Effect of Sparger Position for Solid Suspension in a Stirred Vessel Using Multiple Impeller

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Abstract
In this study, an experimental investigation was conducted to determine the effects of sparger position on Just Suspension Speed in multi-impeller stirred vessel. A cylindrical tank with 20cm diameter and 48cm liquid height and three Rushton Turbine impellers with 2D distance from each other were used. Experiments were conducted for a constant solid concentration of 10 wt% and superficial gas velocity ranging from 1.6 mm/s to 10.6 mm/s. Ballotini particles, water and compressed air were used as solid, liquid and gas phases respectively. The solid suspension was determined by visual observation using Zwietering’s Method. A ring sparger was positioned in the lower, middle and top sections of the tank. The effects of sparger position on just suspended speed and power requirement will be presented in this work.

Keyword: Solid suspension, multiple impellers, just suspended speed, power consumption, Sparger position

1. Introduction
Three-phase stirred vessels are widely used in many industrial processes such as bioreactor, catalytic reactor and chemical process. Several researchers studied solid suspensions after introduction of just suspension speed by Zwietering, 1958 [1]. However, design parameters for a preferable solid suspension remain an open problem in engineering field [2]. Moreover, many researchers have reported that just suspended speed is higher when gas is present in the system [3-5]. It has been reported that the just suspended speed strongly depends on the superficial gas velocity as shown in equation (1).

\[ \Delta N_{js} = k Q \] (1)

Where \( \Delta N_{js} \) is \( N_{js0} - N_{js} \), \( k \) is a constant and \( Q \) is the superficial gas velocity.

Over the years, many researchers have conducted studies on different parameters such as sparger position, impeller type, off-bottom clearance and superficial gas velocity but most of the studies focused on single impeller system [5-10] with only a few studies conducted on multiple impeller
system [11-13]. This work aims to study the effects of sparger position on just suspended speed in a triple-impeller solid-liquid-gas system. The focus of this work is on determining influence of gas sparger position on just suspended speed. Operating at just suspension speed ensures that power consumption is not higher than is required.

2. Methodology
A flat bottomed cylindrical stirred tank of 0.20m internal diameter (T), was fitted with four identical 0.02m (T/10) baffles. A high liquid height to tank diameter (H/T) ratio of 2.4 was used. 10 wt% of ballotini ball with the size of 355-550 µm and density of 2313kg/m³, tap water and compressed air were used as solid, liquid and gas phase respectively. The superficial gas velocity were varies from 1.6-10.6 mm/s.

Three Rusthon turbines with diameter (D=T/3) and off bottom clearance of 0.07m and impeller spacing of 2D were used for all experiments. Three sparger positions were studied where the sparger was placed 2 cm below the top, middle and bottom impeller respectively.

The impeller agitation speed was measured by tachometer. Just suspended speed was determined by visual observation using Zwietering’s method, where the speed record was when there were no solid particles remaining at the bottom of tank for 1-2 s.

3. Result & discussion
3.1 Effect of superficial gas flow velocity
Figure 1 shows that the superficial velocity has significant effects on just suspended speed when the sparger is placed below the bottom impeller. The impeller speed had to be increased by nearly 30% to achieve new just suspended speed when superficial gas velocity increased up to 5.5mm/s. Moreover, the gas phase caused linear increase of just suspended speed with the increase of superficial gas velocity. However, the effects were insignificant when the sparger was placed below the middle and top impeller.

3.2 Sparger position
When the sparger was positioned below the bottom impeller, the presence of gas phase scattered the energy of the bottom impeller to suspend solids. Since solids always settling at the bottom of the tank, the bottom impeller plays a role in solid suspension. However, the presence of gas near the bottom impeller increased the work load of the bottom impeller.

Therefore, more energy or impeller speed was needed to suspend the solid and disperse the gas.

On the other hand, when the sparger was placed below the middle and top impeller, the effect of gas on the bottom impeller was averted. No or minimum gas dispersion was needed near the bottom impeller needed to suspend the solid while the middle and top impeller took the roles for gas dispersion. Less energy or impeller speed was therefore needed.
4. Conclusion
It was found that there were significant effects on just suspended speed when the sparger was positioned below the bottom impeller. The sparger positioned below the top and middle impeller reduced the required impeller speed by at least 30% when the superficial gas velocity was 5.5 mm/s at solid loading of 10 wt % by using triple impeller system.

5. Future Plan
Since the change of the sparger position has significant advantages in just suspension speed, a systematic study on other parameters such as gas holds up and power requirement will conducted to determine their possible effect on mixing performance. Studies on other parameters such as solid loading, particle size, sparger clearance from impellers, and effect of impeller type on just suspension speed will also be studied.

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7. References


