P.36: Determination of Oxygen Equilibrium and Mass Transfert in Water During an High Frequency Ultrasonic Irradiation

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In chemical industry and more largely in all chemical or physical processes, unitary operations are defined and controlled by equilibrium laws acting as determining forced. Every system will tend to move towards its equilibrium by mass or heat transfer at a given kinetic rate, and the starting point is of primary importance. Then any disturbance or even changes in state variables have to be evaluated.

This is particularly applicable sensible for so-called sonochemical reactors, which use power ultrasound in a wide variety of processes for chemical and allied industries. They include cleaning and decontamination, extraction and impregnation, crystallization and precipitation and to a greater or lesser extent electrochemistry. In the majority of cases, some examples of large scale use of sonoreactors are still valid, but generally, design is based on "intuition", and the results quoted in yield are impossible to predict. Indeed, only rarely have attempts been made to design in detail a sonoreactor [Soong et al 2006, Hihn et al 2000, Viennet et al 2009]. For many authors, the necessity to take care of the scale-up aspects is acknowledged, but most of the time this only concerns the cavitation activity and intensity, using solutions based on bubble dynamics equations as well as experimentation with different reactor types and reactions. Design correlations for collapse pressure and their relation to cavitational yield should assist designers in choice of the operating parameters for a desired cavitational effect [Gogate et al 2004]. In the meantime, it cannot be dissociated from the techniques useful for good understanding of cavitational activity distribution [Sutkar et al 2009]. Cavitation is the phenomenon with the most important effect for intensification of physical and chemical processing. However, even after a complete study of dynamic behavior of cavitation, this specificity creates problems in proposing reliable design.

Therefore, the analysis of the behavior of a reference system such as oxygen in water and air was carried out and is the focus of the present work.

The aim of this work was to observe the influence of ultrasound on the oxygen concentration in water under atmospheric exposure and the volumetric mass transfer coefficient k_La as well as the influence of oxygen and sodium sulfite on the quantity and location of sonochemiluminescence in a system.

1. Materials and methods

Frequency generator: "Agilent® 33220A" frequency generator was used

Signal amplifier: To reinforce the generated frequency the "Amplifier Research® Model 150A100B" was used.

Power meter: To measure the transmitted power of the ultrasound transducer the power meter NRVD from Rohde&Schwarz® was used. It allow to keep the transmitted power at a constant level even if temperature of the transducer change.

Ultrasound transducer: For the production of ultrasound a self-made ultrasound transducer with a frequency of 500 kHz was used.

Oxygen Sensor and Measuring System: The heart of every experimental arrangement was the oxygen sensor with the measuring system. O_2 measurements had been done by the oxygen sensor "DurOx 325".

Chemical Reactions that are taking part in the reactor:

$$Na_2SO_3 \longrightarrow 2Na^+ + SO_2^- \tag{1}$$

$$SO_3^{2-} + \frac{1}{2}O_2 \longrightarrow SO_4^{2-} \tag{2}$$

Assuming a reactor filled with water, having a constant influx of oxygen, perfectly mixed, so that the concentration of oxygen is the same in every part of the reactor, and then adding a certain amount of sodium sulfite, the O_2 in the reactor will start to react with the Na_2SO_3, creating SO_4^{2-}. After a short period of time all the oxygen in the water is consumed. The incoming oxygen keeps on reacting with the sulfite until there is no sulfite left. Now the oxygen concentration starts to rise again until the original level is reached. The period of time between the reaction of O_2 in the water with the Na_2SO_3 and the fresh accumulation is called the *steady state regime* t_{ST}.

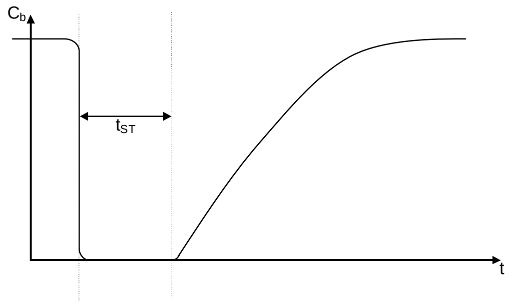


Figure 1-a: C_b-t diagram: Steady State Regime

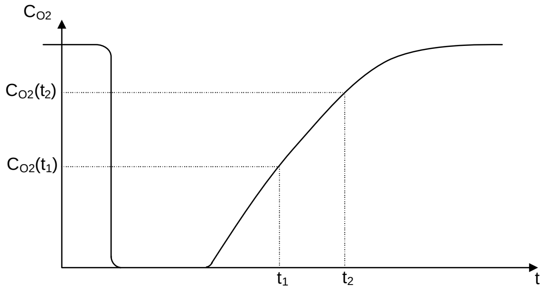
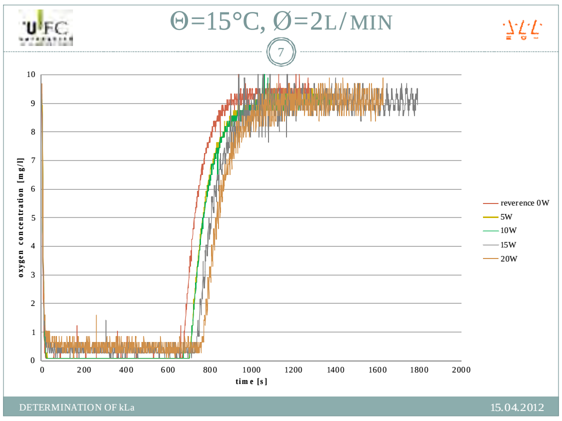


Figure 1-b: C_b-t diagram: Transitory Regime

The experiment was carried out at five different ultrasonic power levels (including 0W as a reference), two different oxygen flow rates and two different temperatures. The volumetric mass transfer coefficient was also evaluated.

2. Results and discussion

The experiments on the ultrasonic's influence on the oxygen concentration showed, that at 500KHzand for weak transmitted power levels, there is no strong decrease in concentration of oxygen which can be linked directly to the occurrence of acoustic cavitation within the reactor.



Θ=15°C, Ø=2L/MIN

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The reason why the decrease is only visible at high power levels is that at lower power less cavitation is being produced in the acoustic sound field. It also can be seen, that the decrease in concentration is higher at lower temperatures because cold water saturates more oxygen than warm water. This allocates more oxygen that can be degassed by the acoustic cavitation. These results show that the measurement of SL or SCL at high frequencies is not perturbed by the oxygen concentration.

References

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