Experiment No - 9

OBJECTIVE

Estimation of power required for liquid agitation (P_L) in a 14L bioreactor.

INTRODUCTION

The total electrical power delivered to agitator shaft to agitator motor is used up for (a) Losses in motor, (b) losses in reduction gear-box, (c) losses due to friction in mechanical seal , and (d) agitation of liquid in the bioreactor (P_L), i.e.,

$P_L = P_1 - P_o$ -- (1)
P_o = VI cosø (measured electrical power without liquid)
P_1 = VI cosø (measured electrical power with liquid)

Where

P_L	Power consumed in liquid agitation
V	Voltage (Volts)
I	Current (Amperes)
Cosø	power factor (0.9)

Rsuhton et.al, develop the concept of power number (N_P). It is defined as the ratio of external to inertial force per unit liquid volume and is given by:

N_P = (external force) / (inertial force)

$$N_P = \frac{P_L}{n^3 \, Di^5 \, \rho} \quad \text{-------------------------- (2)}$$

Where:

P_L	Power consumed for liquid agitation, (kg m^2) / sec^3
n	Impeller rotational speed, per sec
Di	Impeller diameter, m
ρ	Liquid density, kg / m^3 (= 10^3 for water)

The modified Reynolds Number (N_{Re}) is given by:

$N_{Re} = (n\, Di^2\, \rho) / \mu$ -------------------------------- (3)

Where: μ liquid viscosity, (kg / m sec): (= 10^{-3} for water)

If agitation (n) is set such that the flow is in turbulent regime, N_P can be taken as 3 x 6, i.e., 18 (for three sets of flat blade turbines) provided H_L / Di and Di / D_t = 3. Then equation (2) can be used to estimate (P_L). This will be power required for agitation of liquid. Now if electrical power (P_0 & P_1), consumed by the motor, is measured by an ammeter and a voltmeter, we can estimate power consumed for liquid agitation (P_L) by equation(1) and compare it with calculated value using equation (2). The value of P_0 refers to power used up in losses without liquid agitation.

MATERIALS

(a) Fermentor 14L

(b) Voltmeter and ammeter

METHOD

1. For the 14L reactor, Di=0.08m, D_t=0.26m and the ratio D_t/Di = 3. Now fill the reactor with water up to 11L mark. This makes H_L /Di=3.68 instead of literature figure of 3.

2. Set the agitation at 300 rpm & compute N_{Re} for minimum agitator rpm so as to ensure turbulent flow of water in the rpm range selected.

3. Now adjust agitation at 300, 400, 500 and 600. Measure electrical power consumed by the motor using the ammeter/ voltmeter at each rpm.
4. Drain out the water to the mechanical seal height (so the seal does not run dry)

5. Repeat step-3 for the above rpm without water.

CALCULATION

$P_L = N_P\, n^3\, Di^5\, \rho$ kg.m^2 / sec^3 or watts
P_0 or $P_1 = V\, I \cos\phi$ Watts
$\cos\phi$ = Power factor (=0.9)
$P_L = P - P_o$

OBSERVATION

Table-1 Power used in losses without liquid agitation

Rpm	**Current (A)**			**Voltage (V)**			**P_o**
	Lower value	**Higher value**	**Average**	**Lower value**	**Higher value**	**Average**	
300							
400							
500							
600							

Table-2 Power used in losses & liquid agitation

Rpm	**Current (A)**			**Voltage (V)**			**P_1**
	Lower value	**Higher value**	**Average**	**Lower value**	**Higher value**	**Average**	
300							
400							
500							
600							

Table-3 Power used in liquid agitation

Rpm	**$P_{L\,observed} = P_1 - P_o$ (from eqn – 1)**	**$P_{L\,calculated}$ (from eqn – 2)**
300		
400		
500		
600		

RESULTS

Make a plot of P_L vs n. Compare the P_L observed (from eqn–1) with the calculated value from eqn-2.

DISCUSSION

Write a discussion on your observations.
