AN OVERVIEW OF IMPELLERS, VELOCITY PROFILES AND REACTOR DESIGN

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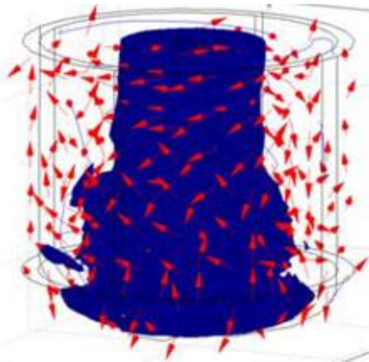

COMSOL CONFERENCE 2014 BANGALORE

Presented by: Pranay. K. Vaidya (IITB)
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Excerpt from the Proceedings of the 2014 COMSOL Conference in Bangalore

INTRODUCTION

Stirred vessel

It is one of the most commonly used devices in the production industry

Mixing

Mixing is important for effective chemical reaction, heat transfer, mass transfer and phase homogeneity

Geometric

Kinematic

AIM

- To find **Optimize** parameters for all process conditions to attain homogeneity in the batch reactor

Pilot plant experiments

- It takes a long time to build a model, perform experiments
- In some cases it is difficult to obtain experimental information

MODELING

Chemical Engineering Module (3D)

- Incompressible Navier-Stokes
- Moving Mesh (ALE)

Geometry

- Cylinder of radius 6e-2 m and height 0.18 m
- Impeller radius 6 mm and impeller height 0.15m
- Blocks of dimensions 0.03 x 0.0025 x 0.015

Bottom

- Flat
- Ellipsoid bottom with x=0.06, y=0.06, z=0.015

Boundary Conditions

- No Slip at walls
- Symmetric at top

Angular velocity in counter clockwise direction

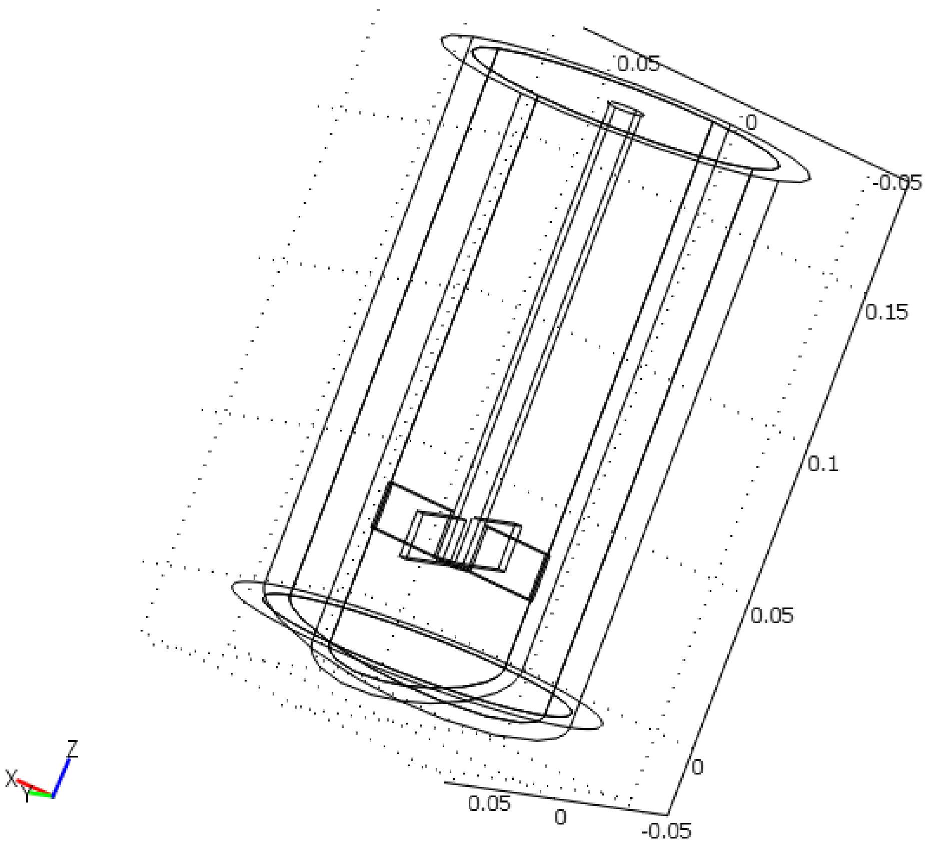


Figure 1: Reactor geometry

Parameters:

rpm	Revolution speed	20,50,100	1/min
eta	Viscosity	0.01	Kg/(m .s)
rho	Density	1600	kg/m^3

GOVERNING EQUATIONS

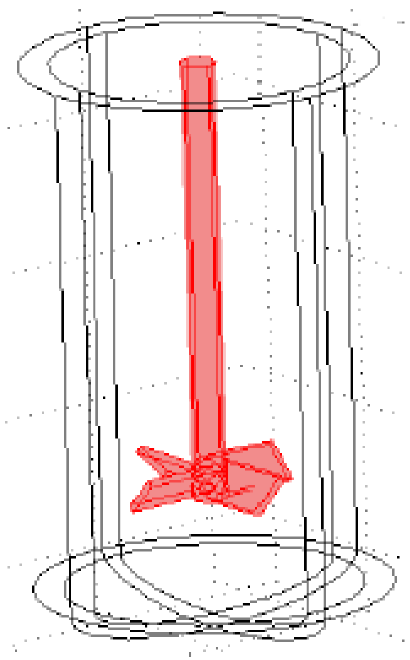
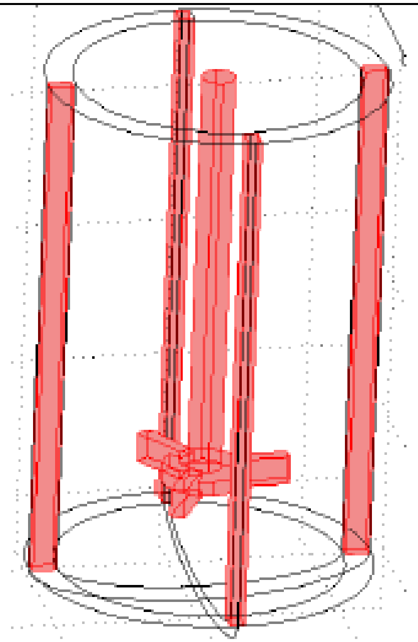
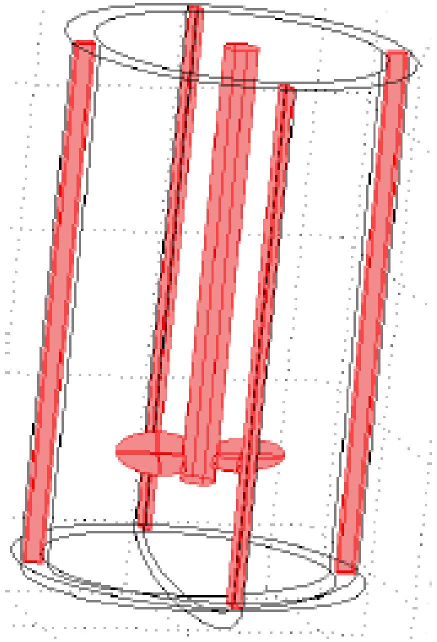
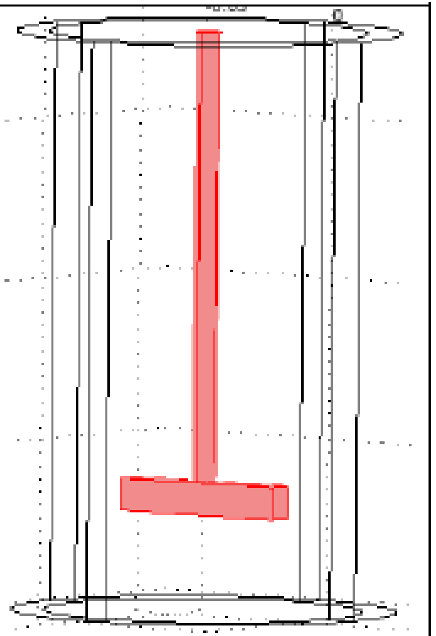
- The flow is described by the Navier-Stokes equations having the local changes term, the convective term, stress term, and the body forces term

$$\rho\frac{\partial u}{\partial t} + \rho(u.\nabla)\mathrm{u} = \nabla.[-pI + \eta(\nabla u + (\nabla u)^T)] + F \qquad ....(1)$$

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho u) = 0 \qquad ....(2)$$

- For turbulence modeling RANS model was used, Reynold's stress term was calculated by using two equation turbulence model (k-ε models)

TYPES OF IMPELLERS

			
4 Bladed 45 pitch Impeller	3 bladed Impeller with Baffle	Pitched Blade Impeller with Baffle	T-Shaped Impeller

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CORROBORATION OF EXPERIMENTAL OBSERVATION WITH MODELING

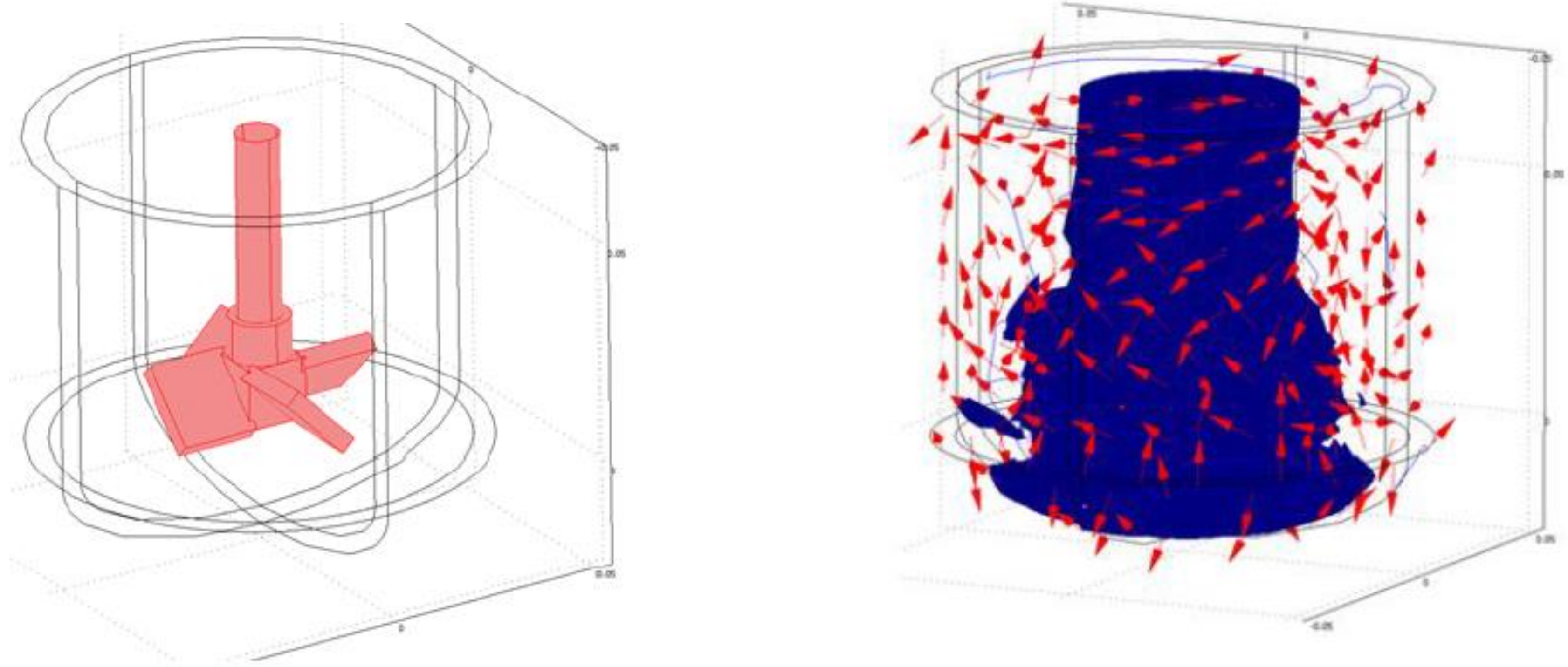

Figure 2: <u>**Left**</u>: Reactor geometry & <u>**Right**</u>: Reactor with streamline flows, 3D Arrows & isosurface plot

- The above figure shows the flow pattern of ethanol with 4 bladed 45° pitched blade impeller
- Same pattern was observed when carried the experiment with same reactor dimensions and impeller dimensions in lab

RESULTS- Velocity field in case of 4-bladed turbine impeller

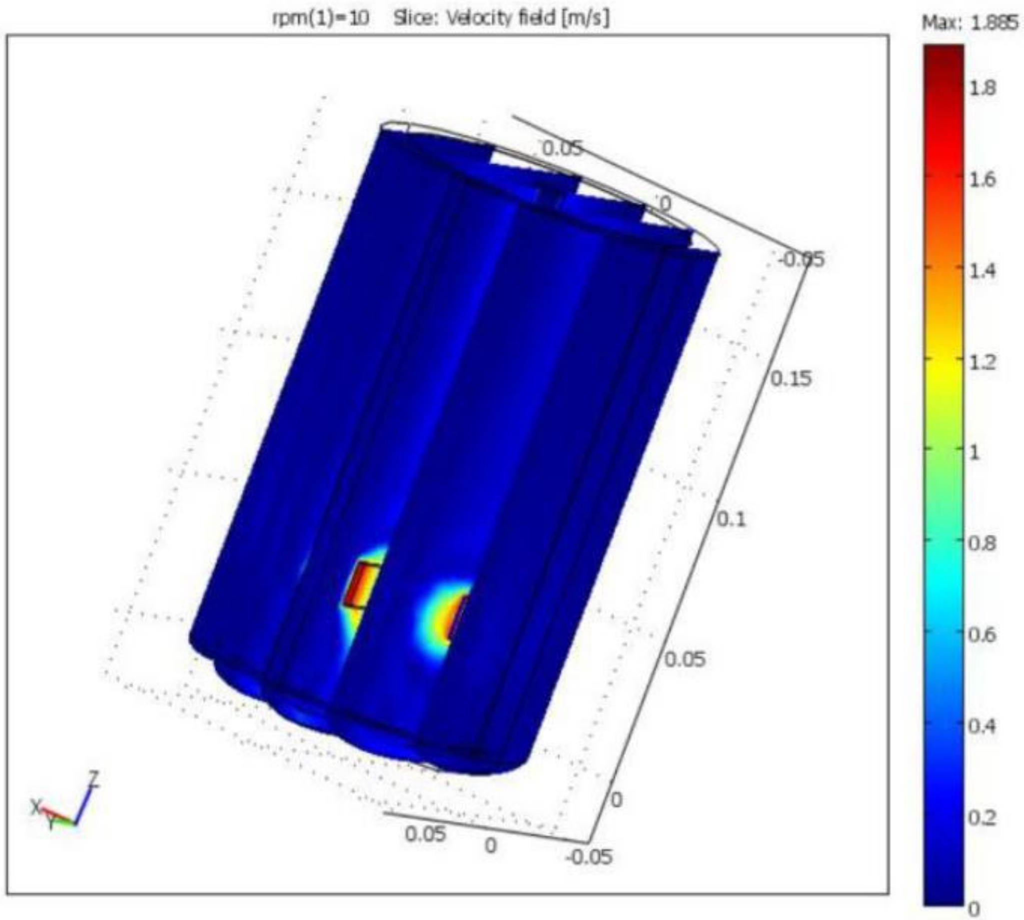

Figure 3: Slice plot of reactor with a 4-bladed impeller revolving with 100rpm

- The above figure shows, that the velocity near the impeller blades is higher, than near the wall

RESULTS- Vorticity in reactor with and without baffle

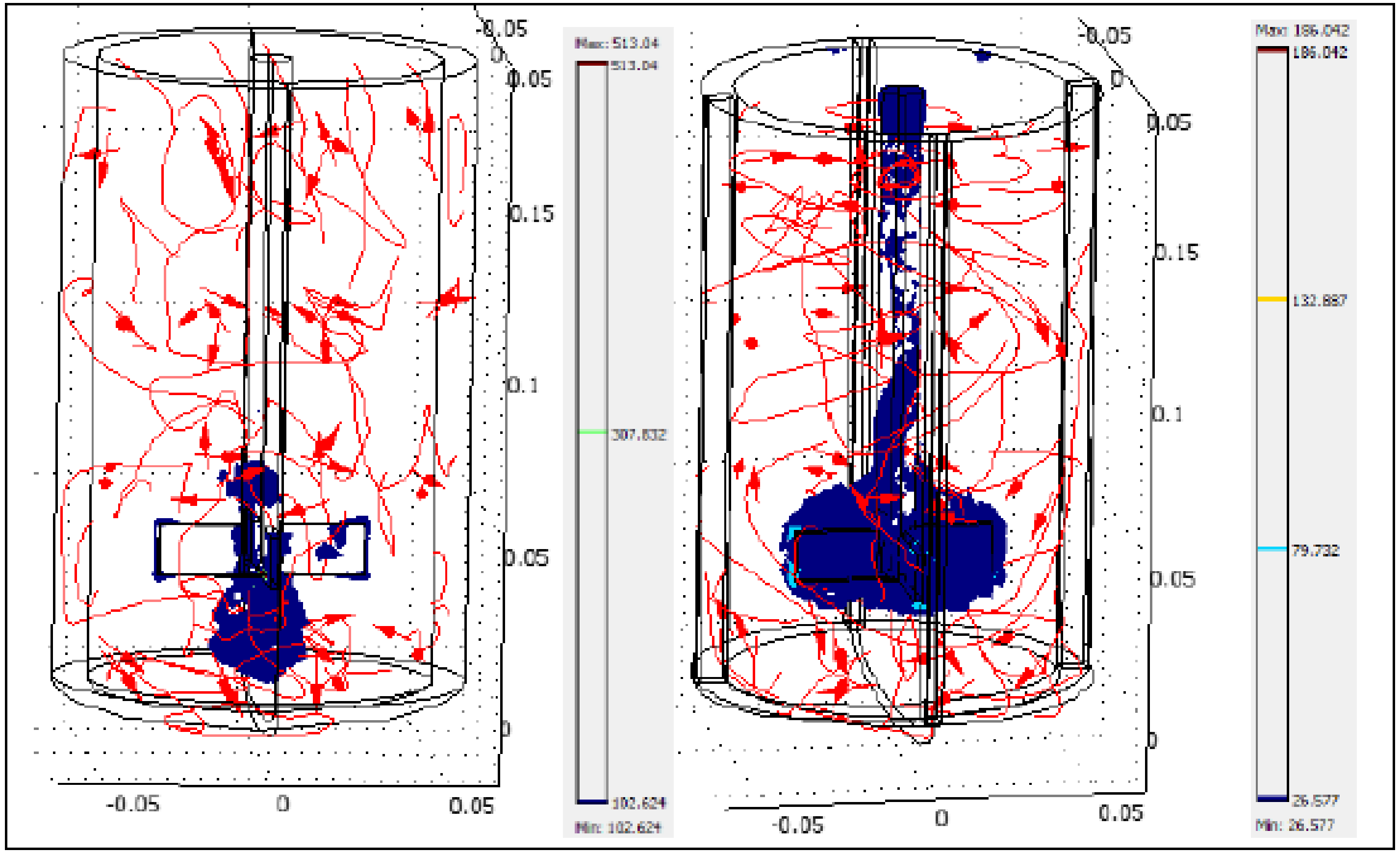

Figure 4: Streamline plots of vorticity in reactor with and without baffle for 4-bladed turbine impeller

Max. vorticity [1/s] (100 rpm)		
Impeller	Without baffle	With Baffle
3 bladed	385	238
4 bladed	513	186
4 bladed 45 pitched	159	390
3 bladed 45 pitched	342	354

- The streamline plot shows, that the reactor is well mixed
- Baffles can be used to achieve a adequate mixing in stirred vessel
- Hence, vorticity can be decreased by introducing baffles when pitch is not presented for 4-bladed

RESULTS- Effect of different impeller geometry on velocity profile

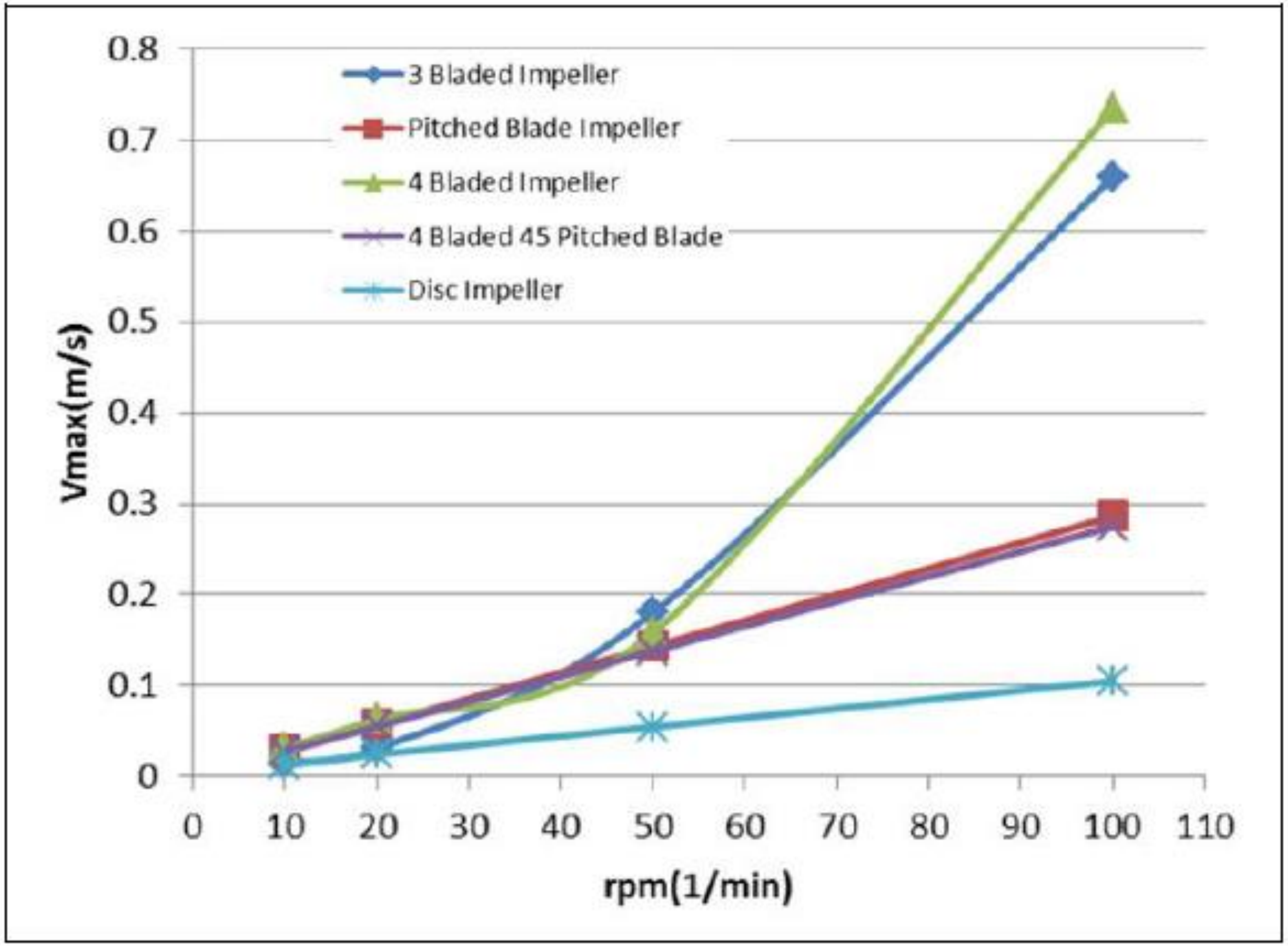

Figure 5: Velocity Vs rpm's for different impeller geometry

- The maximum velocity of fluid in stirred vessel increases with rotational speed
- The maximum velocity for 4-bladed impeller is greater among three bladed impeller, 2-bladed pitched blade impeller, 4-bladed impeller, 4 laded pitched blade impeller and disc impeller at higher revolution speed

RESULTS- Effect of baffles on velocity profile

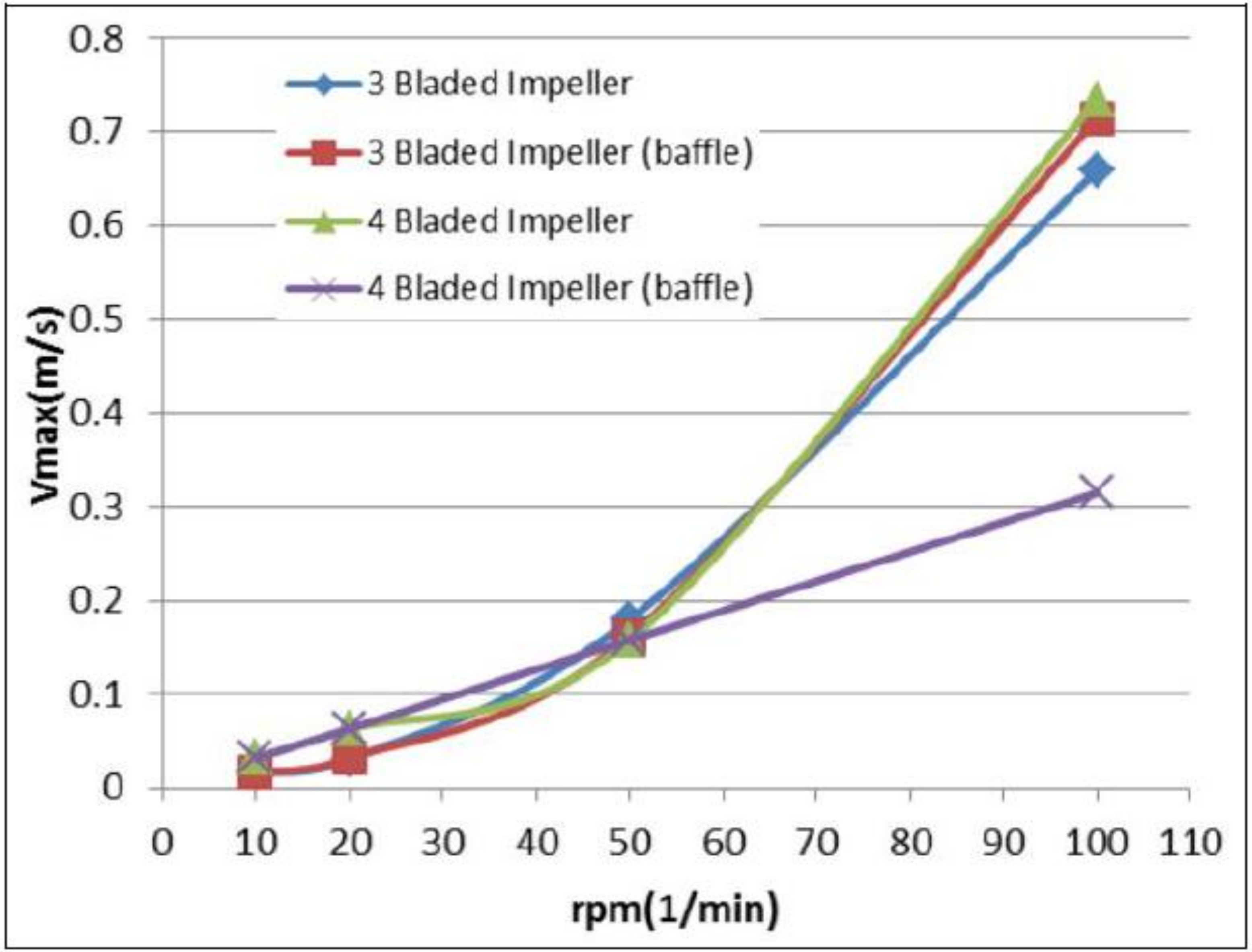

Figure 6: Velocity Vs rpm for 3-bladed and 4-bladed impellers with and without baffles

- Initially the velocity of impellers with baffles is less than that of without baffles and the difference increases with increase in rotational speed
- Baffles can be used to achieve a adequate mixing

RESULTS- Effect of different reactor's dimensions

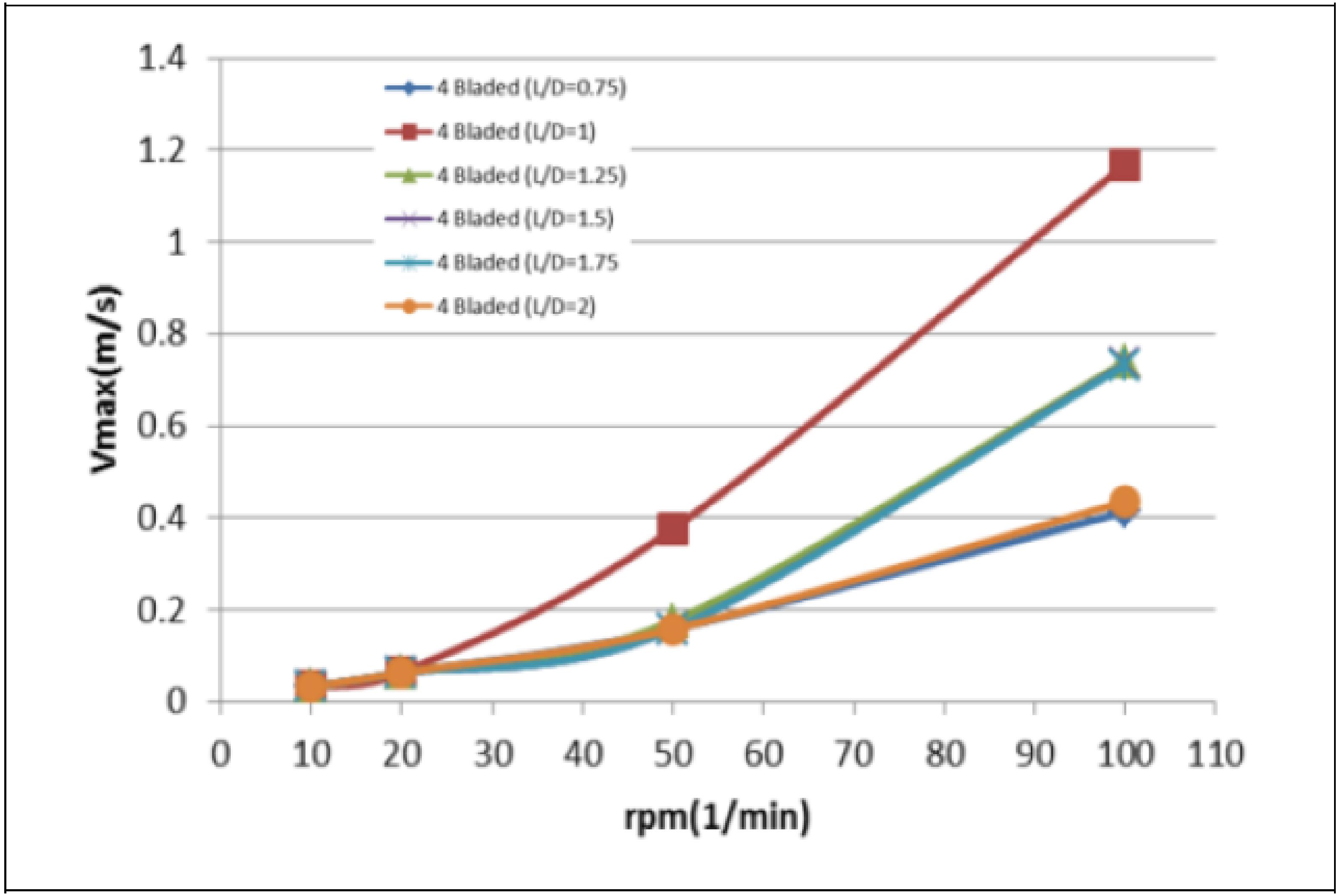

Figure 7: Velocity Vs rpm for different reactor geometry

- The velocity of 4-bladed impeller is optimum at L/D = 1 for higher revolution speed

RESULTS- Effect of different impeller to reactor's diameter (di/D)

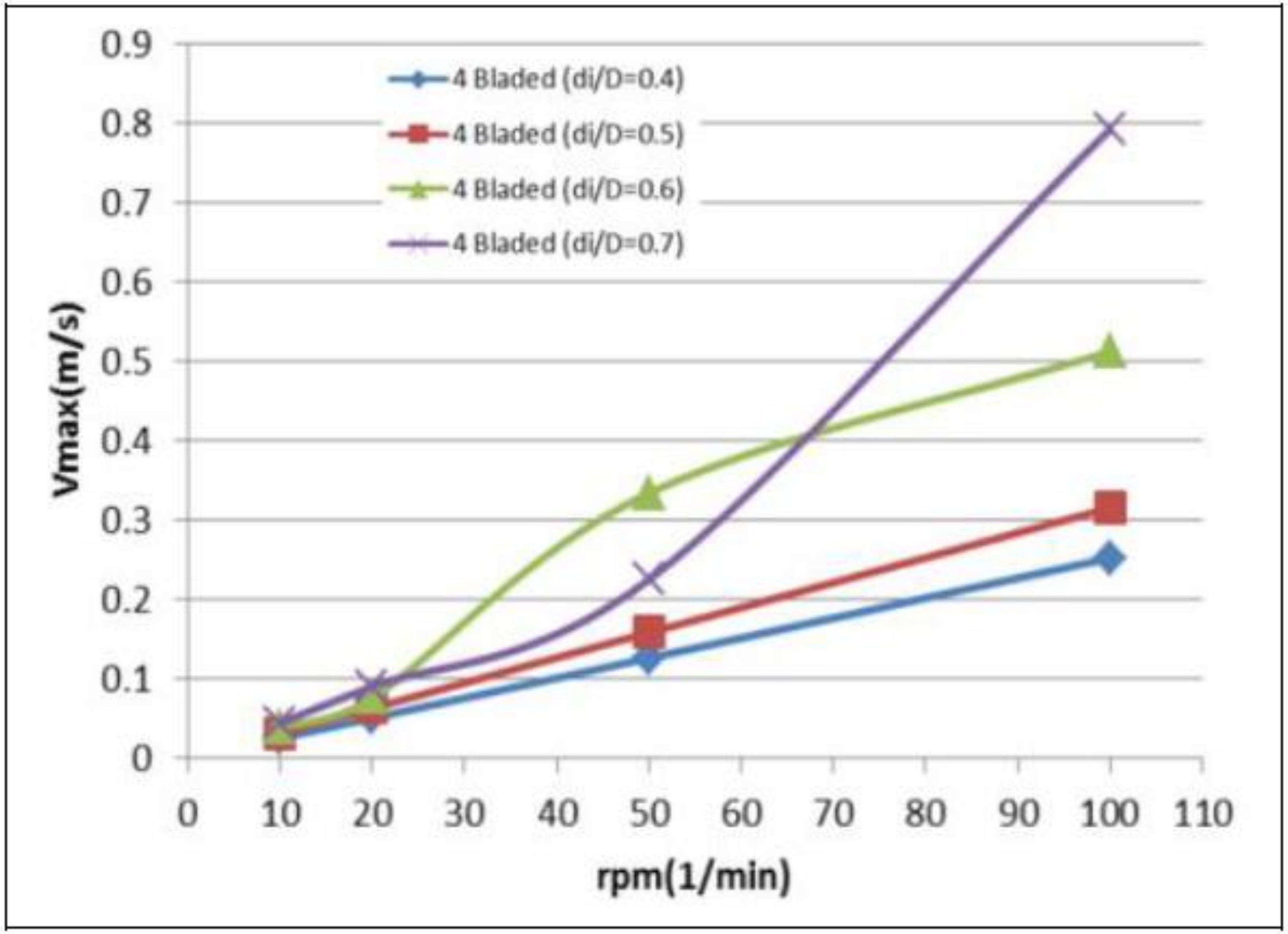

Figure 8: Velocity Vs rpm for different di/D ratio's

- The velocity for 4-bladed impeller is optimum at di/D = 0.6and di/D = 0.7 for lower revolution speed and higher revolution speed respectively

RESULTS- Effect of different fluids (different densities and viscosities)

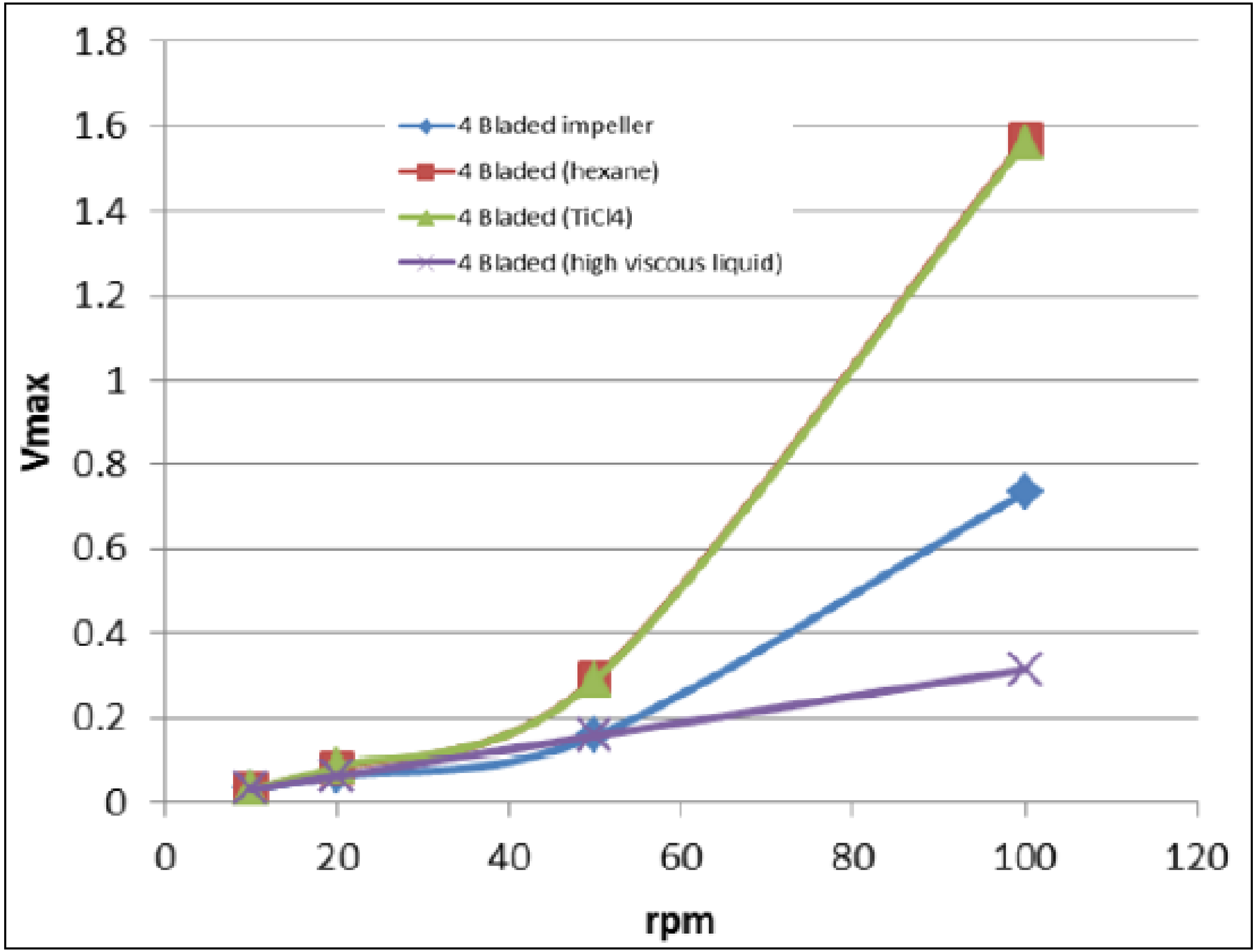

Figure 9: Velocity Vs rpm for different fluids

- The fluid properties like density and viscosity also affect the rate of mixing
- The average velocity decreases as viscosity of fluid increases
- It's evident that velocity for hexane and $TiCl_4$ (less viscous fluid) is greater than the water and high viscous fluid

CONCLUSION

- The effect of reactor geometry, impeller configuration, rotation speed, baffle and fluid properties (density and viscosity) on the mixing phenomenon is understood and can be used for in industries for designing a reactor

SCOPE OF WORK

- In future, one can do the same simulation for higher revolution speeds, multi-impeller systems and continuous systems

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THANK YOU