Laminar Flow of a Power Law Fluid in a Helical Static Mixer

CHEM E 499

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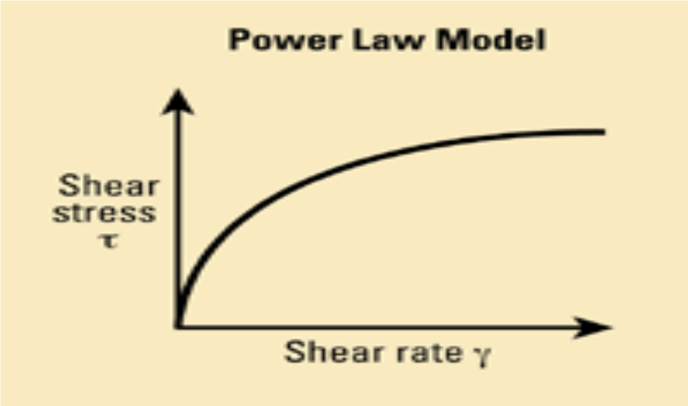
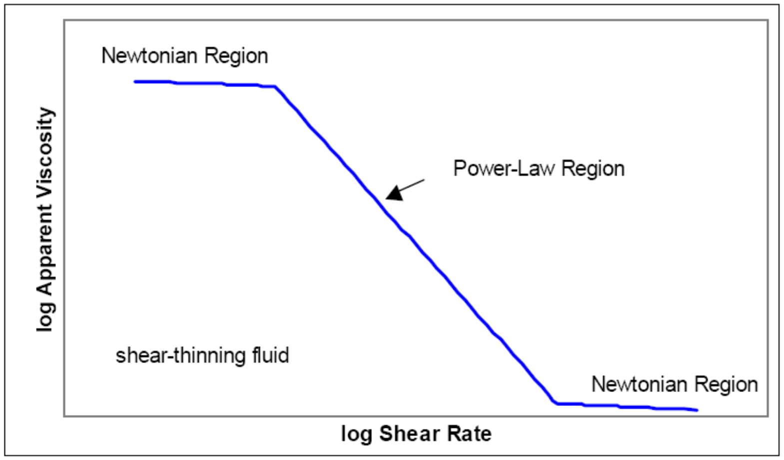
Objectives

- Compare the flow of Newtonian and non-Newtonian power law fluids through a static mixer
- Analyze fluid flow in a laminar static mixer model

What is a Power-Law fluid?

- Power law fluids requires less stress with increasing shear rate
- *n<1*, effective viscosity decreases with increasing shear rate





Experimental Method

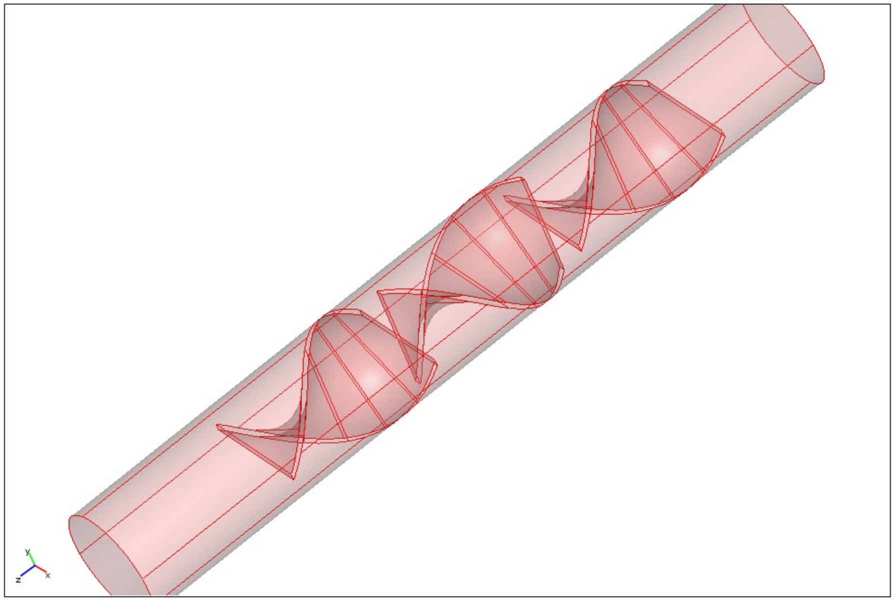
Carreau Viscosity Function

$$\frac{\eta - \eta_\infty}{\eta_\circ - \eta_\infty} = \left[1 + (\lambda\gamma)^2\right]^{(n-1)/2}$$

Shear-Rate Equation

$$\dot{\gamma}^2 = 2\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial z}\right)^2\right] + \left(\frac{\partial v}{\partial x} + \frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial w}{\partial y} + \frac{\partial v}{\partial z}\right)^2 + \left(\frac{\partial u}{\partial z} + \frac{\partial w}{\partial x}\right)^2$$

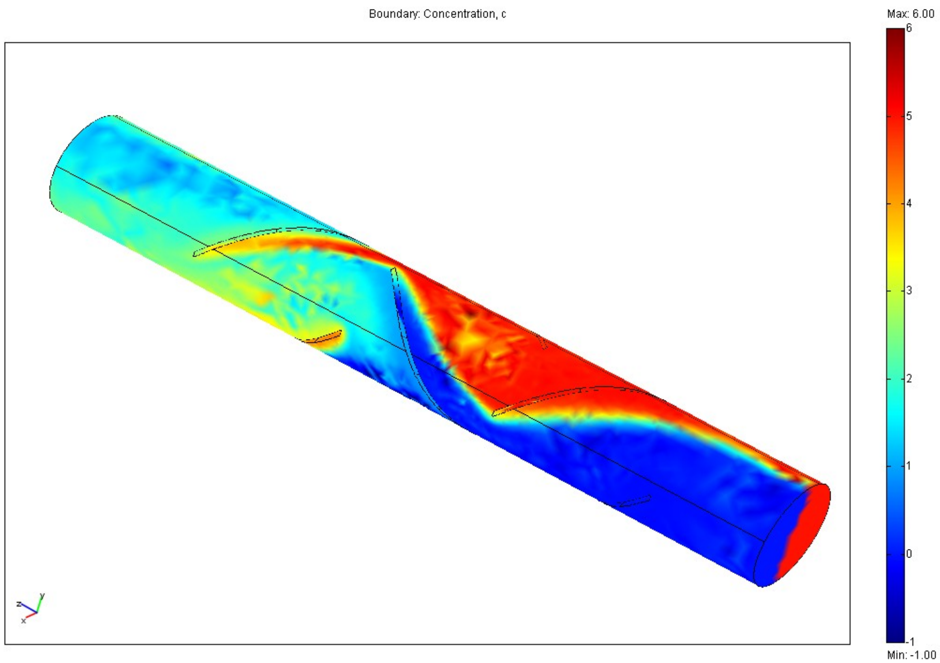
Mixer Geometry

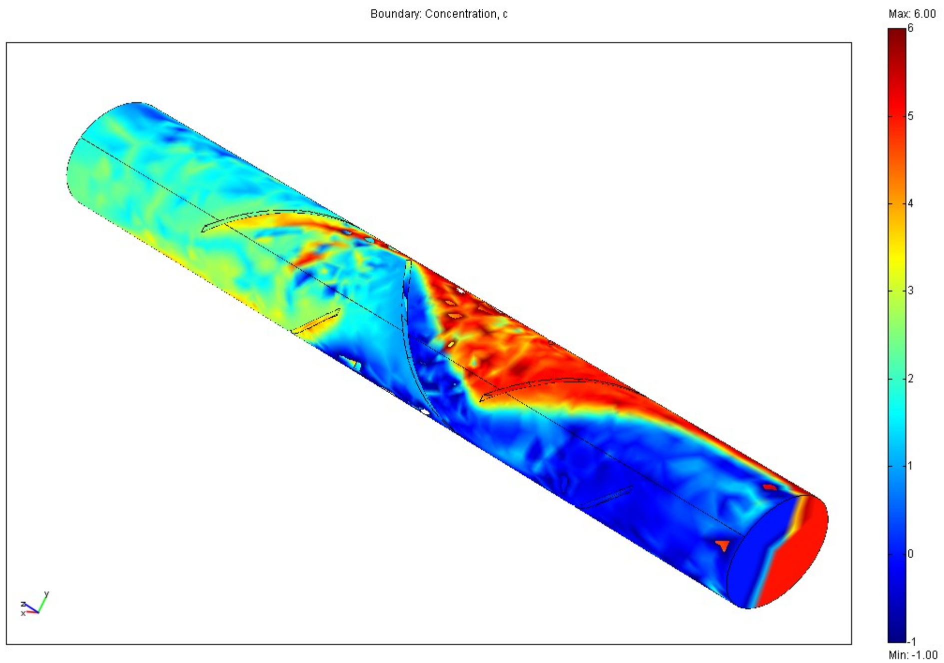


Constants

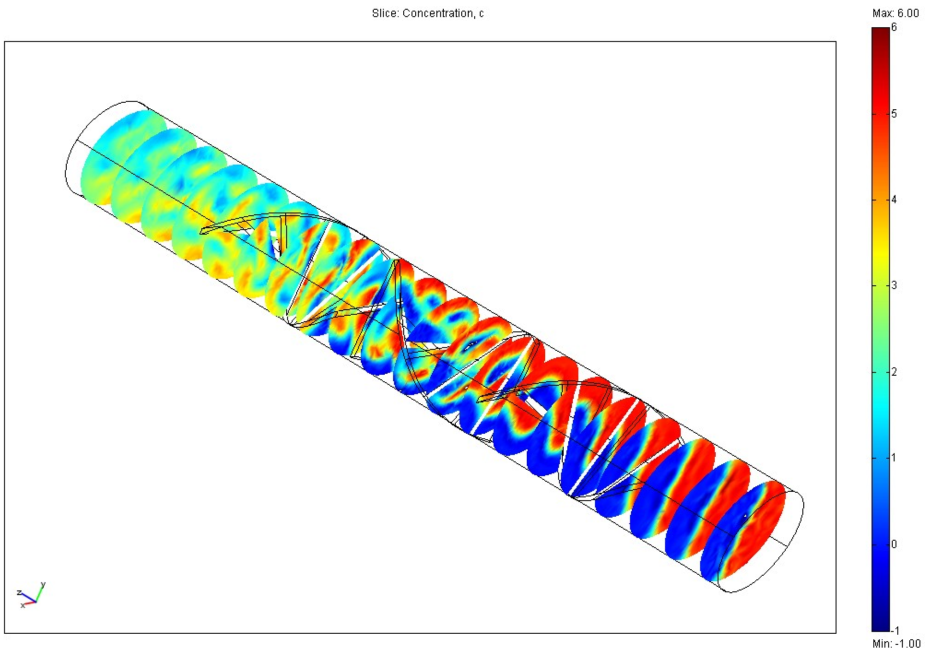
	Newtonian flow	Non-Newtonian flow
Initialized mesh size	13337	13073
Number of degrees of freedom	95956	94436
Density(kg/m^3)	600	600
n	1	0.055
Diffusivity(m^2/sec)	5.0×10^{-8}	5.0×10^{-8}
lambda(sec)	107.674	107.674
η (zero shear)(Pa*s)	1.0×10^{5}	1.0×10^{5}
η (infinite shear)(Pa*s)	10	10

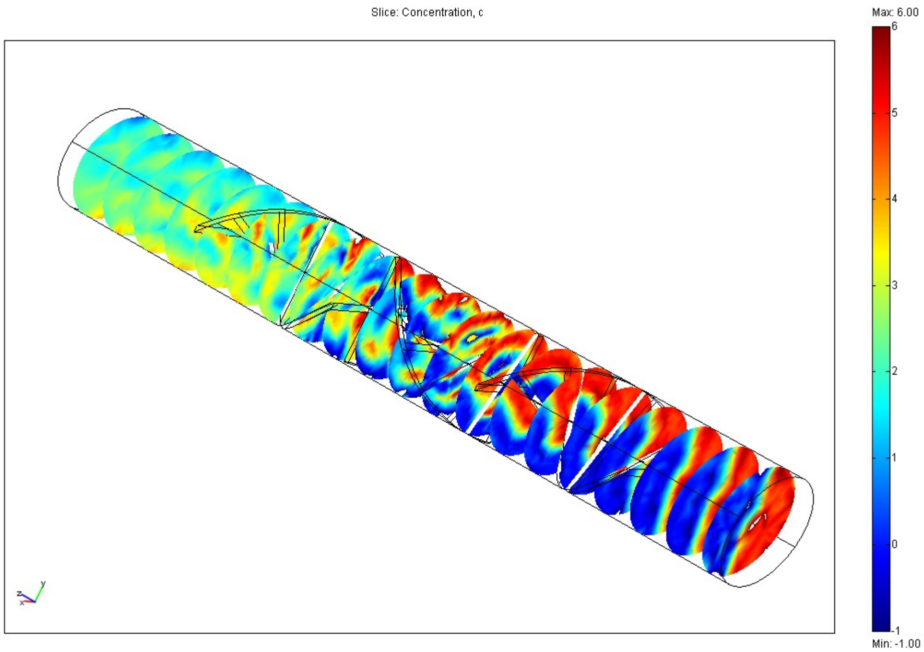
Boundary Concentration





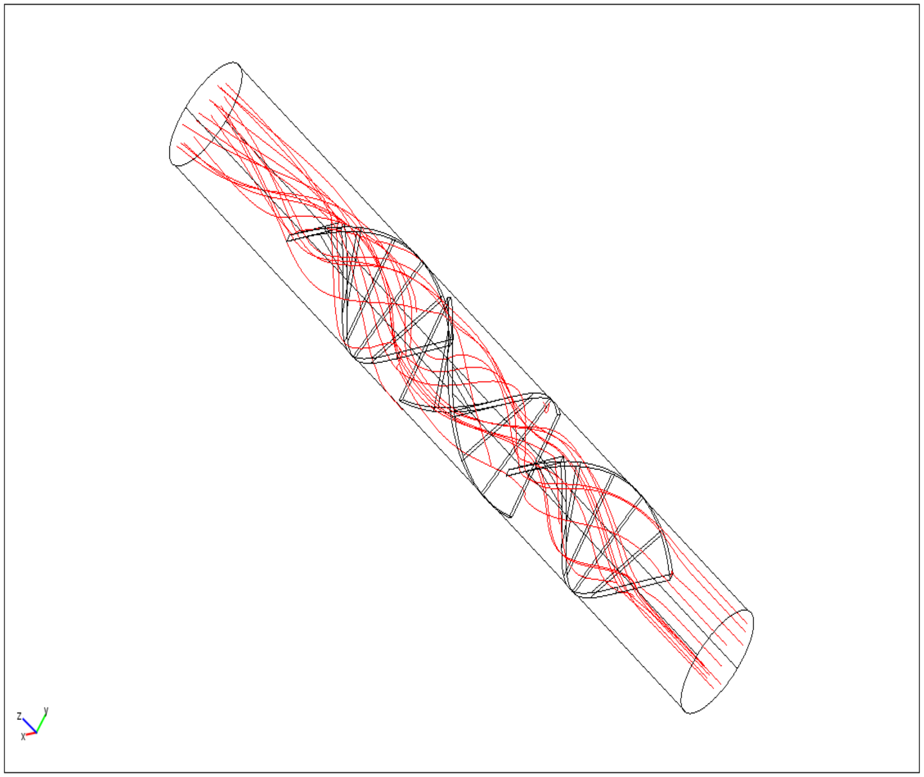
Concentration Slice Plots



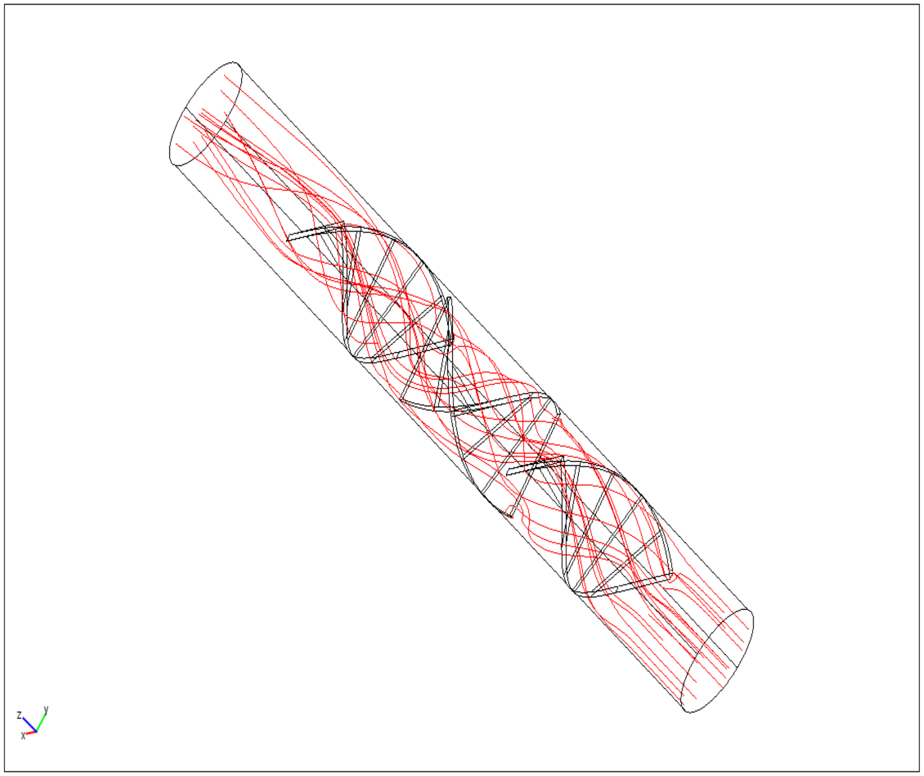


Streamlines

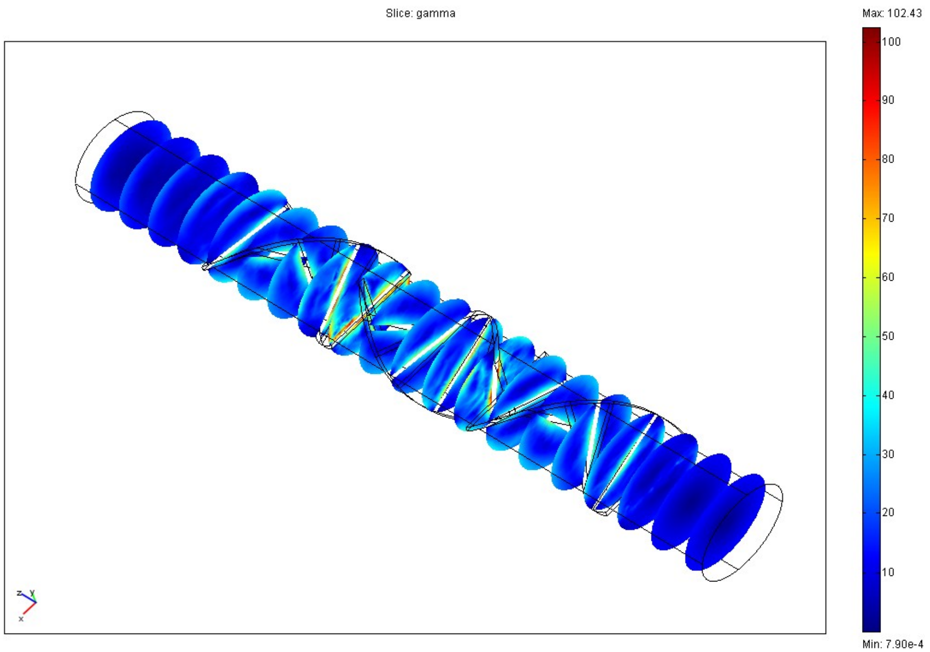
Streamline: Velocity field

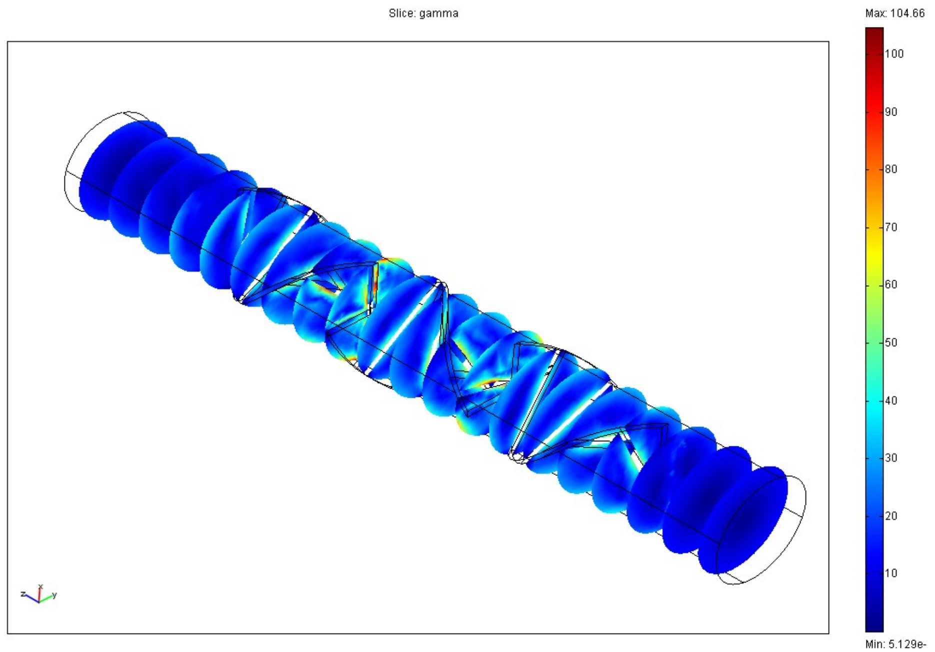


Streamline: Velocity field

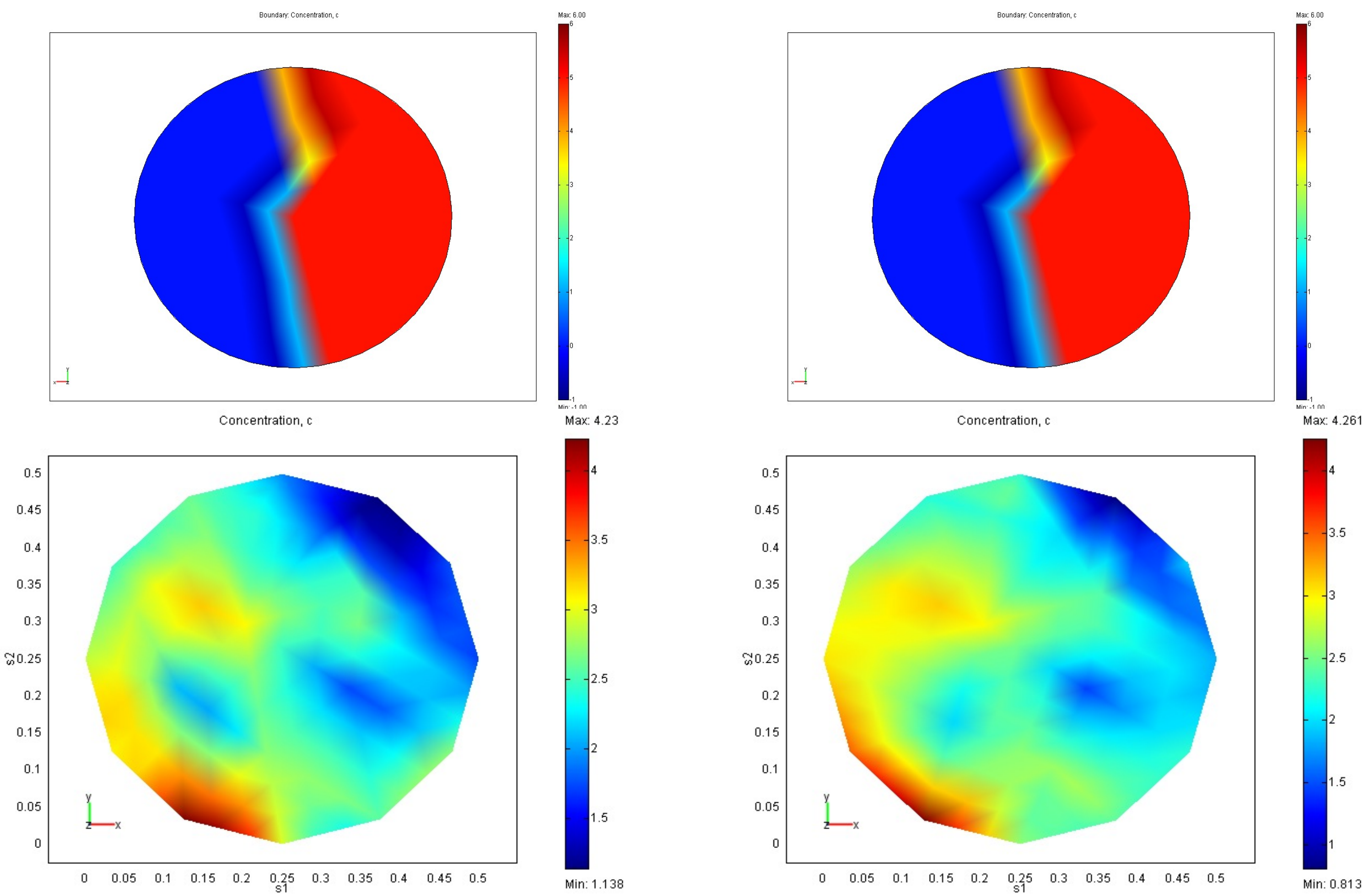


Shear-Rate Slice Plots

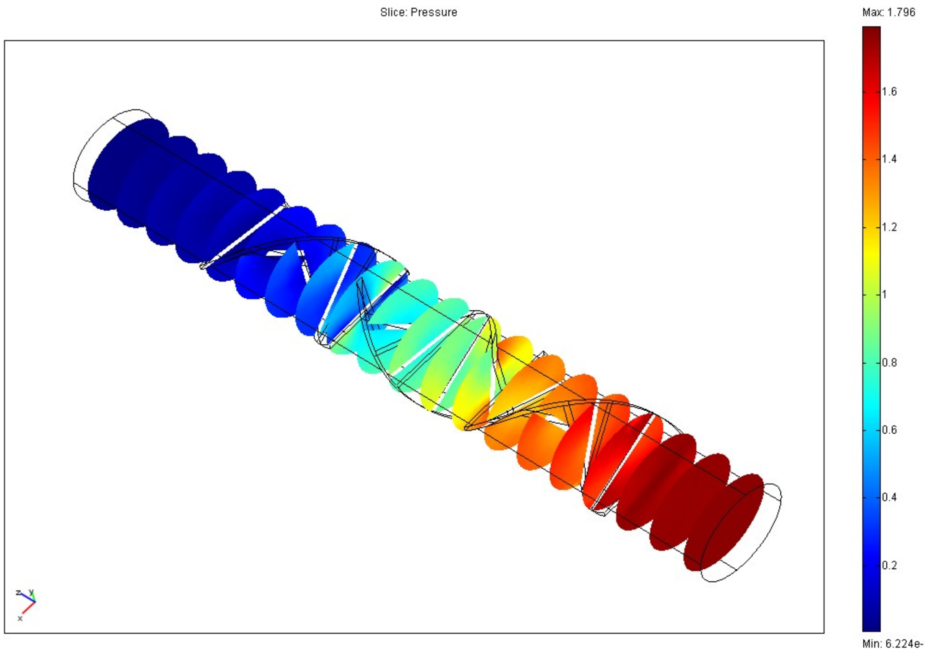


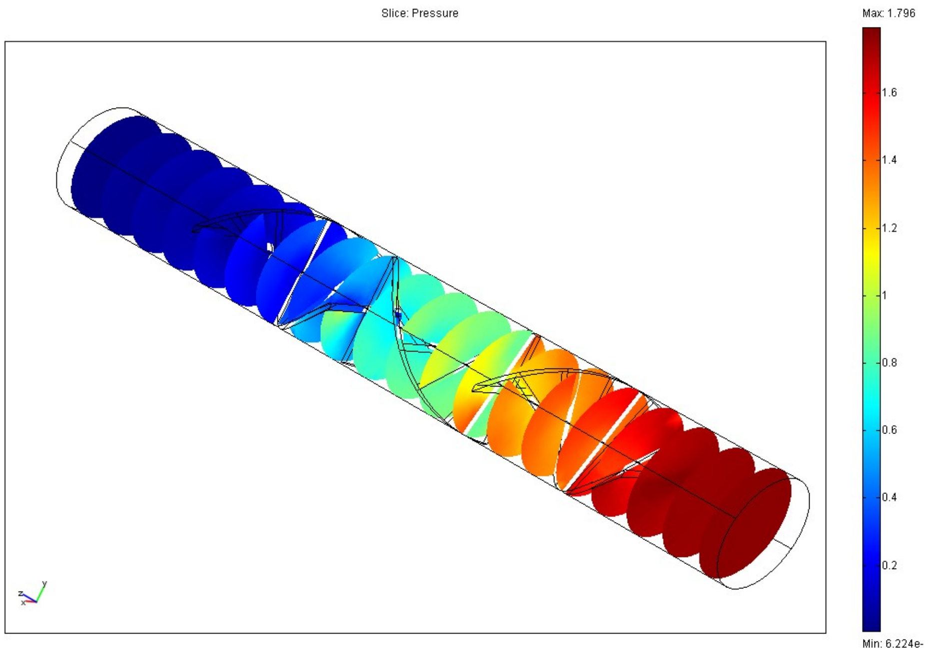


Boundary Concentrations

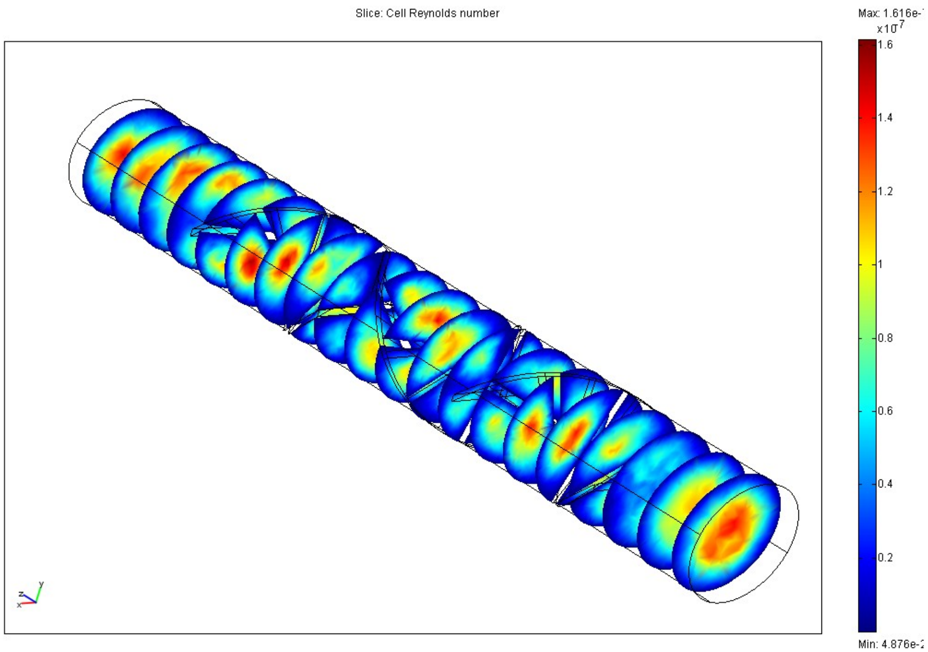


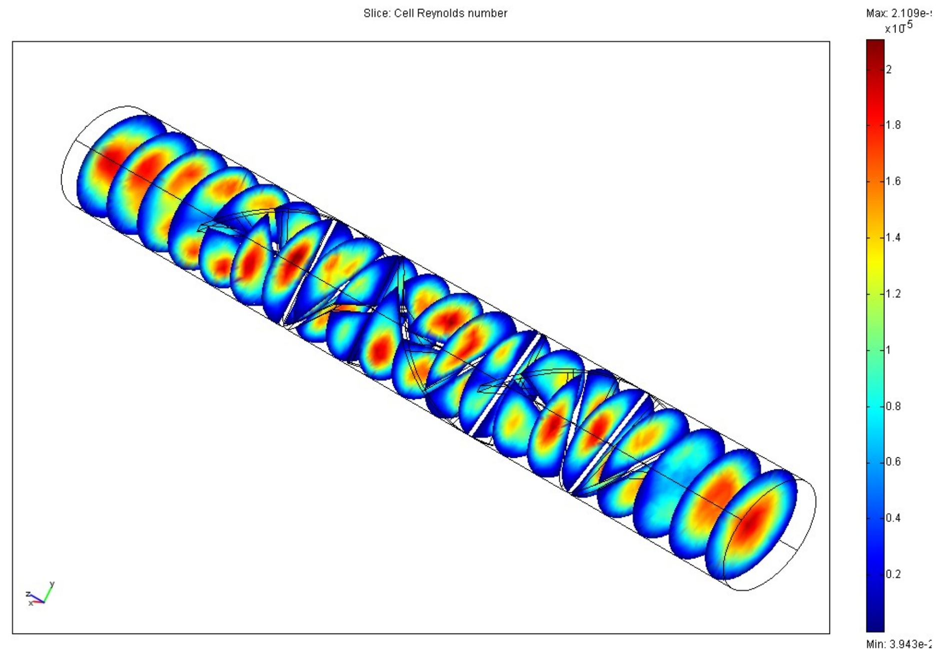
Pressure


Slice: Pressure
Max: 1.796
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Min: 6.224e-


Slice: Pressure
Max: 1.796
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
Min: 6.224e-

Reynold's Number





Conclusions

- No significant deviation when applying Carreau Viscosity Function
- Values used were consistent with actual physical properties of the operating fluids

Recommendations

- Static mixer is effective for flow rates at which laminar layers are observed
- Limitations in our processing capability reduced the quality of our results, improving this would increase accuracy of our data