2011 2nd International Conference on Environmental Science and Development
IPCBEE vol.4 (2011) © (2011) IACSIT Press, Singapore

Impeller Submergence Depth on Power Consumption of Mixing Tank

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Abstract**—**Present work experimentally investigates the effect of impeller submergence depths on power consumption when arrow head impeller has been used in the process. It has been found that at higher range of impeller submergence, mixing tanks consume less power. Optimal range of submergence depth is 0.7 to 0.9 times the impeller diameter**.**

Keywords**—*arrowhead impeller; power consumption; stirred tank; submergence depth***

I. INTRODUCTION

Stirred tanks are among the most commonly used pieces of equipment in the chemical and biochemical processes. Liquids are mechanically agitated to enhance mixing, blending, dissolution, solid suspension, emulsification, crystallization, coagulation, heat and mass transfer. Each process has specific requirements. Achieving the required goal at a minimum expense of energy is a primary task in the design of stirred tanks. The physical and chemical processes taking place in the stirred tank are complex and closely coupled to the underlying transport processes, in particular- the flow field. Therefore, a detailed understanding of the hydrodynamics of stirred tank (velocity field, turbulence, stress field etc.) is useful for optimum design [1-2].

Power draw is a very important variable in stirred tank. It is defined as the amount of energy necessary in a period of time, in order to generate the movement of the fluid within a container (e.g. bioreactor, mixing tank, chemical reactor, etc.) by means of mechanical or pneumatic agitation. The costs associated with power draw contribute significantly to the overall operation costs of industrial plants. Therefore, it is desired that the mixing process is performed efficiently and with a minimum expense of energy required to achieve the objective established a priori [3]. Power draw influences heat and mass transfer processes, mixing and circulation times. Power draw has been used as a criterion for process scale-up and bioreactor design [4].

The economics of stirred tanks, particularly operating costs, are contributing much more heavily to system selection [5-6]. Because of the widespread applications of stirred tanks in the process industry, even a small reduction in the operational costs of these vessels can result in major cost savings. It is essential that the design and operation of stirred tank must be as near as is possible or practicable.

Therefore, the effect of impeller position has been investigated in the present work for optimal power consumption.

II. EXPERIMENTATION

Experiment has been carried out with an objective to find the effect of impeller position on power consumption. Diameter of the tank (D) is 200 mm. Figure 1 shows the experimental setup and schematic diagram of the setup used in the present study.

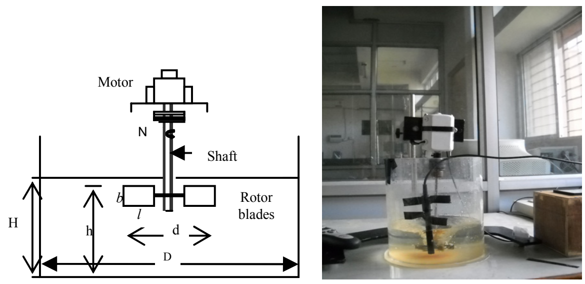

Figure 1. Experimental Setup

The various geometric dimensions of the aerator are: D (tank diameter), H (water depth), h (impeller submergence or distance between the horizontal bottom of the tank and the top of the blades) and d (diameter of the rotor). Standard geometry of impeller (Rushton turbine) has been documented well in the literature [7]. Thus the impeller used in the present study is arrowhead impeller. In the application of high energy agitation and high gas rates, arrowhead impeller will significantly improve the mass transfer rates. Given the same conditions of power per unit volume, mass transfer can nearly double when arrowhead impeller has been used instead of the conventional flat bed disc impeller. Figure 2 shows impeller used in the present study. Geometric parameters of the impeller have been given in the table 1.

Liquid level is maintained as equal to impeller's diameter. When a single impeller is to be used, a liquid level equal to the diameter is optimum, with the impeller located at the center for an all-liquid system [8-9].

Figure 2. Impeller Used in the Experiments

TABLE 1: IMPELLER GEOMETRICAL PROPERTIES

Roto r diameter (d) (mm)	Blade length (mm)	Blade width (mm)	Blade thickness (mm)
80	20	16	0.8
60	15	12	0.6
45	11.25	9	0.45
40	10	8	0.4
30	7.5	6	0.3

A. *Power Consumption*

Power consumption is a basic integral quantity in an aerator, which determines the other processes involved in aeration phenomena such as 'mass transfer rates', 'gas hold up' etc [10-11]. The power usage in mass transfer operations is very important in judging the aeration performance of the aerator. Power draw is defined as the amount of energy necessary in a period of time, in order to generate the movement of the fluid within a container (e.g. bioreactor, mixing tank, chemical reactor, etc.) by means of mechanical or pneumatic agitation [12]. Power draw in systems has been measured by means of a wattmeter. The power available at the shaft was calculated as follows [13]. Let P_1 and P_2 are the power requirements under no load and loading conditions at the same speed of rotation. Then the effective power available to the shaft, $P_{eff} = P_2 - P_1$-Losses. Reproducibility of measurements has been found to be ±5%. The main advantages of the estimation of power draw by electrical measurements are: (1) It is a simple method, (2) little instrumentation is required and (3) high investment is not required.

III. RESULTS AND DISCUSSION

The performance of stirred tank is known to depend on the impeller submergence. Therefore, the effect of impeller submergence has been investigated systematically. Figure 2 illustrates observations made on power consumption with different submergence depths of impeller. The value of h/d varies from 0.3 to 0.9. Power consumption is strongly dependent on the gas holdup near the impeller i.e., the local gas hold-up in the vicinity of the impeller [14]. As the size of this region increases, impeller rotates in progressively increasing liquid free region thereby decreasing the power consumption. This fact can be seen from the Figure 3. It can be seen from the Figure 3, the value of h/d=0.9 consumes less power in most of the cases. Overall these observations suggest that a range of 0.8 to 0.9 is optimal as far as power consumption is concerned.

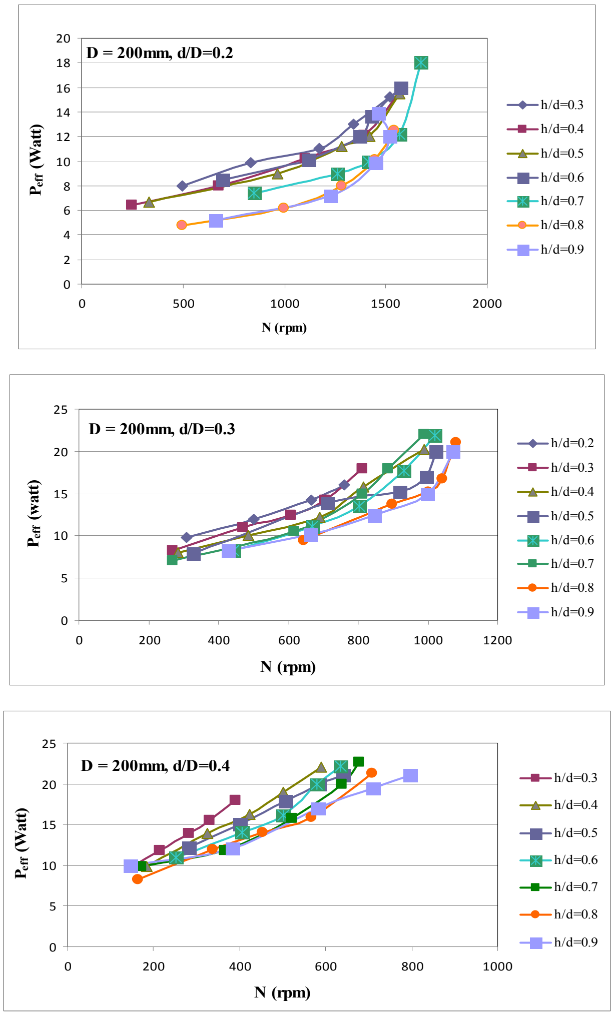

Figure 3. Influence of Submergence Depth at Power Consumption

The less power consumption at higher value of h/d may be attributed to the fact that blades are exposed to the air. Exposure of blades decreases the drag resistance. This decrease in drag results in lower power draw or consumption

IV. CONCLUSIONS

Generally standard guidelines for submergence are being followed for designing the stirred tanks for desired process, which can far from being an optimal point. Slight change in submergence depth can cost much when optimal performance is required. In particular, there is practically no published information which stipulates the optimal submergence depth of impeller. Present work experimentally investigates the influence of submergence depth on power consumption. It can be concluded that h/d=0.9 can be taken as optimal point.

ACKNOWLEDGMENT

The authors gratefully acknowledge financial support from Indian Institute of Technology Guwahati under research project SG/CE/P/BK/01.

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