Microbubbles: properties, mechanisms of their generation - and applications in producing biofuels from algae

Václav Tesař
Institute of Thermomechanics v.v.r.
Academy of Sciences of the Czech Republic
Prague, Czech Republic
e-mail: tesar@it.cas.cz

Lecture 1:
Microbubbles: importance and generation method

Many chemical and biochemical engineering processes use gas bubbles dispersed in a liquid. A typical case is wastewater treatment depending on providing oxygen to bacteria that decompose the wastes. Another case is cultivation of unicellular algae expected to producing food and fuels, dependent on transfer of CO_2 needed for photosynthesis. It is desirable to use bubbles as small as possible having a large total transfer surface for a given gas volume. Simultaneously also increased is the time available for the transport, due to rapid decrease of the bubble ascent velocity with diminishing size. Particularly attractive are sub-millimetre *microbubbles*. They can, perhaps somewhat surprisingly, exhibit physical behaviour qualitatively different from that of larger-sized bubbles [1]. Attractive advantages offered were until recently employed less than they deserve because available methods of generating microbubbles tended to be rather inefficient. The seemingly simplest method – percolating the gas through an aerator having a large number of small parallel exit channels fails because of microbubbles growth by conjunctions due to their slow mobility [2, 4]. Also the shape oscillation [3] following a conjunction is a factor in the process. A promising solution was found [3, 5, 6, 7] in pulsating the supplied gas flow, using fluidic oscillators – simple devices essentially consisting of nothing more than a specially shaped gas inlet [8, 9, 10]. While inexpensive and not extracting much energy from the gas flow, the fluidic oscillators are also maintenance-free and robust. Due to absence of any movable and/or deformed mechanical components, they can reach high pulsation frequency, are maintenance-free, and their life is practically unlimited.

Lecture 2:
Microbubbles in photobioreactors

Our civilisation is based upon availability of cheap fossil crude oil for transporting people and goods. Price is rising, sources being limited – and existing mostly in politically unstable regions. A solution is sought in producing biofuels from simplest unicellular plants, algae [11, 12, 13] . After all, fossil crude oil was formed by anaerobic decomposition from microalgae ancestors [14]. In contrast to use of photosynthesis in higher plants, algae exhibit an unrivalled speed of growth – the doubling time of exponential mass production is mere 3.5 hours under optimal light conditions. Moreover, algae as the source are sustainable, renewable, can use waste water as the growth medium and remove from the atmosphere the CO_2 generated by man-made combustion processes. Suitable technologies were for algal cultivation and processing were already demonstrated, but tend to be expensive. The rather promising goal of independence on existing fossil fuel sources necessitates further development the techniques to make all aspects (beginning from choice of suitable algae species and ending with petrochemical conversion processes) much less expensive. Supplying of CO_2 into water by microbubbles in photobioreactors may be one of those many important development steps towards the fundamental change in world politics.

References

[1] Zimmerman W. B. et al. : „*Evaporation dynamics of microbubbles*“, Chemical Engineering Science, Vol. 101, p. 865, 2013

[2] Tesař V.: “*Mechanisms of fluidic microbubble generation Part I: Growth by multiple conjunctions*”, Chemical Engineering Science, Vol. 116, p. 843, 2014

[3] Tesař V.: “*Shape oscillation of microbubbles*”, Chemical Engineering Journal, Vol. 235, pp. 368-378 , 2013

[4] Tesař V.: “*Mechanisms of fluidic microbubble generation Part II: Supressing the conjunctions*”, Chemical Engineering Science Vol. 116 , p. 849, 2014

[5] Zimmerman, W.B., Tesař, V. , Butler, S., Bandulasena, H.C.H.: „*Microbubble Generation*” , Recent Patents on Engineering, Volume 2, Issue 1, January 2008, Pages 1-8

[6] Zimmerman W.B., Hewakandamby B. N., Tesař V., Bandulasena H.C.H., Omotowa O. A.: „*On the design and simulation of an airlift loop bioreactor with microbubble generation by fluidic oscillation*“, Food and Bioproducts Processing, Vol. 87,p. 215, 2009

[7] Zimmerman W.B., Tesař V., Bandulasena H.C.H.: „ *Towards energy efficient nanobubble generation with fluidic oscillation*“, Current Opinion in Colloid & Interface Science, Vol. 16, pp. 350 – 356, 2011

[8] Raghu S.: „*Fluidic oscillators for flow control*“, Experiments in Fluids, Vol. 54, p. 1455, 2013

[9] Gregory J. W., Tomac M. N.: „*A review of fluidic oscillator development and application for flow contro“l*, 43rd Fluid Dynamics Conf., Code 99250, 2013

[10] Tesař V., Hung C.-H., Zimmerman W. B. J.: „*No-moving-part hybrid-synthetic jet actuator*, Sensors and Actuators“, A: Physical, Vol. 125, p. 159, 2006

[11] Mata T.M., Martins A.A., Caetano N.S.: „ *Microalgae for biodiesel production and other applications: A review*“, Renewable and Sustainable Energy Reviews, Vol. 14, p. 217, 2010

[12] Milledge J.J: „*Energy balance and techno-economic assessment of algal biofuel production systems*“, University of Southampton, Water and Environmental Engineering, PhD Thesis, August 2013

[13] “Biofuels from Algae”, editors Pandley A., Lee D.-J., Chisti Y., Soccol C. R., 338 pages, Publ by Elsevier, 2014

[14] Kvenvolden K. A. : "*Organic geochemistry – A retrospective of its first 70 years*". *Organic Geochemistry* Vol. 37, p. 1, 2006

[15] Tesař V.: “*Microbubble smallness limited by conjunctions*”, Chemical Engineering Journal, Vol. 231. p. 526, 2013