CFD Analysis of a Stirred Vessel Bioreactor with Double Pitch Blade and Rushton Type Impellers

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INTRODUCTION

This research presents a computer simulation investigation to develop a theoretical model to envision and understand the mixing phenomena in a stirred vessel bioreactor. Mixing is required for phase homogeneity and effective heat and mass transfer within the stirred vessel.

Newtonian fluid (resembling lysogenic broth medium) motion in a 5L stirred vessel bioreactor with double pitch blade and Rushton type impellers has been analyzed.

COMPUTATIONAL METHODS

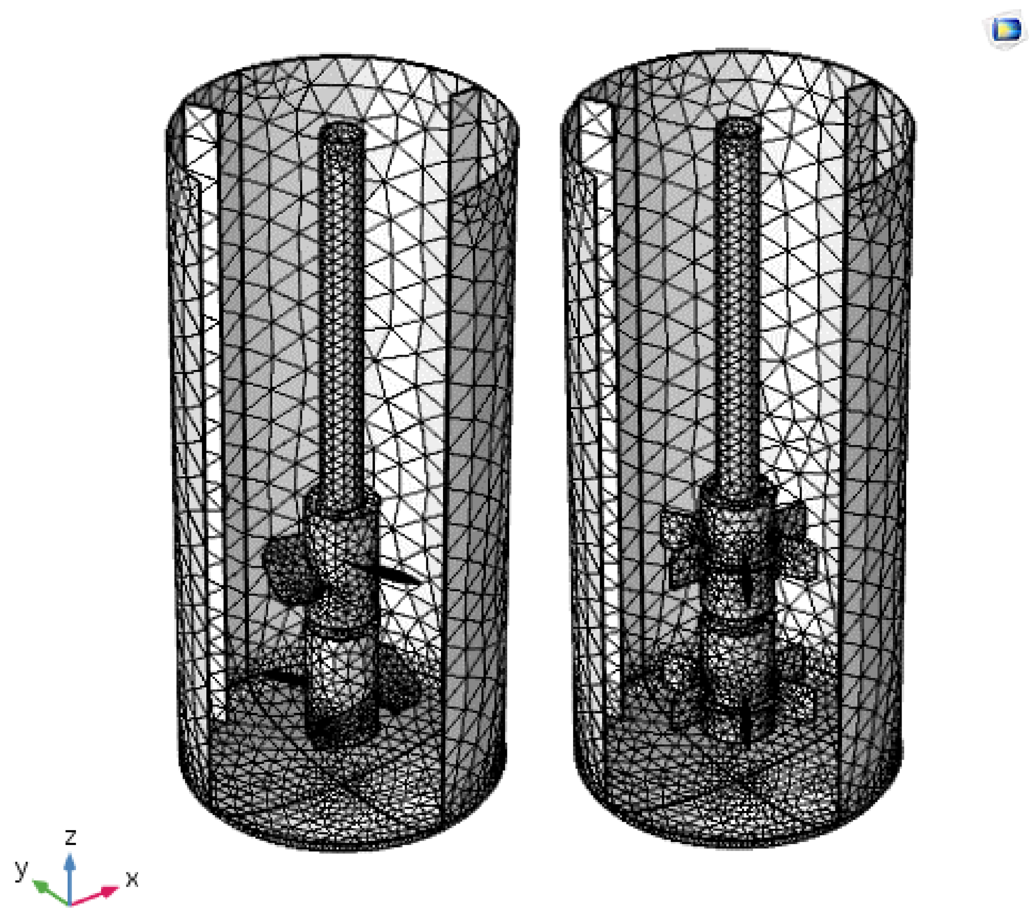

Figure 1. Stirred vessel bioreactor (5L) meshed geometries with pitch blade (left) and Rushton type impellers (right).

COMSOL Multiphysics® CFD Mixer Module and a frozen rotor study has been used to simulate the fluid flow inside the stirred vessel. The Navier-Stokes equations govern the motion of fluid and are at the core of the simulation:

$$\underbrace{\rho\left(\frac{\partial u}{\partial t}+u\cdot\nabla u\right)}_{1}=\underbrace{-\nabla p}_{2}+\underbrace{\nabla\cdot\left(\mu\left(\nabla u+(\nabla u)^{T}\right)-\frac{2}{3}\mu(\nabla\cdot u)I\right)}_{3}+\underbrace{F}_{4}$$

where u is the fluid velocity, p is the fluid pressure, ρ is the fluid density, and μ is the fluid dynamic viscosity. The different terms correspond to the inertial forces (1), pressure forces (2), viscous forces (3), and the external forces applied to the fluid (4).

These equations are always solved together with the continuity equation:

$$\frac{\partial\rho}{\partial t}+\nabla\cdot(\rho u)=0$$

The Navier-Stokes equations represent the conservation of momentum and the continuity equation represents the conservation of mass. Solving them, for a set of boundary conditions (e.g. interiors, exteriors, and walls), predicts the fluid velocity and its pressure in a given geometry[1].

RESULTS

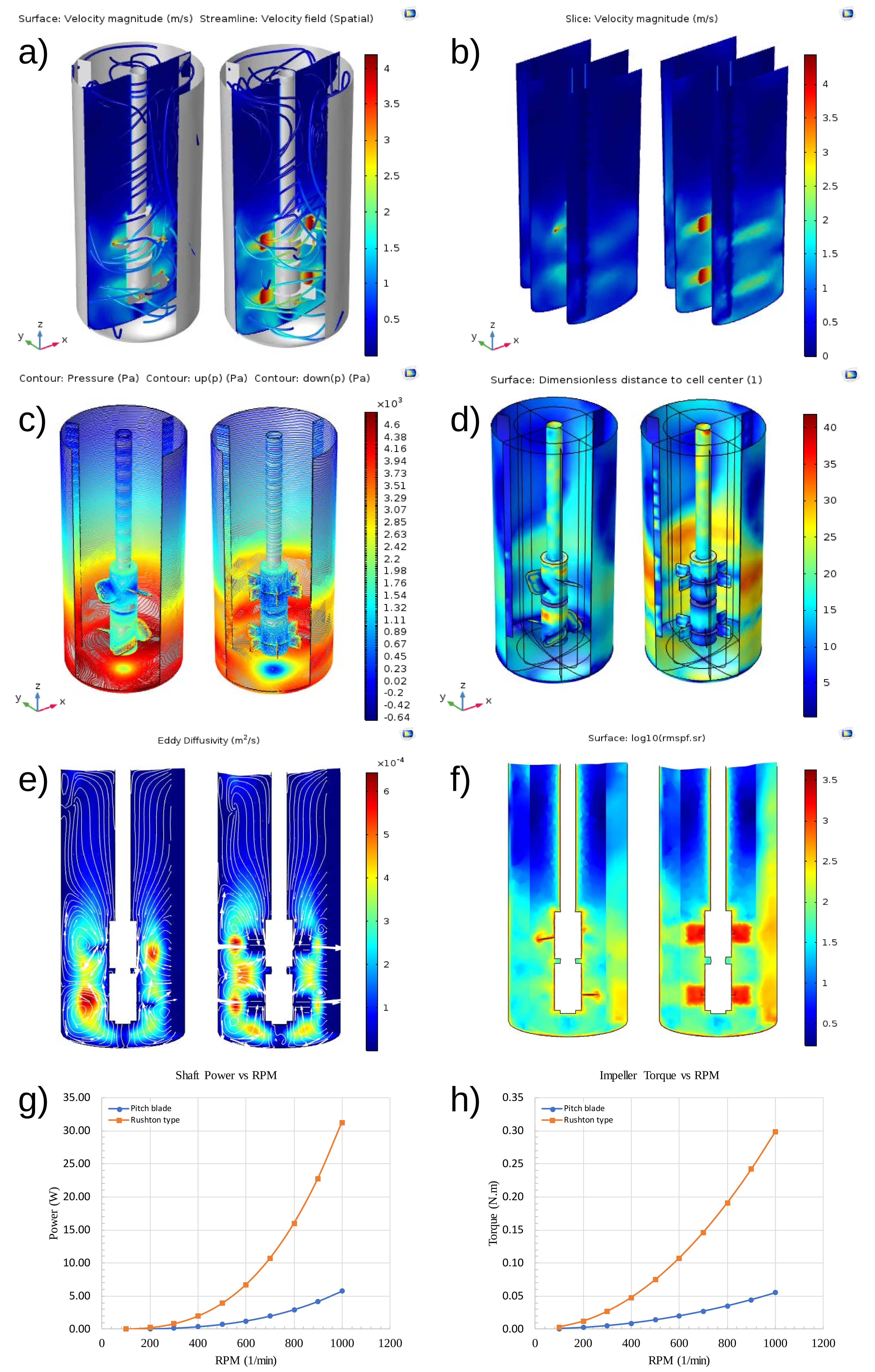

Figure 2. Velocity profiles (a), slice plots (b), pressure distribution (c), wall resolution (d), eddy motion in XZ plane (e), shear rate in XZ plane (f), shaft power vs RPM (g) and impeller torque vs RPM (h).

CONCLUSION

Rushton turbine is more powerful and constitutes to better mixing, however higher shear stress especially near the blades may be damaging to shear sensitive cell cultures comparing to the pitch blade impeller. Future work can be aimed towards the scale-up of the bioreactor and investigation of the 2D and 3D profiles above using COMSOL® time dependent study.

Reference:1. G. P. Galdi, *An Introduction to the Mathematical Theory of the Navier-Stokes Equations: Steady-State Problems*, Springer Science & Business Media, New York (2011)

ACKNOWLEDGEMENT

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