COMSOL CONFERENCE
2020 NORTH AMERICA

Ferrofluid Mixing in A Double-Layer Magnetic Micromixer

Ran Zhou

zhou970@pnw.edu

Assistant Professor, Department of Mechanical and Civil Engineering.

Purdue University Northwest, Hammond, IN, USA

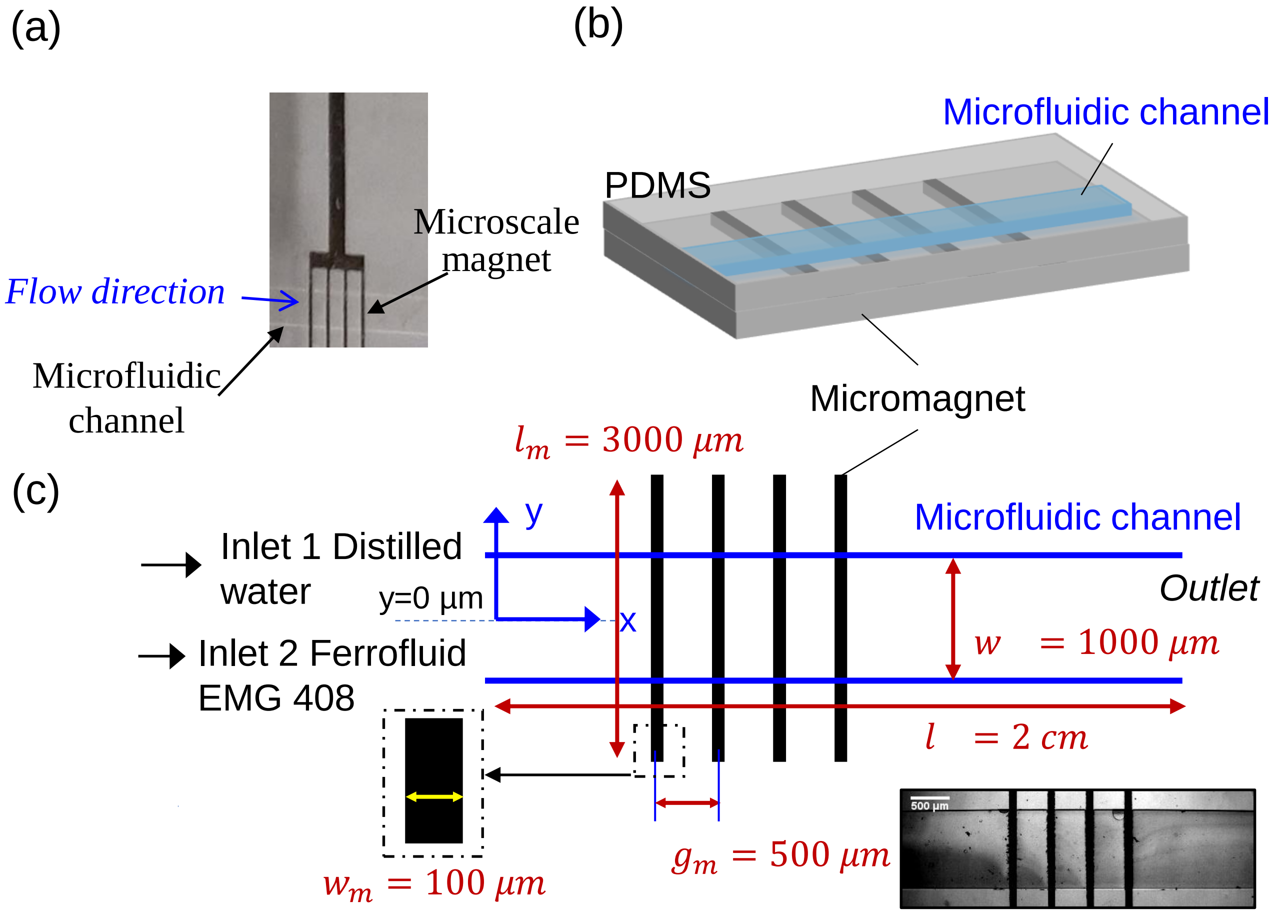
2200 169th Street, Powers Building
211K. Hammond, IN 46323-2094

PURDUE UNIVERSITY NORTHWEST

BACKGROUND AND INTRODUCTION

- Microfluidics-based mixing has been widely used in various areas such as chemical engineering, biomedical engineering and materials science.
- Ferrofluid has been widely used as carrier medium in biological micromixer due to its advances of compatibility with bio-samples.
- In this work, a magnetic micromixer with embedded microscale magnet was developed and the simulation of mixing performance and working mechanism were done by COMSOL Multiphysics.

Prototype and Geometry

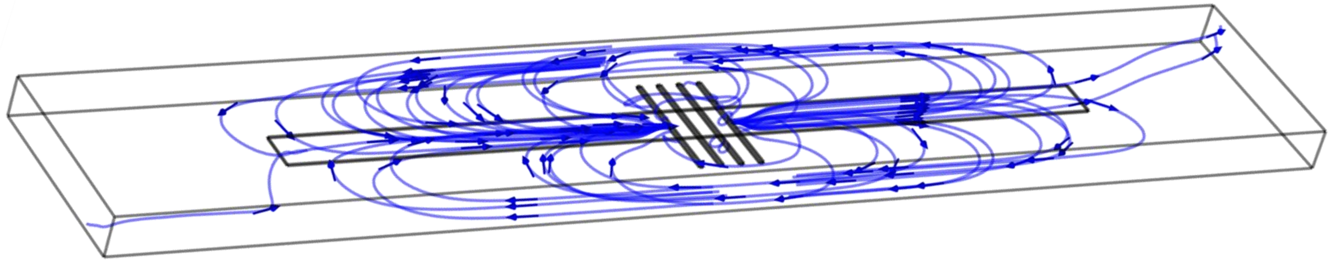


- w_c and l_c are the width and length of the microfluidic channel
- $\alpha = 90°$ is the angle between micromagnet and flow direction
- w_m is the width of the micromagnet
- g_m is the gap distance between each micromagnet
- t_m and t_c are the thickness of microfluidic channel and micromagnet.

COMPUTATIONAL METHODS

- AC/DC Module
  - Magnetic Field

Magnetic field intensity



- Basic Multiphysics Module
  - Single Phase Flow
  - Diluted Species Transport

GOVERNING EQUATIONS

Navier-Stokes equations

$$\rho\frac{\partial \boldsymbol{u}}{\partial t}+\rho(\boldsymbol{u}\cdot\nabla)\boldsymbol{u}=-\nabla p+\nabla\cdot\eta(\nabla\boldsymbol{u})+\boldsymbol{f_m}$$

$$\nabla\cdot\boldsymbol{u}=0$$

where η denotes the dynamic viscosity, $\boldsymbol{u}$ is the velocity (m/s), ρ equals the fluid density, p refers to the pressure, $\boldsymbol{f_m}$ is the magnetic force acting on ferrofluid $\boldsymbol{f_m}=\mu_0\left(\boldsymbol{M}_p\cdot\nabla\right)\boldsymbol{H}$.

GOVERNING EQUATIONS

The mass flux is given by diffusion and convection, the resulting mass balance is

$$\nabla \cdot (-D\nabla c + c\boldsymbol{u}) = 0$$

D denotes the denotes the diffusion coefficient and c gives the concentration

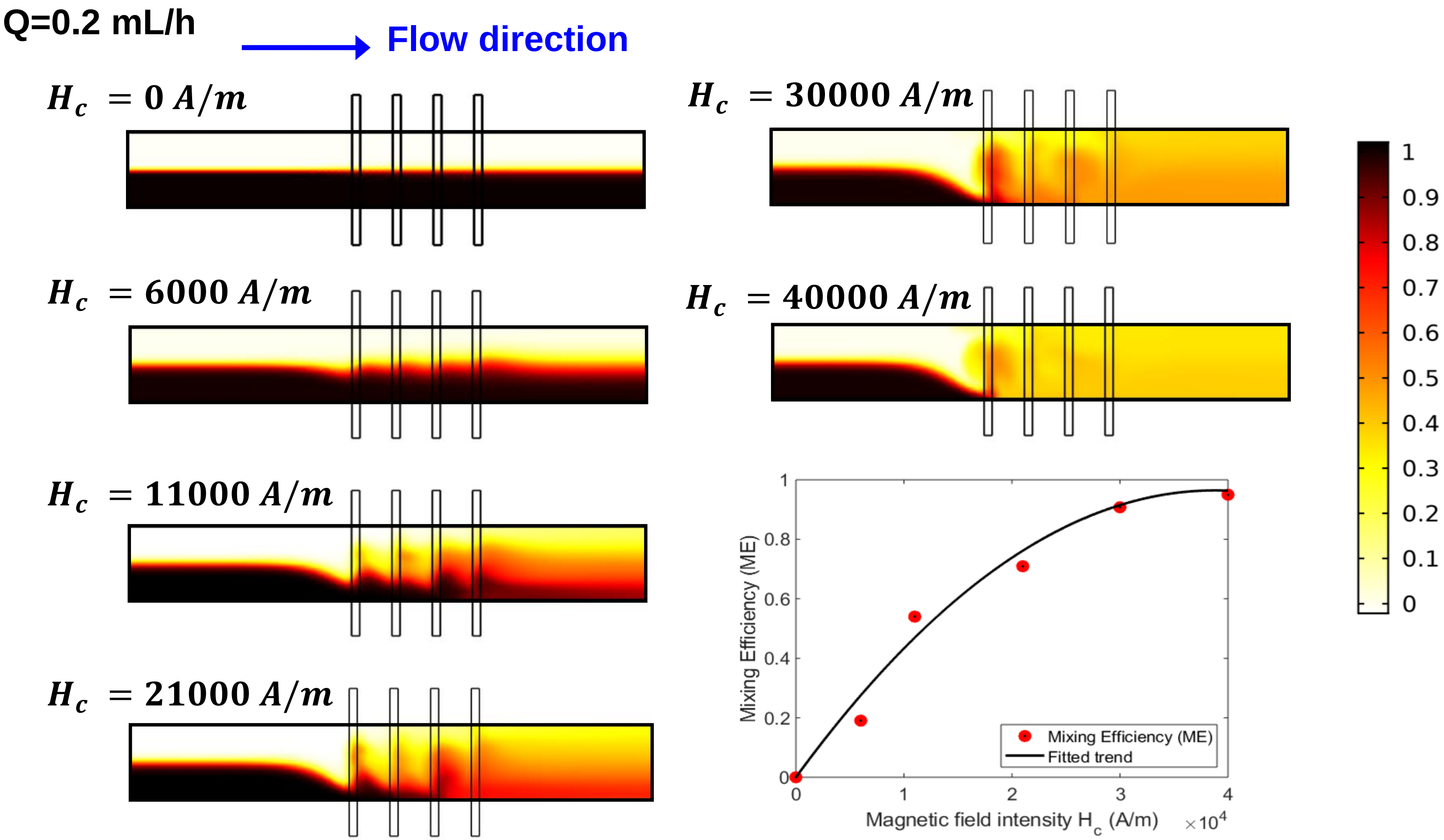
The concentration was calculated by Diluted Species Transport module. In our work, the concentration of ferrofluid at lower half was set as 1, and the upper half filled with pure water has the concentration as 0, so the B.C. was defined as

$$c_{inlet} = \begin{cases} 1, & y < 0 \\ 0, & y \geq 0 \end{cases}$$

Parameters in Mixing Modeling

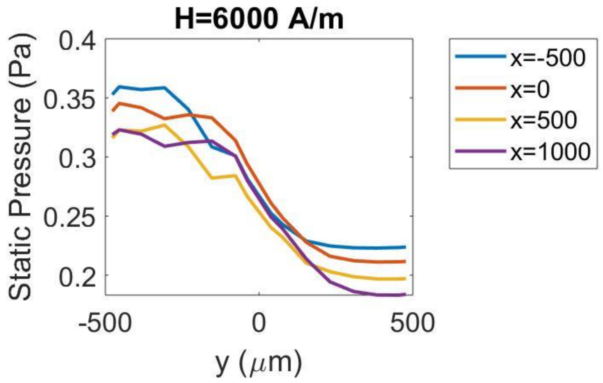
	Parameter	Symbol	Value
Micromagnet	Length	l_m	1000 μm
	Width	w_m	100 μm
	Depth	d_m	35 μm
Microfluidic Channel	Length	l	2 cm
	Width	w	1000 μm
	Thickness	d	35 μm
Original Ferrofluid	Density	ρ_f	1.07×10^3 kg/m^3
	Saturation Magnetization	M_s	6.6 mT
	Magnetic Susceptibility	χ_f	0.5
	Viscosity	η_f	2 $mPa \cdot s$
	diffusion coefficient		3.6 e^{-14} m^2/s.
Distilled Water	Density	ρ	1×10^3 kg/m^3
	Viscosity	η	1 $mPa \cdot s$

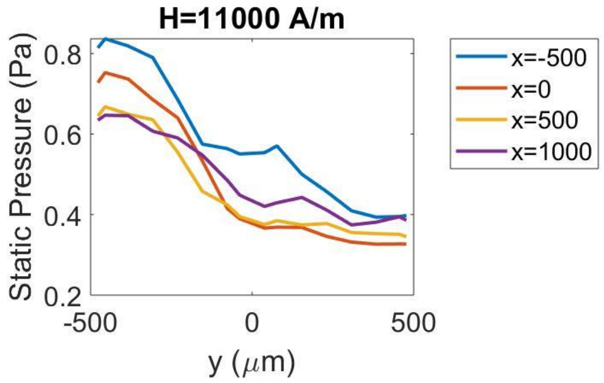
Effect of Magnetic Field Intensity

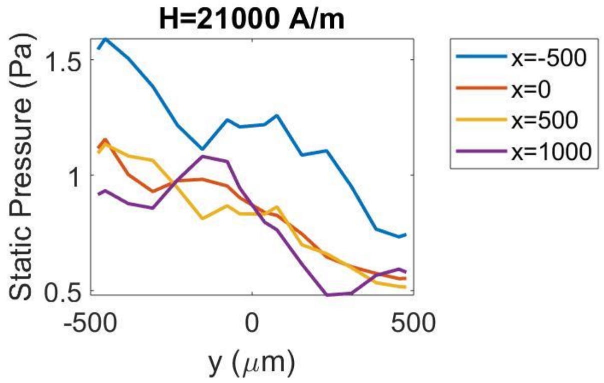


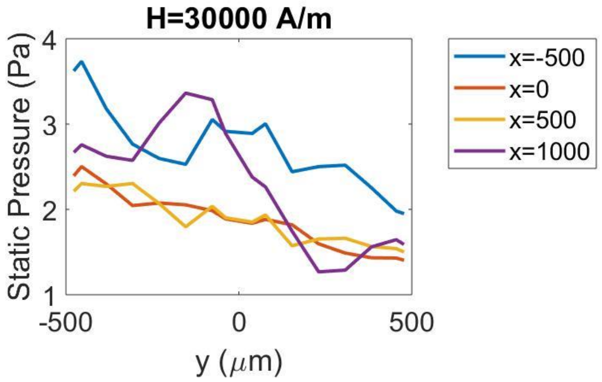
COMSOL CONFERENCE
2020 NORTH AMERICA

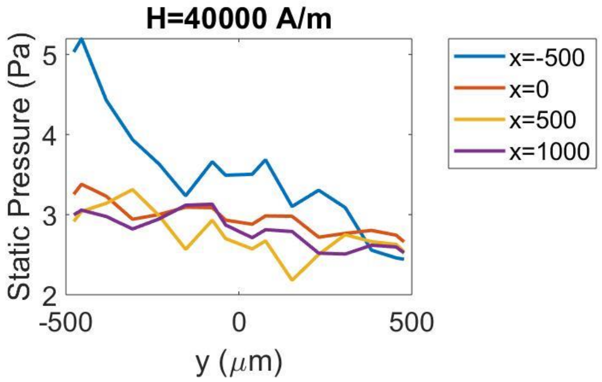
Pressure Distribution in Fluidic Channel

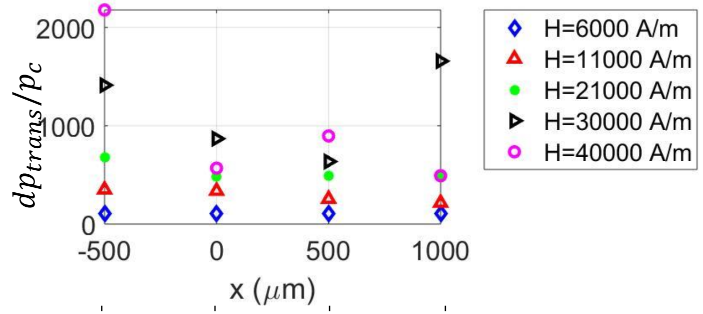


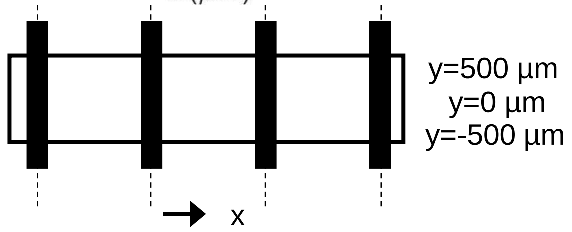












Conclusion

- The basic Multiphysics Module and AC/DC Module were applied in the modelling work using Navier-Stokes equation, convective diffusion equation and magnetic fields generated by the micromagnet.
- The conclusion of this work includes
  - ✓the new design provides an efficient method for high-throughput ferrofluid mixing;
  - ✓the increase of magnetic field intensity can accelerate the mixing performance of ferrofluid in microfluidic channel.

Thank you for watching!