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Study the Effect Of Impeller Design On Power Consumption

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Abstract:
This paper emphasizes on the mass transfer studies that have been carried out in a 370 mm diameter and length of 450 mm Perspex cylindrical vessel attached with a DC motor that can operate on different RPM effect of impeller type on power consumption was calculated for impellers. Flow visualization technique was used to study the hydrodynamic in the cylindrical vessel for kerosene-water system for four types of impellers. Rhodamine-B (water soluble dye) was used to identify the flow patterns in the extraction and separation zones of the contactor.

Keywords: extraction; separation; chromatography; hydraulic power; batch mode; Hydrodynamic

1. Introduction

Liquid-liquid extraction is an important purification enrichment separation method used in the chemical, biochemical, petrochemical, pharmaceutical and food industries. Despite the increasingly extensive applications of liquid extraction, greater versatility, and the extensive amount of research that has been done, it is nevertheless a relatively immature unit operation. There are many problems associated with traditional liquid-liquid extraction equipment like phase separation, solvent loss, emulsion formation, loading and flooding in conventional column contactors and mixer settlers. Moreover, traditional units also have high power consumption and are maintenance intensive due to their interior moving parts. Improving the contacting and separation performance has always been a challenge for technologists involved in developing liquid-liquid extraction equipment [16–19]. Previous studies on the impeller design have shown that the power number is sensitive to the details of impeller geometry, and in particular to the blade thickness, but is independent of the impeller diameter to tank diameter ratio. But latter on it is studied that the power number is independent of blade thickness, but dependent on the impeller to tank diameter ratio. This is exactly the opposite result to one another. In the present research work it is studied that power number is dependent on impeller geometry as well as impeller to tank diameter ratio. Physical explanations are given for the dependencies and differences in behavior between the two impellers. for the angled blades power consumption is dominated by form drag, so details of the blade geometry have a significant impact (30%) on the power number. for the straight blade impeller, form drag is not as important, but the impeller interacts strongly with the proximity of the tank walls, so changes in the position of the impeller in the tank can have a significant impact on the power number in industrial mixing applications, the power consumption per unit volume of fluid is used extensively for scale-up, scale-down and design. in spite of its widespread use, the dependence of power consumption on impeller and tank geometry is dependent only in the most general terms. this is partly due to the difficulty of obtaining accurate torque measurements on the small scale, and partly due to the predictive limitations of drag theory. A significant limitation of this interesting theoretical approach is the assumption that there is no interaction between the impeller and the tank walls.

2. Materials and Method:

The apparatus used in the experimental arrangement comprised of the following items:

1. Cylindrical Vessel Apparatus
2. Impellers
3. Glass Beakers
4. Variable Speed Controller (Precise Power Strength Mixer)

Flow visualization studies and quantitative measurements were performed on experimental models which were mounted in a clear cylindrical vessel. This tank had a dia of 370 mm and height of 450 mm three baffles were used having width of 55 mm and length of 430 mm, equally spaced around the periphery of the tank, supported by an iron frame. The cylindrical vessel was half filled of its capacity approximately 45 liters of water then added 23 liters of kerosene oil in it. Then a dilute solution of Rhodamine-B dye was prepared then this dye was slowly into the solution prepared for the flow visualization purpose. Then the apparatus was operated for various rpm and impellers fabricated for the same purpose and readings were noted, for every run a settling time of 10 min was given to the solution.

Photograph showing the cylindrical vessel in operation with straight bladed impeller small size (Impeller no. 1) at higher rpm (94rpm) and it can be observed that inter dispersion between the phases is reduced due to increased turbulence.

3. Hydraulic Power Consumption:

The hydraulic power, which is the power input through the jet to attain a certain degree of Extraction in the cylindrical vessel can be computed using the following relation

Power = Power Number x Density x Rotational Speed3 x Impeller Diameter5

For common engineering units:

Power (P) – horsepower

Power Number (Np) - dimensionless quantity depending on impeller geometry - a constant for turbulent conditions and geometric similarity - need to know geometry of impeller for value (typical values between 0.3 and 6.0)

Density (sp.gr.) - Specific gravity w/respect to water

Rotational Speed (N) – rpm

Impeller Diameter (D) – inch

$$NRe = \frac{d\ V\ \rho}{\mu} = \frac{\text{Inertial Forces}}{\text{Viscous Forces}}$$

$$BHP = \frac{NP\ D5\ N3\ SG}{6.124\times107}$$

Where:

NP = Impeller Power Number [Dimensionless]

D = Impeller Diameter [mm]

N = Impeller Speed [RPM]

SG = Fluid Specific Gravity

V = Velocity or speed of the liquid at the impeller outside diameter (ft/sec. or meters/sec.)

g = gravity = 32.2 fet/sec2 or 9.8 meters/sec2

$$V = \frac{\pi D \times RPM}{10 \times 60}$$

d = diameter of the impeller

π = 3.14

rpm = speed of the impeller outside diameter

60 = sixty seconds in a minute

The equation for calculating speed is:

$$V\ (ft/sec) = \frac{\pi}{720} \times RPM \times D(in)$$

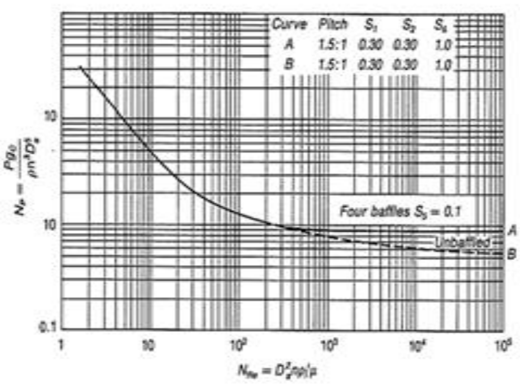
V= Velocity

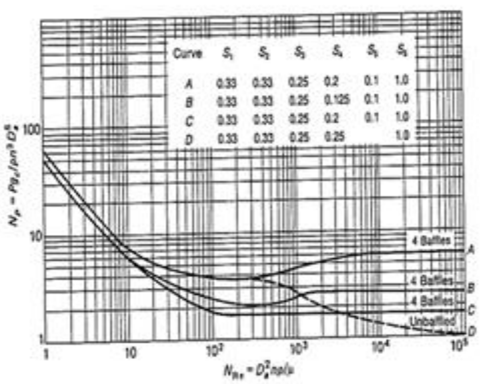
$$P = \frac{N_p n^3 D_a^5 \rho}{g_c}$$

Photograph showing the cylindrical vessel in operation with straight bladed impeller large size (Impeller no. 2) at lower rpm (55rpm) and it can be observed that emulsification is created between the phases. The flow patterns can be observed, drop size is smaller

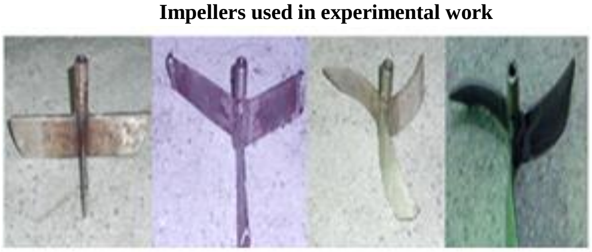
Photograph showing the cylindrical vessel in operation with 20 degree curved impeller blades (Impeller no. 3) at lower rpm (55rpm).With lower curve impeller the lighter phase is in contact with the heavy phase and with the curved blades better contacting and lower energy consumptions.

Photograph showing the cylindrical vessel in operation with12 degree curved impeller blades (Impeller no. 4) at lower rpm (77rpm)

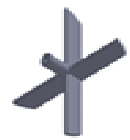




Impellers used in experimental work



Straight bladed impeller small size (Impeller no. 1)



Power required with impeller # 1

RPS	*Da(ft)*	*NRe=Da2nρ́/μ*	*NP*	*P=Npn3Da5ρ́/gc*	*Watts*
0.9166	*0.551*	*8399*	*6.5*	*0.423*	*0.586*
1.2833		11758	6.5	1.186	1.609
1.5666		14354	6.5	2.158	2.927

Straight bladed impeller large size (Impeller no. 2)

Straight blades large size with end flattened

RPS	*Da(ft)*	*NRe=Da2nṗ/µ*	*NP*	*P=Npn3Da5ṗ/gc*	*Watts*
0.9166	*0.669*	*12388*	*6*	*1.054*	*0.835*
1.2833		*17344*	*6*	*2.894*	*2.274*
1.5666		*21173*	*6*	*5.265*	*4.138*

Curved bladed impeller α = 20°(Impeller no. 3)

Tiltation angle =20°
Power required with impeller # 3

RPS	*Da(ft)*	*NRe=Da2nṗ/µ*	*NP*	*P=Npn3Da5ṗ/gc*	*Watts*
0.9166	*0.54*	*8067*	*3.0*	*0.183*	*0.244*
1.2833		*11293*	*2.9*	*0.478*	*0.649*
1.5666		*23787*	*2.9*	*0.870*	*1.180*

Curved bladed impeller upper curve (Impeller no. 4)

Tiltation angle = 12°
Power Required With (Impeller #4)

RPS	Da(ft)	NRe=Da2nṗ/µ	NP	P=Npn3Da5ṗ/gc	Watts
0.9166	0.57	8988	5	0.394	0.534
1.2833		12583	5	1.081	1.466
1.566		15361	5	1.967	2.668

4. Conclusions:

The research work examines the effect of blade thickness blade angle and blade design on power number; the effect of impeller speed on degree of extraction. This work compares the importance of impeller and tank geometry for four widely used impellers. The following conclusions have been drawn from the above study.

•The small blade impeller has a better efficiency of extraction as compared to the large straight bladed impeller,

•Three bladed curved impellers with tiltation angle of 12 degree have lower efficiency and greater power consumption than the standard 20 degree tilted blade Impellers.

•Geometrical simplicity of the pitched three-blade turbine with diagonally folded blades at an angle of 20 degree makes this impeller economical and efficient.

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