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Study of various curved-blade impeller geometries on power consumption in stirred vessel using response surface methodology

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Introduction

Several types of impellers have been designed and created for various applications in chemical, pharmaceutical, petroleum and food processes through standard stirred vessels. Paddled; propellers and turbines are among some of the common types of impellers used in mixing processes. Proper impeller selection for each process requires precise information about the viscosity of fluid, operating conditions, system flow regime, etc. [1]. Power drawn by a rotating impeller has a significant role in the design of the mixing systems and the best choices for impellers are those with the lowest power consumption [2]. Thus, a comparison of different impellers would be helpful in determining the choice of an appropriate impeller for a dispersion process. Several works determined the power number of a wide range of impellers designs such as down pumping 458 pitched blade turbines [3–6], up pumping 458 six pitched blade turbine [3] and Sawtooth impeller [6], Rushton turbine [7–11], Concave blade (semi circular) [3,9,12–14], 6SRGT Scaba [3,15,16], Propeller [4,17], Lightnin A6000 impellers [18], A310 Fluidfoil impellers [18], prochem T [15,19], Parabolic bladed disc turbine [3] and curved pitched blade turbine [4] have performed through the stirred vessels. Table 1 shows some power number values for various impeller types.

Published literature on mixing showed the employment of different types of impellers for various applications but the Rushton turbine is still a very common and applicable type. However, there are several drawbacks associated with the Rushton turbine such as a considerable drop in the power input and mass transfer in the aerated system [9,20,21], in addition to high levels of shear stress in the district of the impeller and a non homogeneous spatial distribution of the energy dissipation rate inside the tank [22]. Compared to the Rushton turbine, Hydrofoil impellers, such as Prochem Maxflow T and Lightnin A315 show a much lower power reduction over a wide range of gas flow rates [23]. Moreover, the curved or hollow blade impellers, such as SCABA and concave blade turbines, also provide better gassed power characteristics and shaft stability performance than the standard Rushton impeller with much less reduction in power drawn [3,15,16,24,25]. For example, Couper et al., described that the gas handling capacity for Chemineer CD-6 is 200% more than the six bladed disk turbines, prior to flooding and at flooding the aerated power reduction is only around 30% [26].

Consequently, large differences in power consumption can be seen among various designs, while the effect of small changes in a particular geometry such as blade angle and central disk size has not been widely established. Literature reviews suggest that published works on curved blade impellers are very limited. Thus, in this work the effects of various curvature angles and central disk sizes for the six curved blade impellers on power in both aerated and un-aerated conditions were investigated. Finally, a comparison was made with the results of the Rushton turbine.

Experimental design technique is a very helpful technique to provide statistical models and giving better recognition of the interactions between the parameters. Furthermore, response surface methodology (RSM) is a compilation of mathematical and statistical techniques which can be employed to determine the importance of affecting parameters [27–29]. There is no information available in literature regarding the modeling of the interaction between angles, central disk size and Reynolds number with power number. Therefore, in this work central composite design (CCD) based on response surface methodology (RSM) were used to evaluate the effects of blades curvature angles and central disk sizes on power consumption in different Reynolds and flow numbers in stirred vessels and to prepare a model through experimental data.

2. Experimental setup

2.1. Setup

All the measurements were carried out in a 0.4 m diameter (T) flat bottom vessel which was constructed from a transparent scratch proof Perspex. The tank was equipped with four equally spaced wall mounted baffles (B) of width, B = T/10. The ratio of impeller clearance (C) to tank diameter (T) followed the standard geometries and was equivalent to 0.133 m. The sparger was provided with 24 equally spaced holes of 0.002 m in diameter with the same outer diameter and impellers equivalent to 0.133 m. The

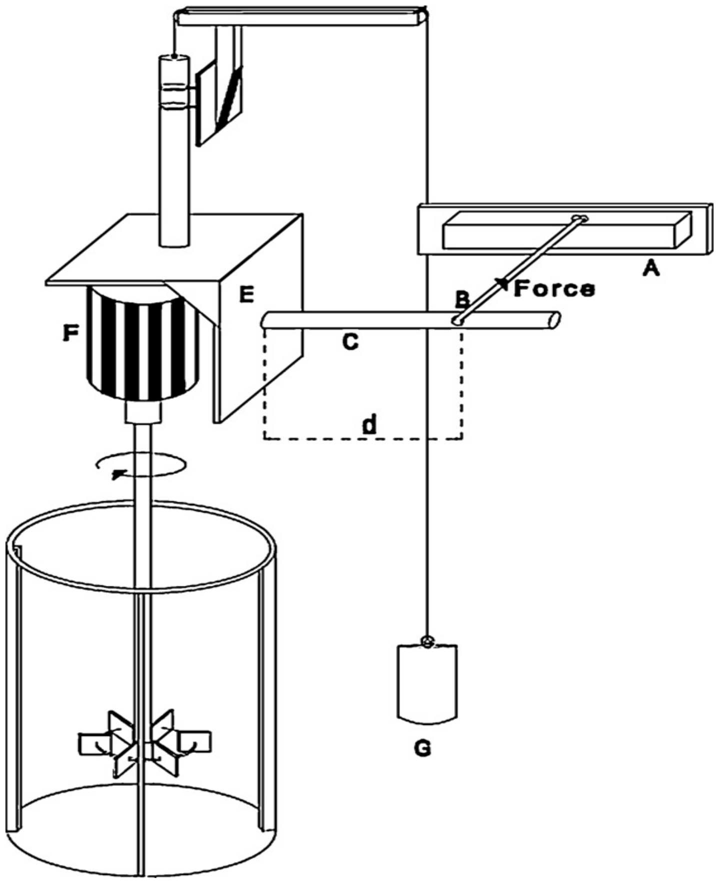

Fig. 1. Schematic of the load cell set-up to determine power number: (A) load cell; (B) connector; (C) rod; (d) a distance from the motor to the central rod; (E) panel; (F) motor; and (G) weight.

sparger was located concentrically to the impeller at a vertical position of 0.13 m below the turbine at the bottom of the vessel. Regardless of the position, the sparger always discharged gas toward the turbine region. Tap water was used directly as a working fluid and the liquid height was equal to the tank diameter (T). In advance of each test, the tank was filled with fresh water regularly. Meanwhile, the temperature was at about 25 8C (room temperature). A load cell was employed to measure weight or force for the determination of power. The load used in this work had different standard weights and the calibration curve was plotted using averaged mV and grams so as to increase the accuracy and the performance of the system. A schematic of the experimental set up and load cell design are illustrated in Fig. 1. Based on the objectives of this project, i.e., to use six curved blade turbines, it focused on six curved blade impellers with different blade curvature angles and central disc sizes. In addition, a comparison was also made with the well-known six straight bladed Rushton turbine. The description and schematic of each impeller is given in

Fig. 2 and Table 2.

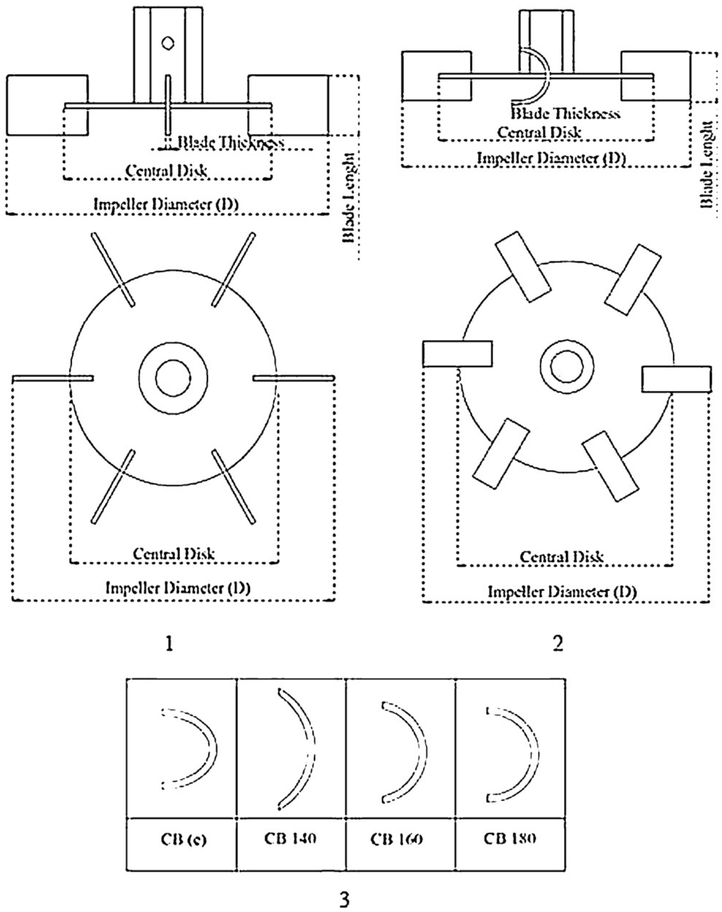

Fig. 2. The Schematic of different types of impellers utilized in this work: (1) 6RT; (2) 6 curved blade impellers; and (3) various curvature angles.

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