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The efficiency of the aeration process in airlift reactors with moving beds

Efektywność procesu napowietrzania w reaktorach barbotażowych ze złożem ruchomym

Abstract

The current work consisted of performing tests on the prototype airlift reactor, examining the efficiency of oxygenation in an airlift reactor equipped with an airlift pump and an additional nozzle to aerate and mix water in the tank. In particular, the objective was to find the optimal submergence of the nozzle which would allow achieving the best possible oxygenation of water with adequate lift efficiency. The testing was performed in two series: with a tank fully filled with water; with a tank filled with 80% water and 20% moving bed. The use of a moving bed with a high specific surface area significantly improved aeration conditions and decreased mixture flow velocity thus causing an increase of gas and liquid contact time. The research has shown the effect of nozzle position on the aeration and circulation conditions in the reactor.

Keywords: airlift reactor, aeration, moving bed

Streszczenie

Praca polegała na wykonaniu serii doświadczeń na modelu fizycznym prototypowego reaktora barbotażowego. Badano skuteczność natleniania wody w reaktorze barbotażowym wyposażonym w podnośnik powietrzny, zaopatrzony w dodatkowy króciec napowietrzający i powodujący cyrkulację cieczy w zbiorniku. Celem było znalezienie optymalnego zagłębienia króćca, które pozwoliłoby na osiągnięcie jak najlepszego natlenienia cieczy przy odpowiedniej wydajności podnośnika. Badania wykonano w dwóch seriach: dla zbiornika napełnionego wyłącznie wodą i dla zbiornika wypełnionego w 20% objętości złożem ruchomym. Zastosowanie złoża o dużej powierzchni właściwej znacznie poprawiło warunki napowietrzania, zmniejszyło prędkość cyrkulacji mieszaniny, co pozwoliło zwiększyć czas kontaktu cieczy i gazu. Badania wykazały wpływ położenia króćca na warunki tlenowe i cyrkulację mieszaniny w reaktorze.

Słowa kluczowe: reaktor barbotażowy, napowietrzanie, złoże ruchome

1. Introduction

Bubbling processes in the form of gas flows of bubbles can be found in many installations such as airlift reactors and airlift pumps [3, 5]. The latter are considered to be the simplest in terms of pump construction – these operate by transporting liquid through the creation of a significant difference between the densities of the liquid and gas-liquid mixture. The first commercial use of airlift reactors dates back to 1958 when Lamount [5] modified a gold ore flotation tank. Airlift reactors have found widespread use in chemical engineering and industrial biotechnology due to their unique construction and oxygenation of the reaction environment [5].

2. Airlift reactor constructions

Due to modification of bubble column of reactor there are two main types of air lift reactor constructions [5, 7]: a) with internal circulation of medium; b) with external circulation of medium. Four main hydrodynamic zones of airlift reactor can be distinguished [5]: I – riser zone, wherein gas-liquid mixture rises; II – downcomer zone, wherein a completely or partially degassed gas-liquid mixture falls; III – degas zone, wherein gas-liquid mixture degasses either completely or partially; IV – bottom zone.

3. Aeration of liquid-basics

Currently, the use of airlift reactors in biotechnology is very popular – it is, for example, successfully used in wastewater aeration. Methods can be found in various papers in the literature [3, 15]. Appropriate selection of technology, equipment and efficiency affects operating costs and process parameters [1, 2, 14, 15]. Oxygen capacity is a parameter that characterises the process of aeration – this is described by Borowski [2]. The main factors affecting oxygen capacity are temperature, salinity, and pressure [2]. To obtain an effective aeration process requires adjusting the amount of dosed air to comply with reactor parameters; appropriate bubble size; identification of the number of carriers which fill the reactor [2, 14]. Materials used for the production of carriers are mainly plastics with fibres that have a solid texture firm consistency. The selection of appropriate carriers influences the effectiveness of the aeration and treatment processes in bioreactors [6, 8, 9, 10]. Moving beds can occupy 20–70% of the reactor volume [11]. Many studies confirm the beneficial impact on aeration by using a moving bed in reactors [13]; due to the bed circulation effect and resistance to motion, it is assumed that a 60–70% fill is the maximum value [9, 10, 12].

4. Subject matter and methodology of laboratory tests

Laboratory tests were performed on a physical model located in the water laboratory of the Department of Hydraulic Engineering. The subject matter of the research was a physical model of a prototype airlift reactor. The efficacy of water oxygenation in an airlift reactor that was equipped with an airlift pump with a diameter of 50 mm was studied – this included use of an additional nozzle that aerates and circulates water in the tank. The purpose of the study was to find the optimal degree of submergence of the nozzle which would allow achieving the best possible oxygenation of water with adequate lift efficiency. The test was performed in two series: tank fully filled with water; tank filled with 20% moving bed and 80% water, by volume. Before the measurements were taken, water was deoxygenated using sodium sulfate. Additionally, measurements of dissolved oxygen concentration, for various levels of water in the tank (Hs from 40 to 50 cm) and for the various position of the nozzle (H = 34 cm and H = 84 cm), were performed using a Hach Lange LDO optical oxygen sensor with HQ40d multimeter. The measurements were taken at 10-minute intervals [4]. The scheme of the installation is shown in Fig. 1.

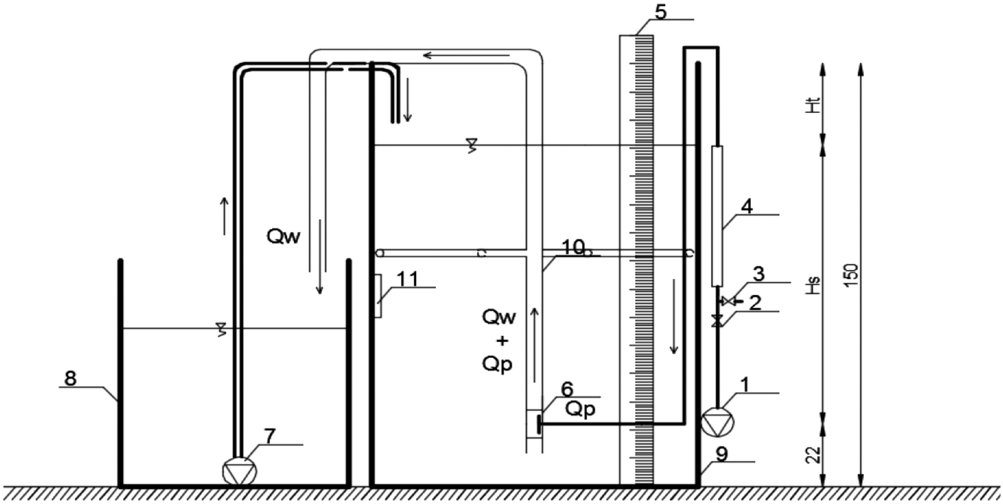

Fig. 1. Schematic of the installation: 1 – air blower; 2 – control valve; 3 – blow-off valve; 4 – rotameter; 5 – scale; 6 – diffuser; 7 – rotodynamic pump; 8 – recirculation tank; 9 – main tank; 10 – air lift pump with nozzle; 11 – hydrostatic liquid level sensor

5. The results of laboratory tests

The results of laboratory tests are presented in graph form in Figs. 2 & 3 for various levels of water in the reactor and for both positions of the nozzle. The most favorable oxygen condition was obtained for settings with nozzle position H = 84 cm and 20% fill of the moving bed (Fig. 2).

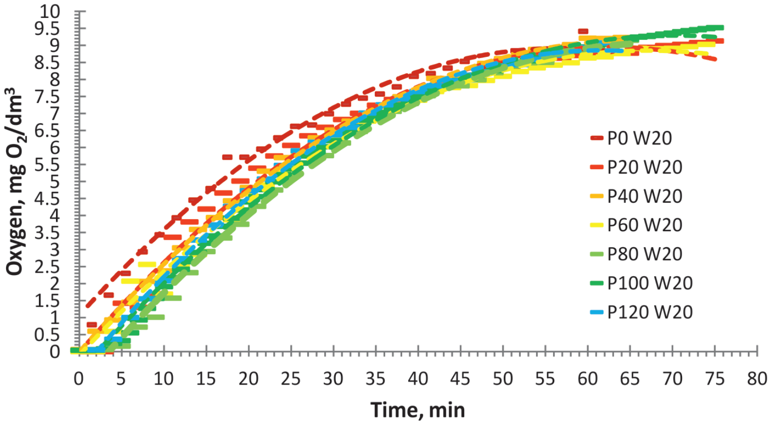

Fig. 2. Graph of the dissolved oxygen concentration in the reactor. Nozzle position H = 84 cm, 20% fill of moving bed

From the raw data, average values of dissolved oxygen concentration were calculated for the four variations of reactor construction (H = 34 cm, 0% fill; H = 34 cm, 20% fill; H = 84 cm, 0% fill; H = 84 cm, 20% fill) with measurements obtained at 10-minute intervals. A graph of average values of dissolved oxygen concentration is shown in Fig. 3.

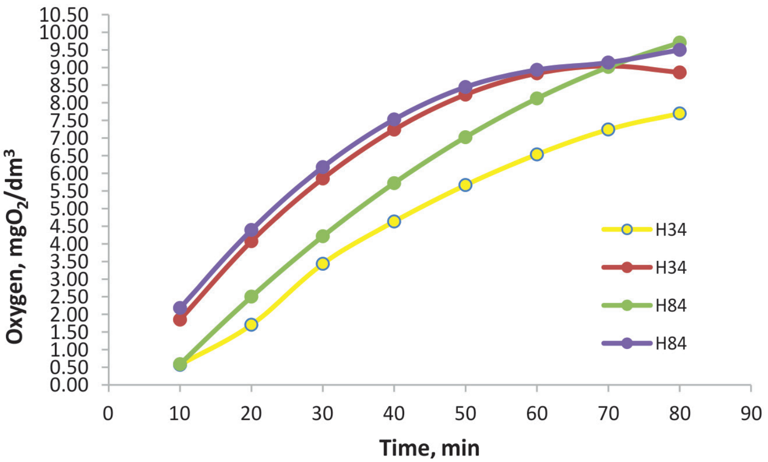

Fig. 3. The average value of dissolved oxygen concentration in the reactor. Nozzle position H = 34 cm, 20% fill of moving bed

6. Conclusions

The purpose of the study was to determine the effectiveness of an airlift reactor equipped with an airlift pump and an additional nozzle that aerates and circulates water in the tank. The results of this research indicate that:

- the use of a moving bed improves oxygen conditions in both reactor constructions – this is caused by the extended contact time of liquid and gas, and the high specific surface area of the bed;
- based on analysis of the impact of the nozzle position on aeration and circulation in the reactor, oxygen conditions in the construction with the nozzle located at a height of 84 cm are more favourable than in the construction with the nozzle at height of 34 cm – this was possibly caused by locating the nozzle in the middle of the tank with regard to height;
- for both constructions (H = 34 cm and H = 84 cm) and both filling levels (0% and 20%), there are three hydrodynamic zones (upper, central, bottom); the size of the first two zones is dependent on the position of the nozzle;
- the use of moving bed, which accounted for 20% of the volume of the reactor, caused a significant non-linear resistance – this reduced the output of the airlift pump for both of the constructions by an average of 20%.

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