Department of Biochemical Engineering & Biotechnology
IIT Delhi
BEL850 (Bioprocess Engineering Laboratory)

Experiment 2

OBJECTIVE

To estimate the power required to overcome the friction in the mechanical seal of a 3 L ungassed bioreactor.

INTRODUCTION

The total electrical power supplied to the agitator motor denoted P_T is consumed in two ways, i.e.,

$$P_T = P_0 + P_S \tag{1}$$

where P_0 denotes the power for stirring the liquid in an ungassed bioreactor, and P_s denotes the power for overcoming the frictional forces in the mechanical seal.

Now P_0 can be estimated from the impeller Reynold's number

$$\mathrm{Re}_i \equiv \frac{\rho N_i D_i^2}{\mu} \tag{2}$$

where ρ denotes the density of the liquid (1000 kg m^{-3} for water), μ denotes the viscosity of the liquid (10^{-3} kg m^{-1} s^{-1} for water), N_i denotes the rotational speed of the impeller (in revolutions per second), and D_i denotes the diameter of the impeller (in m). In particular, if the flow is turbulent, i.e. $\mathrm{Re}_i \geq 5 \times 10^3$, the power number

$$N_P \equiv \frac{P_0}{\rho N_i^3 D_i^5} \tag{3}$$

approaches a constant value $N_P^{'}$ which depends on the type of the impeller and the geometry of the reactor. It follows that under turbulent conditions, P_0 can be estimated from the formula

$$P_0 \approx N_P^{'} \cdot \rho N_i^3 D_i^5 \tag{4}$$

where $N_P^{'} = 5$ if the reactor contains a Rushton impeller and the reactor geometry is such that $H_L / D_T = 1$ and $D_i / D_T = 1/3$, where H_L and D_T denote the liquid height and tank diameter, respectively.

We can also calculate the total electrical power consume P_T from the voltage V and the current I measured with a multimeter. Indeed, P_T is given by the expression

$$P_T = VI \cdot \eta \, Cos(\Phi) \tag{5}$$

where $\eta = 0.8$ denotes the electrical motor efficiency and $Cos(\Phi) = 0.9$ denotes the power factor.

MATERIALS:

- Fermentor 14L
- Voltmeter and ammeter

METHOD

1. Measure D_i and D_T and check that $D_i / D_T = 3$. Now fill the reactor with water such that $H_L / D_T = 1$.
2. Compute minimum impeller rotation speed which will ensure turbulent flow of the water in the bioreactor.
3. Choose the impeller agitation speed at any value above the minimum value obtained in step 2, and measure the voltage and current using the multimeter.
4. Repeat step 3 for six different agitation speeds.

CALCULATION

For each N_i, calculate the corresponding P_0 and P_T using (4) and (5), respectively, and then use (1) to calculate P_s.

RESULTS

Plot P_0, P_s, and P_s / P_T against N_i.

DISCUSSION

Discuss your observations.

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