TECHNICAL SCIENCES
Abbrev.: Techn. Sc., No 10, Y 2007

DOI 10.2478/v10022-007-0001-9

STUDY OF NEGATIVE PRESSURE IN SUCTION PROPELLER AND TUBE AGITATORS

Anatoliy Molchanov, Andrzej Wróblewski

Department of Environmental Engineering
University of Warmia and Mazury in Olsztyn

Key words: suction agitators, negative pressure, velocity, intensity.

Abstract

The paper presents the results of studies on negative pressure generated in propeller and tube agitators. The value of negative pressure depending on the number of agitator revolutions $n‹5000$ min^{-1} under conditions of the turbulent area (Reynolds number $Re_m ‹ 2 \cdot 10^5$) was determined.

BADANIE PODCIŚNIENIA W MIESZADŁACH SAMOZASYSAJĄCYCH ŚMIGŁOWYCH I RURKOWYCH

Anatoliy Molchanov[1], Andrzej Wróblewski[1]

Katedra Inżynierii Środowiska
Uniwersytet Warmińsko-Mazurski w Olsztynie

Słowa kluczowe: mieszadła samozasysające, podciśnienie, prędkość, natężenie.

Streszczenie

Przedstawiono wyniki badań podciśnienia, które powstaje w mieszadłach samozasysających – śmigłowym i rurkowym. Określono wielkości podciśnienia w zależności od liczby obrotów mieszadła $n‹5000$ min-1 w warunkach obszaru turbulentnego (liczba Reynoldsa $Re_m ‹ 2 \cdot 10^5$).

Introduction and goal of the study

In the processes of biological wastewaters treatment aeration is applied to supply oxygen for aerobic microorganisms and for oxidation of organic compounds. Aeration is also used in various configurations during water preparation processes. Aeration with appropriate compression devices at ca. 0.15 MPa through diffusers or porous plates is commonly used. Such installations are complicated and costly and, as a consequence, it was proposed to apply suction agitators with turbine agitator in modern treatment plants and in chemical industry (KARCZ 2001, BŁASIŃSKI et al. 1991, KOWAL 2001). Such agitators create the radial stream of gas-liquid medium and do not cause uplifting the microorganic sediment from the bottom. Additionally, during the process of mixing air with water in turbine agitator air bubbles of large diameters are formed, which contributes to small contact surfaces between water and air. It is known (AKSIELRUD 1981, LEWICKI 1999) that the speed of mass exchange between the gas bubbles and the liquid increases with increasing the own surface of contact between phases (m^2/m^3) and the speed of sliding of the bubbles in the liquid. There is a possibility of creating conditions for intensification of mass exchange (absorption of air oxygen) through movement of agitator blades with orifices on the surface through which the air is sucked. Under such conditions gas bubbles smaller in diameter than the bubbles formed in the turbine agitator are torn off the rotating surface.

This study aimed at investigating the dependence of negative pressure ΔP on agitator blade surface with orifices and at the end of the tubes of the tube agitator from the revolutions frequency. That negative pressure provides the base for computation of the sucked air velocity W, its flow intensity Q and agitator immersion depth H (KOCH 1998):

$$W = \sqrt{\frac{2\Delta P}{\varsigma}}\text{, m/s} \tag{1}$$

$$Q = \frac{\pi d^2}{4} W\text{, m}^3\text{/s} \tag{2}$$

$$H = \frac{\Delta P}{\varsigma g}\text{, m} \tag{3}$$

where:
d – diameter of suction orifice, m/s^2;
g – acceleration of gravity,
ς – air density, kg/m^3

In case of suction agitators at a depth exceeding the H value the air is not sucked and that is why computing the H value from formula (3) on the basis of ΔP determined experimentally is so important. Computing the Q value from formula (2) is needed for computation of technological quantities of oxygen sucked from the air (LEWICKI 1999).

Selection of agitator types and experimental parameters

The above information indicates that testing the triple blade propeller agitator designed by the Kiev Institute of Technology (KOWAL 2001), that assures movement of the liquid towards the tank bottom raising the active sediment containing microorganisms would be helpful (Fig. 1a).

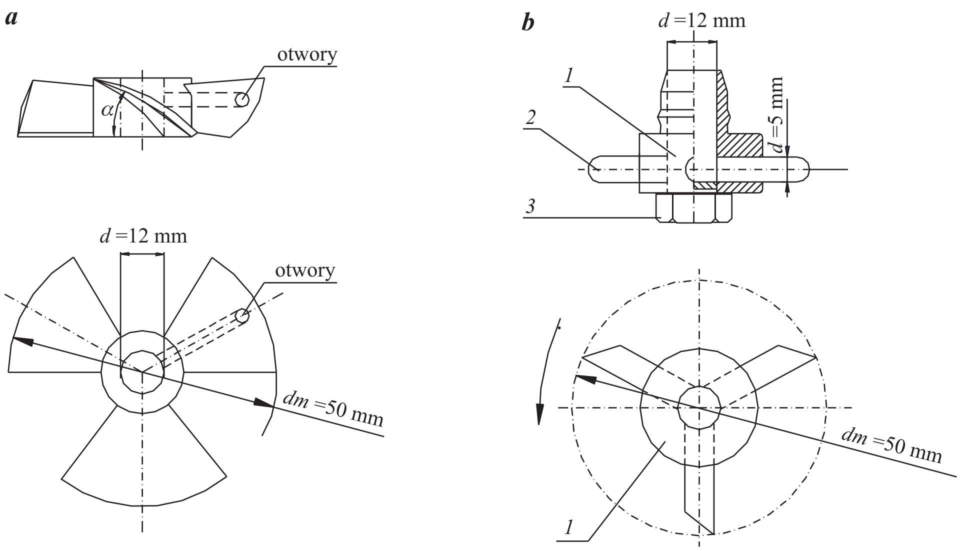

Fig. 1. Scheme of propeller agitator a) and tube agitator b) *1* – casing, *2* – tube, *3* – screw

The diameter of that agitator is d_m= 50 mm. At high revolutions (n<5000 min^{-1}) such an agitator secures generating a turbulent zone, which is generally applied (KOCH, NOWORYTA 1998, HEIM et al. 1995) with Re_m:

$$\mathrm{Re}_m = \frac{n d_m^{\ 2}}{\nu} \leqslant 2 \cdot 10^5$$

where:
ν – kinematical viscosity coefficient, m^2/s,

The study by HEIM et al. 1995 presents the results of studies on tube and disk suction agitators. The oxygen volume penetration coefficient was calculated showing practically equal effectiveness of those agitators. The rube agitator, however, is simpler and cheaper. That is why the triple tube agitator with the diameter d_m = 50 mm was chosen.

Description of the laboratory station and the methodology of experiments

The diagram of the laboratory station is presented in Figure 2. It consisted of a tank in which the agitators in the form of perforated cone or with triple blade agitator with the diameter d_m = 50 mm were mounted (MOLCHANOV 2003).

Electric motor (*1*) is connected through the clutch (*2*) with the shaft (*3*) that is installed on bearings in the case with a flange. The water container

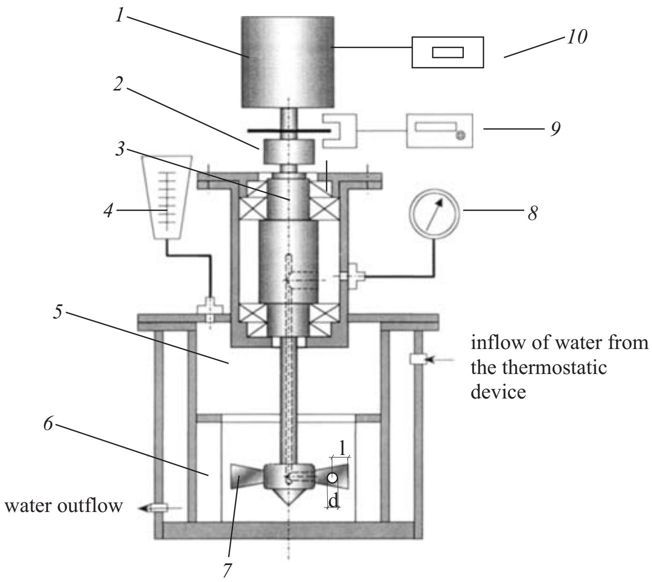

Fig. 2. Diagram of the laboratory test station for the propeller agitator *1* – motor, *2* – clutch, *3* – shaft, *4* – container, 5 – tank, *6* – fins, *7* – propeller agitator, *8* – vacuum meter, *9* – tachometer, 10 – power meter

is made of stainless steel. It possesses a mantle to which a thermostatic device is connected. The propeller agitators are operated at high speeds and as a consequence they can operate without reduction or belt couplings. At high rotation speeds of agitators a funnel forms, which can uncover the entire propeller. In this case the power demand decreases, the suction of air starts and the mixing effectiveness decreases rapidly. To avoid funnel formation 4 fins are mounted on the walls of the tank (*6*). The pressure behind the blade is measured using the vacuum meter (*8*), the revolutions frequency with a tachometer (*9*) and engine power with a wattmeter (*10*).

The methodology of the experiment involves measurement of negative pressure ΔP at various revolutions frequencies of the agitator n. The gases dissolved in the liquid were sucked through the orifices in agitator blades and they accumulated in the container (*4*), from which the water was going to the tank (*5*). Water from the tank (*5*) was filling the lidded container (not shown in Figure 2).

Results and analysis of experiments

The average results from three tests are presented in table 1.

It was determined experimentally that the negative pressure ΔP on agitator blade increases with the increase of propeller and tube agitator

Table 1

Dependence of negative pressure ΔP on revolutions frequency of studied agitators

No.	n min^{-1}	ΔP, KPa for agitators	
		propeller agitator	tube agitator
1	1000	2,5	–
2	2000	15	10
3	3000	27	35
4	4000	35	46
5	5000	38	50

revolutions frequency. On the basis of the determined value of negative pressure ΔP increase the velocity of air sucked and the intensity of its flow Q as well as the agitator immersion depth H can be computed.

Conclusions

On the basis of the examination of negative pressure that is generated in suction propeller and tube agitators:

– a method for computing the immersion depth H for those agitators on the basis of the experimentally determined value of negative pressure ΔP was developed;

– the value of negative pressure depending on the revolutions of the agitator n < 5000 min^{-1} under the turbulent zone conditions (Reynolds number $Re_m = nd_m^2/\nu < 2 \cdot 10^5$) was determined;

– it was concluded that although the tube agitator is simpler and cheaper, it creates a radial stream and as a consequence application of a combination of two agitators on a single shaft: at the top an ordinary propeller agitator that forms the vertical stream and a suction tube agitator under it, seems rational.

References

Aksielrud G., Molchanov A. 1981. *Rozpuszczanie ciał stałych*. WNT, Warszawa.

Błasiński H., Michalski H., Rzyski E., Stelmach J., Urbanowicz T. Pat. Polski nr 148476, 1991.

Heim A., Rzyski E., Stelmach J. 1995. *Mieszanie z napowietrzaniem. Mieszadła samozasysające.* Inżynieria i aparatura chemiczna. 2: 20–22.

Karcz J. 2001. *Mieszanie układu ciecz-gaz w aparatach z mieszadłem szybkoobrotowym*. Inżynieria i aparatura chemiczna, 1: 3–13.

Koch R., Noworyta A. 1998. *Procesy mechaniczne w inżynierii chemicznej.* WNT, Warszawa, p. 514.

Kowal O. 2001. *Wpływ kawitacji na charakterystyki reologiczne i hydrauliczne potęgowych płynów nienewtonowskich.* Autoreferat pracy doktorskiej, Politechnika Kijowska, Kiev.

Lewicki P., Lanert A., Kowalczyk R., Połacka Z. 1999. *Inżynieria procesowa i aparatura przemysłu spożywczego*. WNT, Warszawa, p. 468.

MOLCHANOV A., WIŚNIEWSKA A., WRÓBLEWSKI A., JACHNO O., KOWAL O. 2003. *Badanie podciśnienia na łopatce samozasysającego mieszalnika śmigłowego do aeracji wody i ścieków.* Referaty VI Konferencji Naukowo-Technicznej „Aktualne problemy naukowo-badawcze budownictwa", Olsztyn – Kortowo, pp. 241–244.

Accepted for print 26.04.2007