Mixing of EFB Fibre – Liquid in Stirred Tank Using Intermig Impellers

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ABSTRACT: Mixing process involving palm oil empty fruit bunch (EFB) and liquid such as in production of the carboxyl methyl cellulose has never been studied. Better understanding of their mixing performance is of great interest in process design and scale-up. This paper presents mixing of palm oil empty fruit bunch (EFB) fibre-liquid in a stirred tank agitated by two Intermig impellers. The tank dimension was H=1.4T with the impeller diameter of 25.5 cm fixed at T/3 and 2T/3, respectively. Measurement of the power draw was carried out using an IKA Eurostar torque meter for a wide range of impeller speed. The result shows relative power draw increases as concentration of EFB fibre increases. The relative power draws increases as much as 5 times higher when concentration of EFB fibre increases from 1 wt.% w/w to 4 wt.%, which suggests higher operational power requirement. The result also suggests that a constant power number (desired mixing characteristic) can be achieved when the tank operates at Reynolds's number above 60000. The Intermig impellers are capable of handling up to 4 wt.% of EFB fibre, which is a significant improvement compared to conventional solid mixing impeller such as the pitched blade impeller which is limited to 2 wt.%. Results from this work might be useful for an efficient design of EFB-liquid mixer or reactor.

Key words: Fibre-liquid,Mixing, Intermig impeller, Empty fruit bunch (EFB)

1. INTRODUCTION

Empty fruit bunch is obtained after stripping off the fresh oil palm fruit bunch [1]. In Malaysia according to Biomass Energy Cooperation Officeis about 19 million ton of EFB is thrown away every year [2]. Because of it availability in large amounts and has a fairly high cellulose content with an average of 50% based on oven dried basis it appear to be potential substrate for cellulose production [3]. A big scale cellulose production requires an effective mixing of EFB fiber and liquid in the reactor to facilitate a higher reaction rate.

EFB-liquid mixture poses serious mixing challenges that require a careful impeller selection. Wrong impeller selection cause uneven mixing and hence affecting the reaction which in turn resulting in very low (10 to 20%) fiber yield. Impellers like helical ribbons, anchors and screws are applicable for a mixture with difficult rheology such as EFB fiber-liquid. All these impellers are also known as close clearance impeller [4] intended to sweep through a large volume of the tank and as a result formation of stagnant zone within the fluid can be prevented [5]. Due to large diameter and small clearance between the impeller edge and tank wall, these impeller normally operated at low speed but at high power [6]. However if when has a changes in viscosity occurs throughout the process, coaxial stirring system combining a close clearance impeller like intermig impeller are more appropriate [7]. However, no previous work concerning performance of intermig impeller for EFB fibre-liquid mixture available elsewhere, and hence this is the aim of this work.

Intermig is an interference multistage counterflow impeller that has an inner pitched blade and outer double arranged in staggered position with an opposing blade angle. Due to this design, these low-shear axial flow impellers used at large diameter ratios (0.5T – 0.9T) and effectively operated at Reynolds Numbers > 100 [4]. These impellers are usually installed in pairs, with each impellers rotated at a 90^oC angle respects to its neighbors [8].

In this study, the power characteristics of intermig impeller at various EFB concentrations were examined due to their importance in improving carboxyl methyl cellulose production.

2. MATERIALS AND METHODS

2.1 Preparation of Oil Palm Empty Fruit Bunch (EFB) fiber

ShreddedEFB with length 2 inch was collected from a local company in the East Coast Region of Malaysia. The EFB was dried at 103°C for 30 minutes, followed by cooling at room temperature and then weighed again until it shows constant weight [9]. The EFB was weighed and packed to represent 1% to 5% dw.of water capacity at H=1.4T and kept in sealed plastic bag to prevent from moisture absorption.

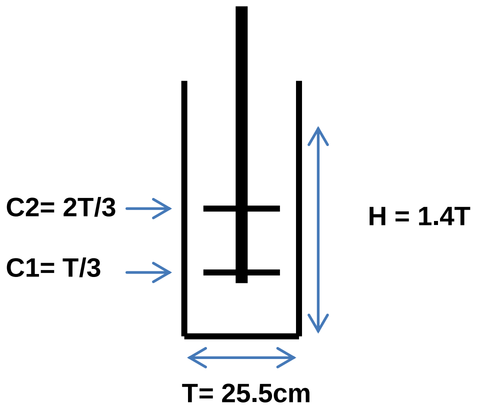

Figure 1: Tank geometry and impellers position

Figure2: Pitch blade turbine (PBT) with impeller diameter, D = 0.4T

Figure 3: Intermig impeller with impeller diameter, D = 0.88T

2.2 Experimental Setup

The experiments were carried out using a flat bottomed cylindrical vessel with diameter, T = 25.5cm and filled with water up to the height H=1.4T. The mixing was driven by either a pair of pitched blade impeller (Fig. 2) or intermig impeller (Fig. 3). Impeller positions were fixed at T/3 and 2T/3, respectively.Experiment using PBT was conducted in a fully baffled vessel but no baffle was used for intermig impeller as the impeller size of 0.88T is already very close to the tank wall. Dried EFB fibre ranged from 1 to 4% dw. were added and it was ensured that the fibre is suspended well prior to experiment. The impeller power draw was determined from the rotational speed, and the torque measured using the integrated torque meter by the IKA motor (IKA EUROSTAR power control-visc).Up to 10 sets of data (from the torque meter) was taken for each case and the ones reported in this paper were the average value.Reynolds number (Re), mixing power (P) and power number (N_{po}) were obtained as follows:

$$Re = (\rho N D^2)/\mu \quad (1)$$

$$P = 2\pi \Gamma N \quad (2)$$

$$N_{po} = P / (\rho N^3 D^5) \quad (3)$$

where N is the impeller speed in rev/s, D is the impeller diameter, ρ is fluid density in kg/m^3, μ is the fluid viscosity in kg/ms and Γ is the impeller torque in Nm.

3. RESULTS AND DISCUSSIONS

3.1 Mixing using PBT

Results for PBT shown in Fig. 4 suggest that mixing power number increase proportionally with increment of EFB fiber loading by 0.5 times which in in agreement with previous work related to solid-liquid mixing [10-11]. It was observed that mixer needs to operate at higher Reynolds number like above 100,000 for 2% w/w EFB loading for better efficiency (i.e. flat N_{po} pattern) instead of Reynolds number at 40,000 for 1% EFB loading as shown in Fig. 4. However, there is a significant issue in EFB fiber-liquid mixing as there is a limited movement of fiber close to tank wall and fiber at a centre of the mixer stacked to impeller like shown in Fig. 5. This phenomenon resulted in lower mixing capacity and hence possibly very limited reaction. It was also observed that it was impossible to use PBT for mixing involving EFB loading greater than 2% due to increases in the torque requirements beyond the limit of the motor used in this work. Increasing of EFB loading also increases skin friction and therefore, drag coefficient [10]. Higher torque requires greater power consumption, and hence it is not economical to run. The results suggest that PBT is unsuitable for mixing of EFB fiber because it is not capable to sweep whole fiber [5].

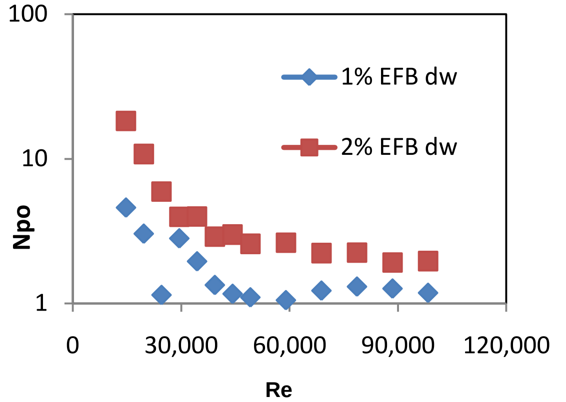

Figure 4: PBT Impeller: Comparison of mixing power number at different EFB concentration

Figure 5: Fiber stacked at centre of impeller shaft

3.2 Mixing using Intermig Impeller

The intermig impeller is capable of operating at higher EFB loading up to 4% as shown in Fig. 6. The mixing power number increases proportionally with increasing EFB loading, in agreement with observation by other researchers [10-11].Results in Fig. 6 shows 5 times power demand required to operate the mixer when fiber load increase from 1% to 4%. It was impossible to operate the intermig impeller beyond 4% EFB loading due to increases in the torque requirements beyond the limit of the motor used in this work. The intermig impeller are, however, much better than the PBT as they can operate EFB loading twice as higher than the latter. It is also not practical to operate the mixer at EFB loading beyond 4% because EFB occupied almost all the vessel volume making the mixing process impossible.

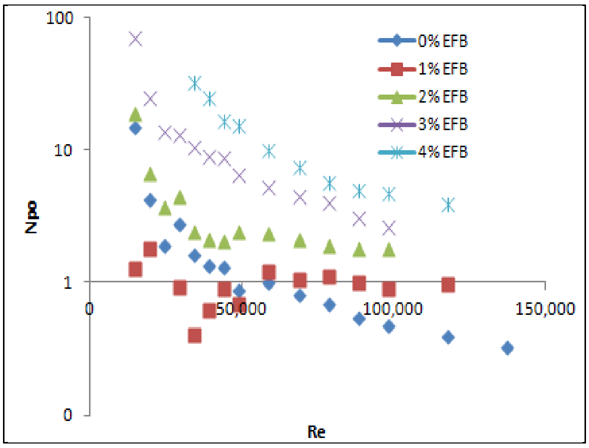

Figure 6:Intermig Impeller: Comparison of mixing power number at different EFB concentration

Operation within fully turbulent regime is always desired for a reactor to facilitate a higher reaction rate and hence higher product yield. The fully turbulent regime is characterized by the flat power profile. Fig. 7 shows mixer should operates at Reynolds Number above 60,000 for various EFB concentration up to 4% to ensure a fully turbulent regime can be achieved and hence better efficiency.

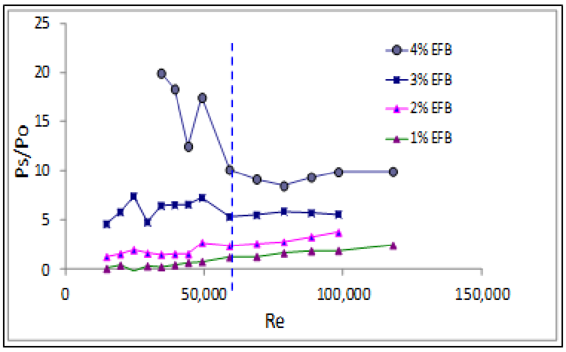

Figure 7:Intermig Impeller: Comparison of relative power draw (Ps/Po) at different EFB concentration

4. CONCLUSION

Study on EFB fiber-liquid mixing suggest that intermig impeller suit this application better than PBT since the former type are capable of handling EFB loading twice as higher than the latter. This work has demonstrated the impeller selection for a process involving EFB fiber-liquid operation is vital and may affect the process efficiency. Result from this experiment might be useful in designing better mixer or reactor involving EFB fibre and liquid such as in production of carboxyl methyl cellulose.

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