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The Characteristic of Liquid Film Flow on Disc in Rotating Biological Contactor

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ABSTRACT

The characteristic of liquid film over the disk surface, with the disc as contact media in Rotating Biological Contactor (RBC) would be evaluated on the flat and contoured surface. Measurement of the thickness of liquid film is important, because it affect the transfer of oxygen from the air into the water, through the liquid film. There was an influence from surface roughness toward liquid film thickness characteristic. The result of the study, it was gained that surface roughness was influence to liquid film thicknes. That liquid film thickness in flat surface was thicker than on the contoured surface.
KEYWORDS: liquid film, rotating biological contactor, flat surface, contoured surface.

INTRODUCTION

In the ideal liquid, the flow through liquid film had good spread velocity distribution. While in the real liquid, because of the viscosity influence, the velocity in the area near boundary area had a velocity decrease. The liquid layer near boundary area where viscosity influence was dominant was called as liquid film [1]. This study was done in order to know the characteristic of liquid film thickness on the flat and contoured surface. The benefits in this study in waste water reactor biologically like RBC was using biofilm that was patched to the disk surface, to lose the contaminant in waste water. Liquid film that was patched over the disk surface, in the application would flow over the biofilm surface. This liquid film had function as the entrance for oxygen from the air. Meanwhile oxygen was needed for respiration by biofilm [2,3,4].

In processing system with using RBC, some disks as contact media were grouped in one horizontal shaft. That disk partially immersed in the water, so in the rotation, liquid film (™) was carried by the disk surface upside so there was a contact between the liquid film with gas phase, right after the rotation was moving below the liquid film and accepted by the water that passed [5]. Some of the research had studied gas-liquid diffusion specifically since 1960, by Hartman [6], who declared that DO in the reactor had influence to equipment working efficiency, DO was gained from the disk rotation, so the mixing from the air was diffused in the liquid was happened.

Kubsad *et al*. [7] were one of several researchers that had focused on the physical mass transfer characteristic that went through the boundary layer in RBC. The basic math similarity for oxygen gas transfer caused by the diffusion that went to the thin liquid film on the flat-surface shaped disk with the time dependent variable and space co-ordinate that finished the theory with the deferential equation to calculate oxygen diffusion to liquid film that covered the disk, based on some assumptions. Liquid film rotational speed was assumed to be similar with disk rotational speed and there was a perfect liquid film mixing to the liquid in reactor in one way rotation. Other assumption that liquid film thickness in the disk was assumed to be similar or uniform. That assumption was appropriate for high rotational speed, with the disk depth (immersion) was comparable with disk radius, and the media used was flat surface.

Bintanja *et al.* [8] found that were the first who studied oxygen transfer with low rotational speed. It was assumed that over the disk, the liquid film with uniformed thickness (δ), came from the water mixing that went through it. Average contact time (t_R) between air and liquid film during one rotation, defined depended on angular velocity and disk depth. Liquid film velocity was assumed to be similar with disk velocity. Gained experimentally, oxygen transfer value (K_L) was 49% - 87% from K_L value theoretically.

Continued by Zeevalkink *et al.* [9], they explained that the deviation from mathematic model of [8] then he assumed reactor was not mixed perfectly with oxygen, based on his research. To measure *liquid film thickness* (δ) used Navier-Stokes equation and also verified that formula with a research in laboratory. It was

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assumed that liquid film thickness δ was uniformed, means that it was same in the entire disc, and could be calculated.

Ritmann *et al.* [10] analyzed that liquid turbulence increased and rotational velocity declined, assuming two phenomena for oxygen transfer. Made a new model, for two oxygen transfer phenomena, it through two way that turbulence and liquid film diffusion, which was related to physical parameter. K_La_t was tested with arranging disk rotational velocity that made to be high so it made a turbulence. K_La_t was gained from full power fraction from propeller mixer [11]. And K_La_d was tested with arranging low velocity.

K_La measurement in RBC with three stages and clean flat disc, in 2008 continued by Chavan and Mukherji [12], who made three reactors with different reactor's dimension representing the reactors that were used by previous researchers. With the hope of K_La value that gained could be used extensively in any reactor's type. In the measurement of oxygen transfer value, added the liquid film thickness value (δ) in the disk, as the influenced variable. (δ) Value that was used, the equation approach [9].

The study was continued by Hendrasarie *et al.* [13] with using dimensional analysis approach, it was gained that liquid film thickness influenced the oxygen transfer. In her research, besides the liquid film thickness, rotational velocity, it was also gained the way to optimized oxygen transfer in RBC, and also the importance of calculating disk surface roughness factor.

MATERIALS AND METHODS

For the experiment use has been made of a laboratory scale rotating disc apparatus. Type of the disc was varied from flat and rough surface and a water reservoir formed semi-cylinder made of acrylic material. The depth of immersion of the discs was varied by varying the water level in the trough. For practical reasons only the outer discs were used for the measurements. The water temperature was kept at 26±0.5^{o}C. And physical property of water is used: surface tension= 2.69 .10^{-3} N/m, density of water = 996,81 kg/m^3, absolute viscosity of water = 0,8746.10^{-3} kg/m.s.

The material for the disc used, consisted of three materials, namely: novotex, acrylic, and novotex exfoliated layer. Contoured surface shape, used radial and modifications, which consists of three types of surface contours.

There were several methods for measuring liquid film thickness patched to the disc surface which rounded vertically. But, in this study, the liquid film thickness was below 100 micro meter, because the temperature used was 26^{o}C, suitable with temperature condition in Indonesia. In that temperature, the liquid film that was patched to the disc when the disc came out of water, the thickness was below 100 micro meter, so it was hard to be detected.

In this work the amount of water entrained by the discs was measured by holding sponges against one of the discs. After one or two rotations the increase of weight increase M per rotation the mean film thickness was calculated assuming that the water was equally spread over the disc and that the film velocity equals the velocity of the disc, used formula 1 and the formula of the disc submerged area used the disc total area.

The application from the formula mentioned above, by Zeevalkink *et al.* [9,14], that studied about liquid film thickness, in his experiment used volume method meanwhile disc material used was made of polysterene. The way how it worked, some water that carried by the disc when exposed to the air as a result of the rotation, measured with sponge that was pasted on disc (Along the surface that is not submerged with water, was called the area of film ultimate thickness), see Figure 1. So the formula was:

$$\delta = \frac{M}{\rho\pi(R^2-H^2)}\delta = \frac{M}{\rho\pi(R^2-H^2)} \quad \text{.......} \quad (1)$$

Where M is the difference of sponge weight (gram). He related liquid film to be a function of the rotational speed as well as depth of immersion in addition to the forces of gravity and viscosity.

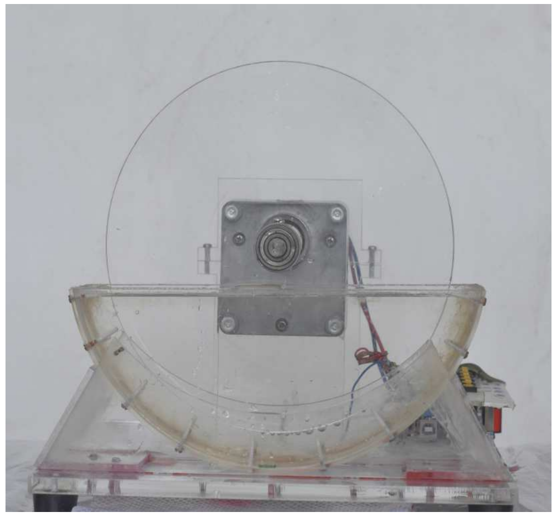
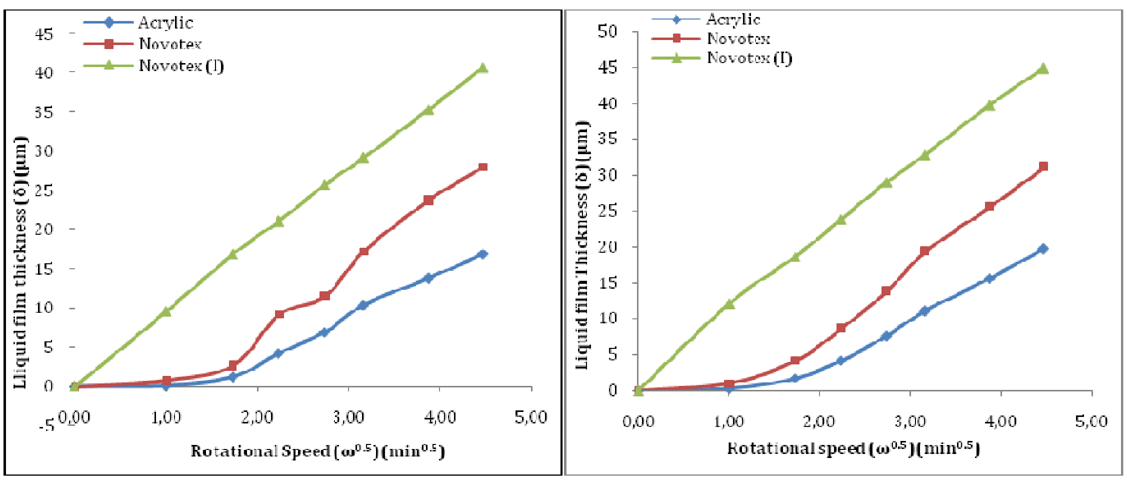


Figure 1. The Rotating Biological Contactor, that uses One Disc

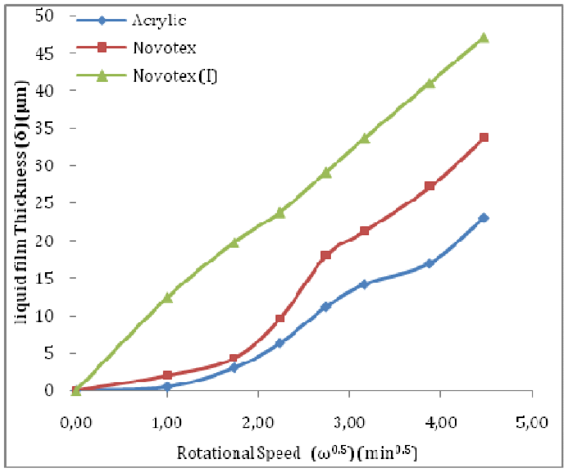
RESULTS AND DISCUSSION

In order to measure liquid film thickness on the flat surfaced disc, tested with using 3 materials to disk media that was exist in the market. Those three materials had different surface characteristic. The reason of choosing that plastic material, based on disk material analysis that was different from the literature [5,9,11]. Because every literature produced liquid film thickness result and different oxygen transfer value, in the temperature and same water characteristics.

Below, explained the influence of disk velocity component toward liquid film thickness on the flat surfaced disk (Figure 2).



(a) (b)

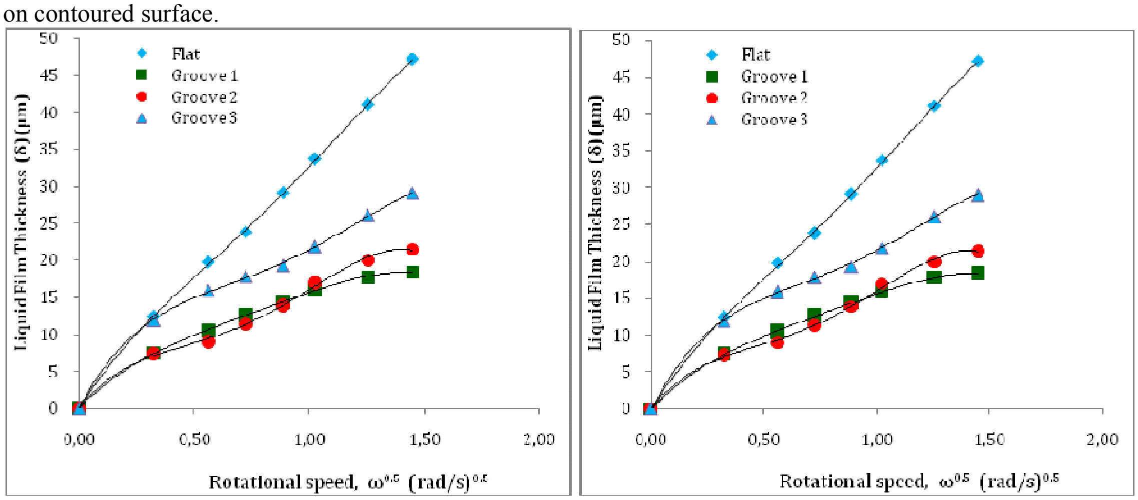


(c)

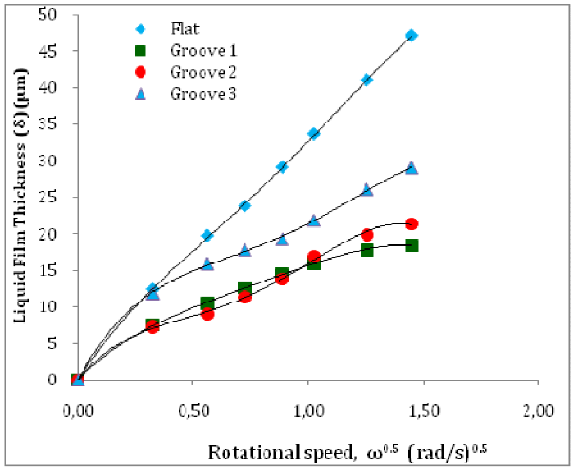
Figure 2. The relation between liquid film with $\omega^{0.5}$ in the flat surface of disk, in (a) H=0.07m; (b) H=0.063m; (c) H=0.025 m

Reviewed from the water depth variation from study result it was gained that liquid film thickness was in 39% depth in average, compared with other's depth, dominantly higher. This was also happened for material type variety, the experiment result showed that in gaining the result at the H=0.025 m, average liquid film thickness was highest.

After the experimentally research with the flat disc, it was found that the disc rotational speed factor and disc depth had took influence. So, the research was continued to evaluate liquid film thickness characteristic on contoured surface.



(a) (b)



(c)

Figure 3. Liquid film thickness on the contoured surfaced of disc (a) type radial patern with the same size width, (b) type radial patern with the different size width, (c) type radial patern with modification.

From Figure 3**,** it gained the liquid film thickness profile on the contoured disc surface towards rotational speed 1-20 rpm, from the research result was non linier, polynomial shaped. But for 1-10 rpm rotational speed, liquid film thickness phenomena on the contoured disc was linier, happened for all disk material. Highest Liquid Film thickness was on the contoured disc type three, with the lowest depth in H =0.07 m.

There were several things to compare liquid film thickness film on the flat disc with contoured disc, which were:

a. Liquid film thickness on the flat disc for material novotex I, thicker if compared with contoured disc.
b. But for novotex O material that had hydrophobic surface, at the low rotational speed (1 and 7.5 rpm) liquid film thickness on the contoured disc was still thicker if it was compared with flat surfaced disc.
c. In every disc depth, liquid film thickness on the contoured disc type radial patern with modification was thicker if it was compared with other contoured disc.

CONCLUSIONS

Liquid film thickness profile in single flat and RBC contoured disc from experiment's result, it was gained that in the 39% depth, on the flat surfaced disk, the liquid film thickness value was the highest. Meanwhile the contoured disc, liquid film thickness value was lower if it was compared with flat disc, with liquid film thickness value was the highest in 19.6% depth, rotational speed in 7.5-10 rpm, contoured disc type 3 and material type that was using hydrophilic.

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