DEPARTMENT OF BIOCHEMICAL ENGINEERING AND BIOTECHNOLOGY
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BE-314P (Bioprocess Engineering Laboratory)

Experiment 3

OBJECTIVE

The goal is to estimate the dimensionless mixing time in a batch reactor.

INTRODUCTION

Many processing operations depend for their success on the effective mixing of fluids. Mixing is the random distribution of two or more initially separate phases to form a solution/suspension where concentration gradients of either phase do not exist. Efficient mixing is essential in a bioreactor in order to maintain uniform dissolved oxygen and nutrient salt concentrations. Poor mixing may result in formation of anaerobic zones in the bioreactor, which may be undesirable for aerobic processes.

The dimensionless mixing time θ_m is defined as

$$\theta_m \equiv t_m N_i$$

where t_m is the mixing time (in seconds) and N_i is the impeller rotational speed (in revolutions per second). The mixing time is measured as the time required to reach 90 % of the ultimate steady concentration following a pulse.

We know that in the turbulent flow regime, the dimensionless mixing time approaches a constant value, say $\theta_{m,\infty}$. It follows that under these conditions, the mixing time is

$$t_m = \theta_{m,\infty} / N_i,$$

i.e., the mixing time is inversely proportional to the impeller rotation speed.

MATERIALS

- Fermentor 3L
- 300 mL each of 4N NaOH and 4N H_3PO_4 solutions.

METHOD

1. Fill the bioreactor with 2.2 L of demineralized water. Add 1g of KH_2PO_4 to impart some buffering capacity to the medium.
2. Set the impeller rotation speed N_i to obtain turbulent flow by computing the corresponding impeller Reynold's number $\mathrm{Re}_i = \rho N_i D_i^2 / \mu$.
3. Set the stopwatch. Adjust pH to 7.
4. Add a tracer pulse (5 mL of 4 N acid) and note down pH readings with time until a steady value is obtained.
5. Reset the pH to 7 by adding 4 N NaOH.
6. Repeat steps 2-5 for different impeller rotation speeds (400,600,800,1000 rpm).

CALCULATIONS:
At each N_i, plot the pH vs time curve at obtained and calculate the mixing time as the time required to achieve 90% of the ultimate pH value.

Plot t_m vs. $1/N_i$ and calculate the dimensionless mixing time $\theta_{m,\infty}$ as the slope of the straight line.

RESULTS: Report the value of the dimensionless mixing time.

DISCUSSION: Write a discussion on your observations.