An Overview of Impellers, Velocity Profile and Reactor Design

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Abstract

This paper presents a simulation approach to develop a model for understanding the mixing phenomenon in a stirred vessel. The mixing in the vessel is important for effective chemical reaction, heat transfer, mass transfer and phase homogeneity. In some cases, it is very difficult to obtain experimental information and it takes a long time to collect the data. Such problems can be solved using Computational Fluid Dynamics (CFD) modeling, which is less time consuming, inexpensive and has the capability to visualize the real system in three dimensions.

In our research using COMSOL Multiphysics® software, different reactors with varying impeller configurations have been modeled to achieve a better understanding of mixing and hydrodynamics in a stirred tank. Velocity profile and homogeneity of the system were studied. The reactor constructions were flat bottom and ellipsoid bottom tank with different types of impellers: T-shaped impellers, rotating disc, three-bladed impeller, four-bladed impeller and, pitched blade impellers [Figure-1]. Each reactor configuration was simulated at different revolution speeds such as 10, 20, 50 and 100 RPM. With such detailed modeling, the ideal parameters were computed for reactor design.

The slice plot is a type of post processing. In Figure 2, five parallel vertical slices are implemented through the whole diameter of the reactor, which shows the results of the dynamic simulation, the velocity field in the case of a three-bladed turbine impeller. The revolution speed is 100 1/min. The figure shows, that the velocity near the impeller blades is higher, than near the wall.
Figure 3a shows the velocity profile for the different type of impellers. The figure shows average velocity is higher for higher rotational speed, and also shows that the average velocity for 4-bladed impeller is greater among 3-bladed, 2-bladed pitched blade, 4-bladed, 4-bladed 45° pitched blade impellers and disc impeller above 60 RPM.
Figure 3b shows that the average velocity for 3-bladed impeller is grater among the 2-bladed pitched blade impeller, 4-bladed impeller, 4-bladed 45° pitched blade impellers with baffle.
Combining Figures 3a and 3b, shows that velocity profile of impellers with baffles is less than that of without baffles and it helps in preventing vortex formation. Velocity decreases as viscosity of fluid increases.
Figure 4 shows the average velocity for different reactor and impeller configurations. From the table, one can easily conclude for a rector with L/D=1, we should use 4-bladed impeller over 3-

bladed and 4-bladed 45°pitch impellers. Similarly, for any geometry of reactor and impeller, we can easily select type of impeller; or for any impeller, we can model best reactor configuration.

Velocity profile and mixing in stirred vessel has been investigated using CFD. The purpose was to understand the effect of reactor geometry, impeller configuration, rotation speed, baffle and fluid properties (density and viscosity) on the mixing phenomenon. In future, one can do the same simulation for higher revolution speed, multi-impeller systems and continuous systems.

Reference

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2. James R. Couper, W. Roy Penney, James R. Fair and Stanley M. Wala, Chemical Process Equipment, Second edition -Selection and Design.
3. A. Egedy, T. Varga, T. Chován, "Investigations on Hydrodynamic in Stirred Vessels for Educational Purposes" Department of Process Engineering, University of Pannonia.
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Figures used in the abstract

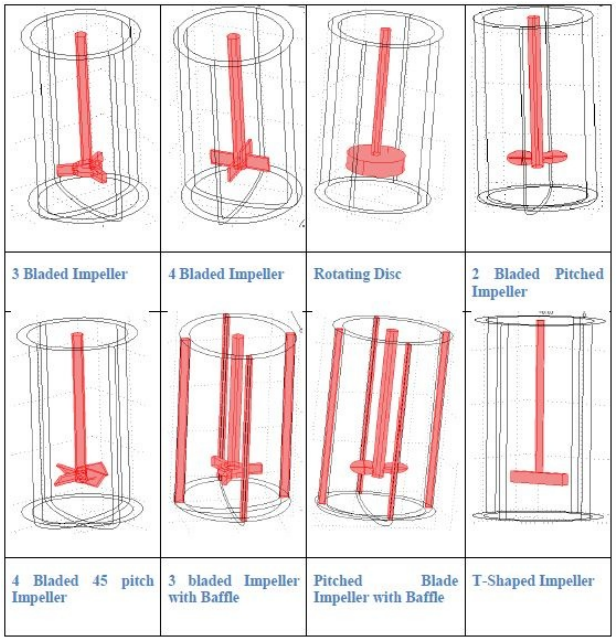

Figure 1: Different types of impeller geometries.

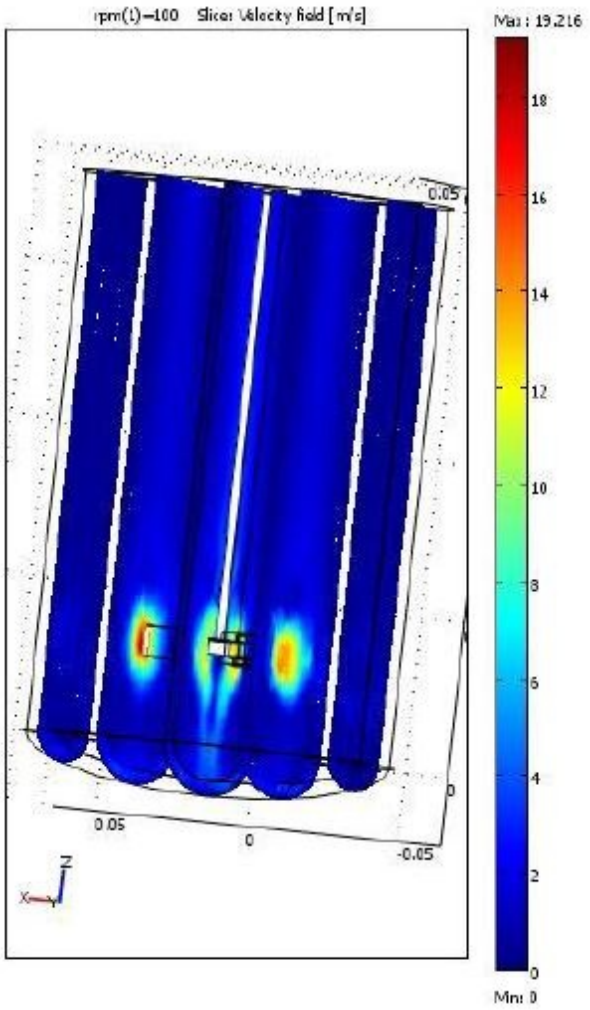

Figure 2: The simulation results of the stirred tank with a three bladed impeller.

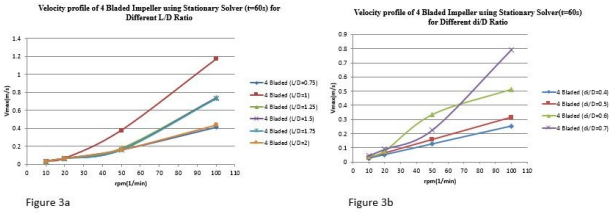

Figure 3: 3a)The velocity profile for different type of impellers, 3b)Velocity profile for different impellers with baffle.

10 rpm										
Impeller	di/D				L/D					
	0.4	0.5	0.6	0.7	0.75	1	1.25	1.5	1.75	2
3-bladed	0.0104	0.0155	0.02	0.0202	0.0205	0.0162	0.0198	0.0155	0.0147	0.0118
4-bladed	0.0252	0.0315	0.0378	0.0444	0.0315	0.0315	0.0315	0.0315	0.0315	0.0315
4-bladed 45°pitch	0.0179	0.0278	0.0313	0.0378	0.0294	0.0286	0.0283	0.0278	0.0287	0.0254
20 rpm										
Impeller	di/D				L/D					
	0.4	0.5	0.6	0.7	0.75	1	1.25	1.5	1.75	2
3-bladed	0.0224	0.0304	0.0414	0.0422	0.0403	0.0318	0.04	0.0304	0.0272	0.0228
4-bladed	0.0504	0.063	0.0757	0.0903	0.063	0.063	0.063	0.063	0.063	0.063
4-bladed 45°pitch	0.0344	0.0551	0.124	0.26	0.0579	0.0528	0.0562	0.0551	0.057	0.0494
50 rpm										
Impeller	di/D				L/D					
	0.4	0.5	0.6	0.7	0.75	1	1.25	1.5	1.75	2
3-bladed	0.0479	0.18	0.252	0.181	0.099	0.169	0.139	0.18	0.171	0.0672
4-bladed	0.126	0.158	0.334	0.225	0.158	0.376	0.176	0.158	0.158	0.158
4-bladed 45°pitch	0.0805	0.138	0.407	0.348	0.144	0.126	0.14	0.138	0.141	0.121
100 rpm										
Impeller	di/D				L/D					
	0.4	0.5	0.6	0.7	0.75	1	1.25	1.5	1.75	2
3-bladed	0.177	0.659	0.73	0.686	0.223	0.768	0.499	0.659	0.773	0.28
4-bladed	0.252	0.315	0.512	0.792	0.413	1.169	0.739	0.734	0.732	0.435
4-bladed 45°pitch	0.172	0.275	0.31	0.375	0.495	0.597	0.279	0.275	0.281	0.239

Figure 4: The velocities of each impeller with different geometries.