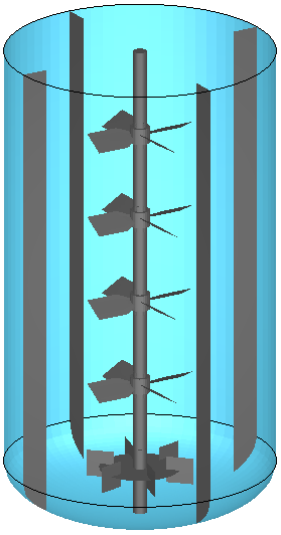
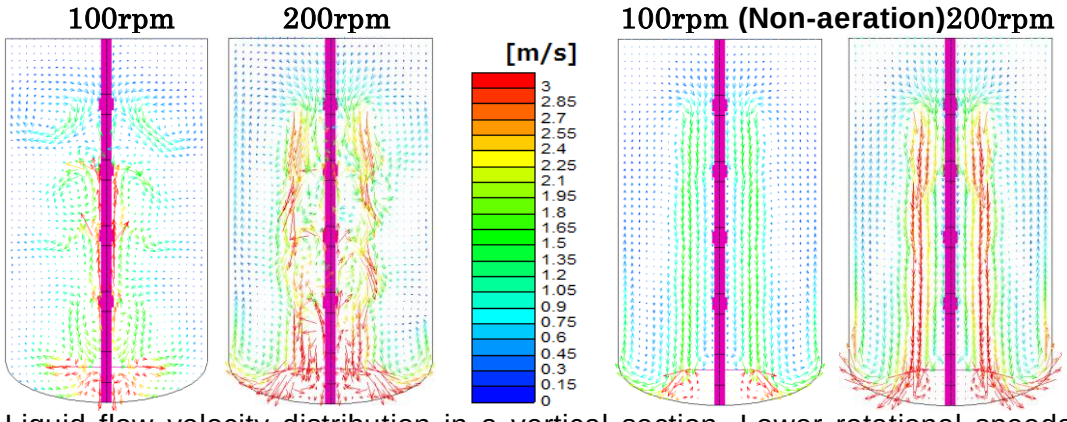
Gas Absorption Simulation in Bioreactor

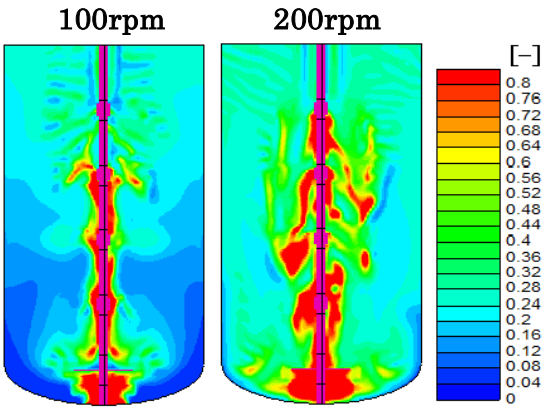
CFD simulation of an aerated bioreactor for cultivating micro-organisms such as animal cells. The oxygen component in the bubbles sparged by aeration is dissolved into the liquid as dissolved oxygen (DO) by gas absorption. In the liquid, DO is consumed by respiration of micro-organisms and carbon dioxide is released at the same time. In addition to kL_a, which is determined from the flow field, bubble void fraction and bubble diameter, dissolved oxygen, carbon dioxide, oxygen in bubbles, carbon dioxide and culture medium concentration in the liquid are also simulated with the liquid and gas flows. The bubble diameter distribution is also simulated using an N+1 (N dispersed phases and the continuous phase) multiphase fluid model considering the breakup and coalescence of bubbles.



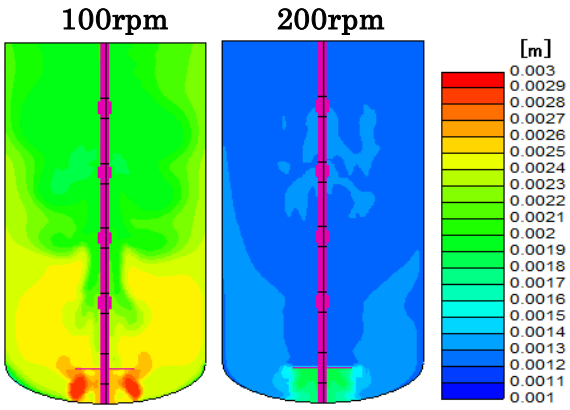
Main simulation conditions	
Tank Diameter	2[m]
Liquid depth	3.6[m]
Blade rotation speed	100/200[rpm]
Liquid density	1000[kg/m^3]
Liquid viscosity	0.001[Pas]
DO diffusion coefficient	3.3×10^{-9}[m^2/s]
DCO_2 diffusion coefficient	2.2×10^{-9}[m^2/s]
Sparged gas	air
Air flowrate	0.2[m^3/s]
Microbial respiration rate	0.0012[kg/m^{3}s]
Culture fluid injection vol.	0.001[m^3/s]



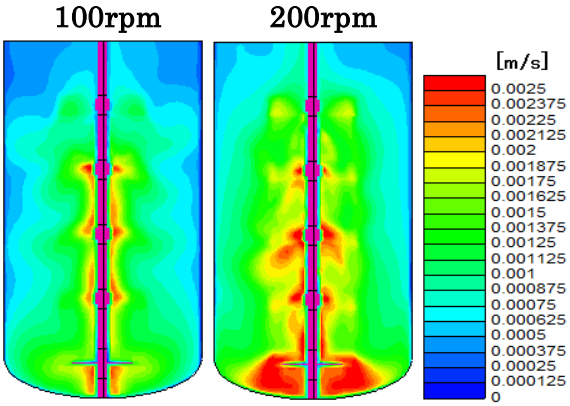
Liquid flow velocity distribution in a vertical section. Lower rotational speeds are more affected by aeration, which weakens the downward flow near the center. The figures on the right correspond to the cases without aeration (for reference).



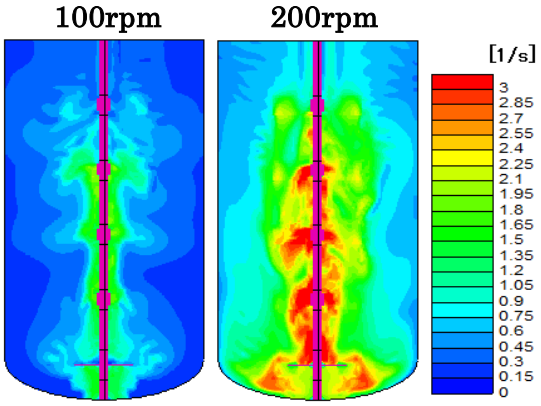
Spatial distributions of the bubble void fraction. The average of void fraction is 0.164 at 100 rpm and 0.265 at 200 rpm, with the mean value being greater at 200 rpm.



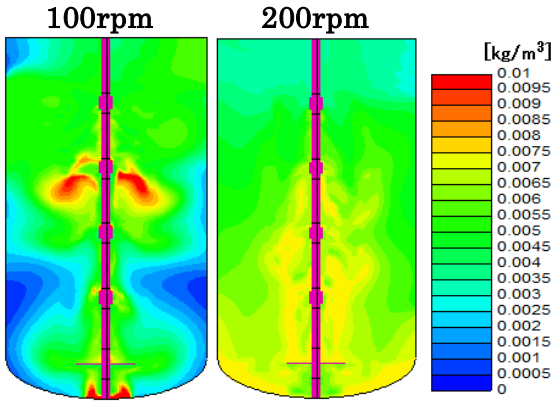
Spatial distributions of Sauter mean bubble diameter. The average of bubble diameter is 2.26 [mm] at 100 rpm and 1.20 [mm] at 200 rpm, with the bubble diameter being smaller at 200 rpm.



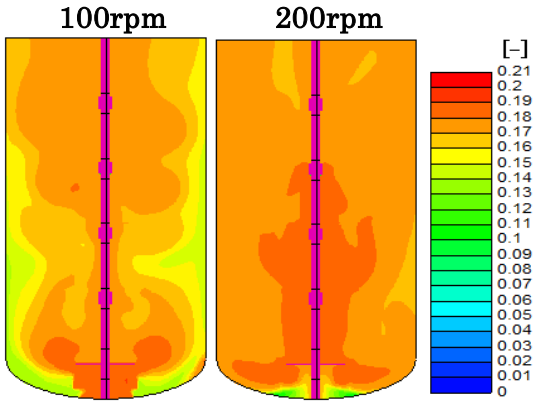
Spatial distributions of Oxygen k_L. The average of k_L is 0.000683 [m/s] at 100 rpm and 0.000968 [m/s] at 200 rpm, with the mean value being slightly higher at 200 rpm.



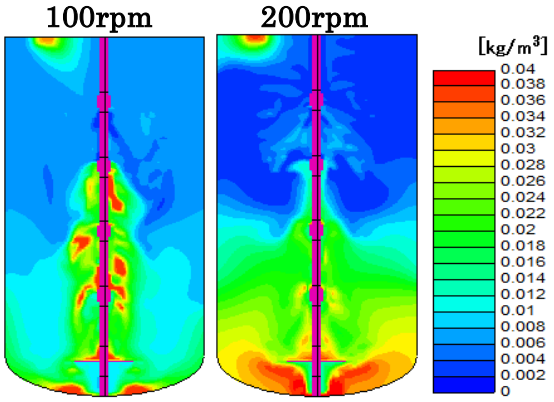
Spatial distributions of k_La (oxygen). The average of k_La is 0.252 [1/s] at 100 rpm and 0.944 [1/s] at 200 rpm, with the mean value being significantly larger at 200 rpm.



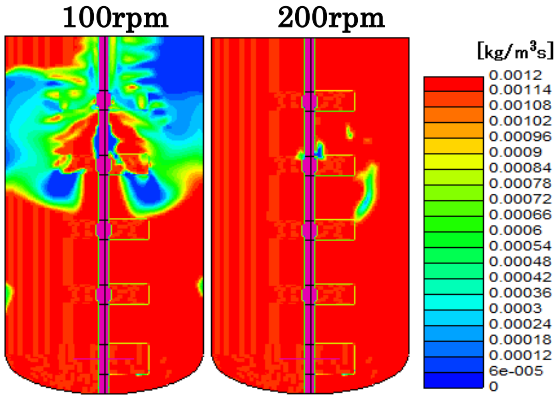
Spatial distributions of dissolved oxygen (DO) concentration in the liquid. The average is 0.00348 [kg/m3] at 100 rpm and 0.00548 [kg/m3] at 200 rpm.



Spatial distributions of Oxygen concentration in bubbles. The average is 0.170 at 100 rpm and 0.183 at 200 rpm.



Spatial distributions of culture medium concentration. The average value is 0.0121 [kg/m3] at 100 rpm and 0.0081 [kg/m3] at 200 rpm.



Spatial distributions of respiratory rate. At 100 rpm, there is a region in the upper part of the tank where sufficient respiration cannot be performed due to poor mixing.