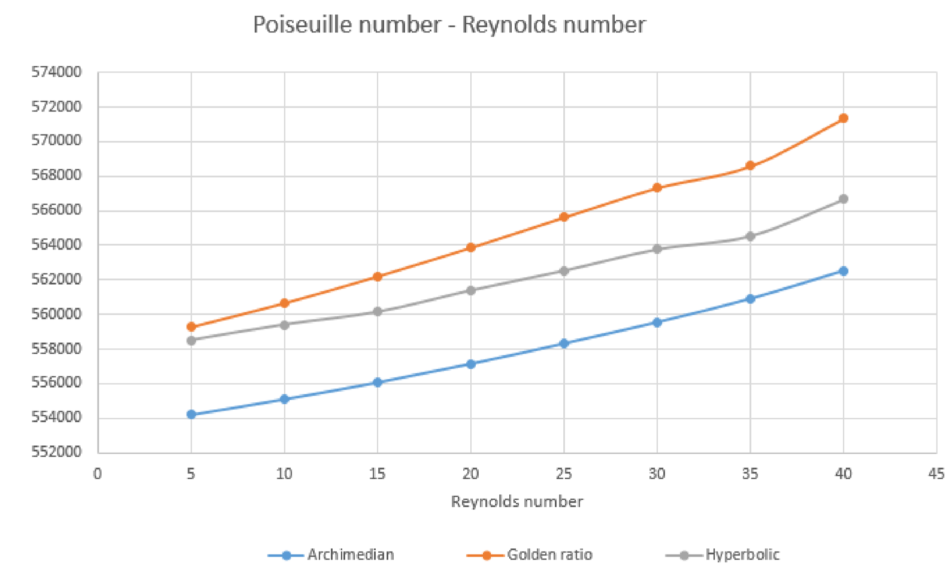


Figure 6. *Poiseuille number over Reynolds number*

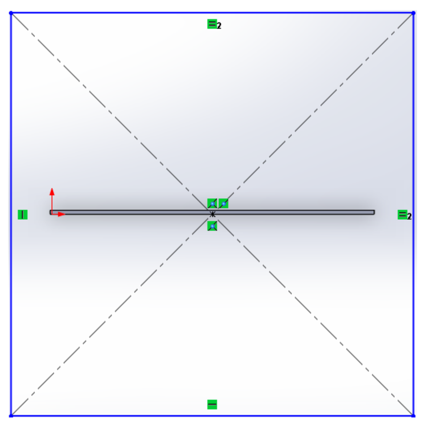
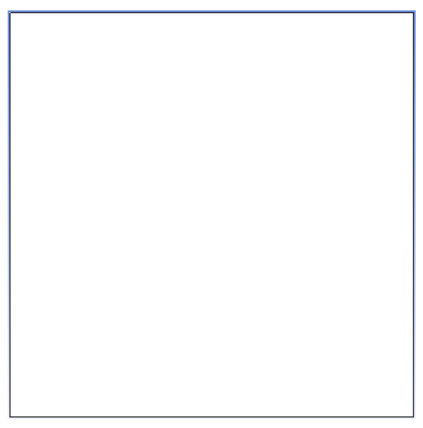
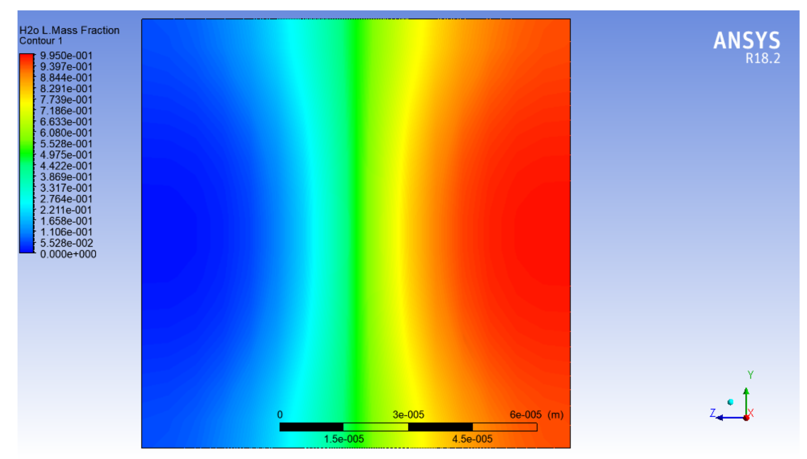
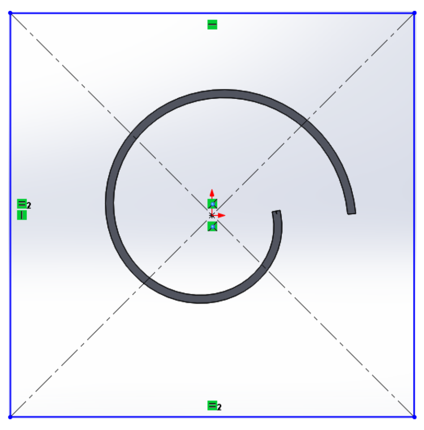
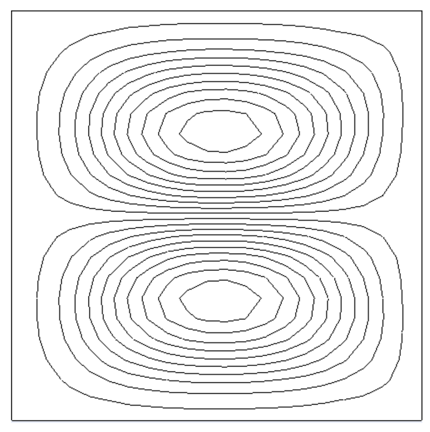
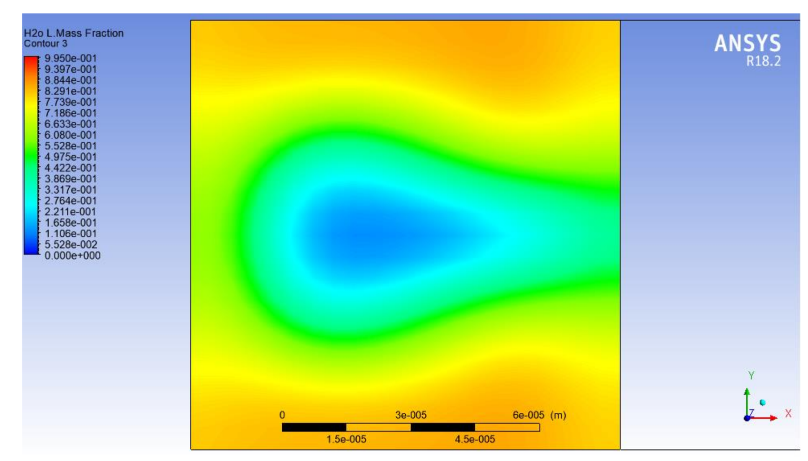
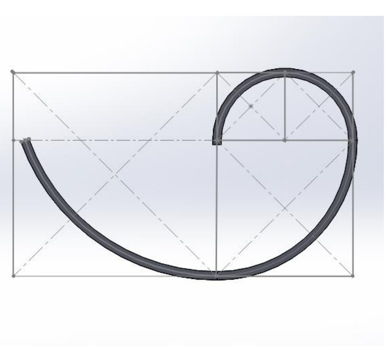
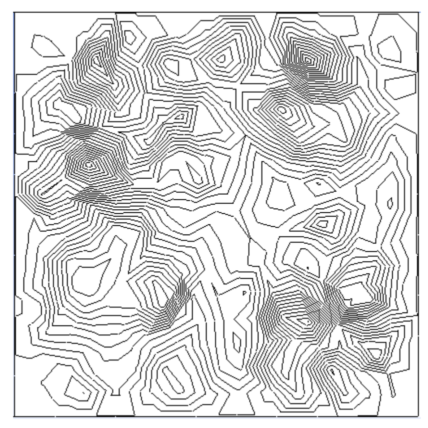
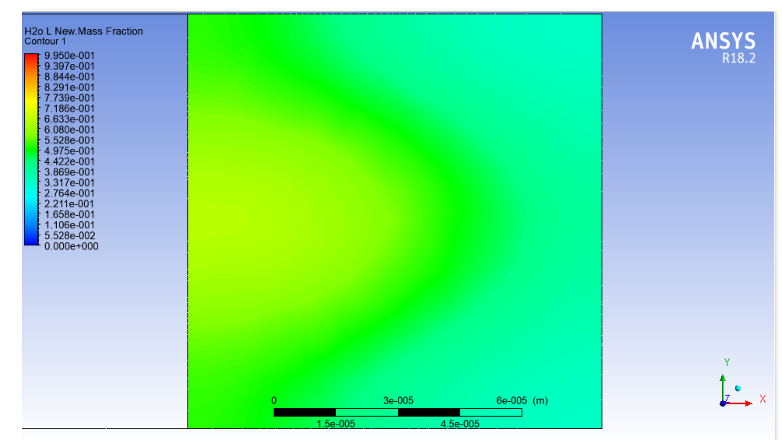
Geometry	Velocity helicity at the outlet	Mass-fraction at the outlet
		
		
		

Table 1. *Comparison among straight, Archimedean and Golden ratio spiral microchannel*

- All contours above are plotted at Re-10. Red and blue dyed water is passed through inlets in a vertical configuration. Green indicates complete mixing.

Conclusions:

- The anomalous behavior of the golden ratio spiral can be attributed to the sudden change in the radius of curvature of the spiral (for every quarter turn).
- A sudden change in the dean's number(Re.√(2.R/D)) is observed.
- A dispersion of the dean's vortices is observed, which also lead to an increase in the swirling strength.
- The golden ratio[4] spiral gives us an insight on how fluid mixing can be enhanced through a crude approximation of the growth rate as the golden ratio.

Important References:

- [1] **V. S. Duryodhan, R. Chatterjee, S. G. Singh and A. Agrawal** , "Mixing of Planar Spiral Microchannel," Experimental Thermal Fluid Science, vol. 89, pp. 119-127, 2017
- [2] **Di D Carlo,** Inertial Microfluidics, Lab on a chip (9) 2009, 3038.
- [3] **A. Alam, K.Y. Kim,** Analysis of mixing in curved microchannel with rectangular grooves, Chem. Eng. J. 181–182 (2012) 708.
- [4] **Omotehinwa T, Ramon S.O** Fibonacci Numbers and Golden Ratio in Mathematics and science, *International Journal of Computer and Information Technology (ISSN: 2279-- 0764)*
- [5] **openwetware.org**/wiki/Sythetic_Organs_on_a_Chip,_by_Manuel_Escanciano_and_Chris_Lowe

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