論文の内容の要旨

論文題目　Water treatment using cavitating flow
(キャビテーション流れによる水処理)

氏名　Hoseyn SAYYAADI

Abstract:

Pollution in drain water or water resources is a serious environmental problem nowadays. Its quality has been declining over the years due to pollution from industries, agricultural activities, and amount of domestic wastes due to ever-increasing population. There are many efforts to reduce the pollutants in water.

One effort is trying to force harmful molecules to take apart in chemical reaction and oxidizing them into harmless or less toxic molecules. Indeed, such oxidation processes are corresponding to reaction at high temperature. Cavitation is one of known method to provide such temperature required for oxidation phenomenon. Chemical reaction, which is activated by cavitation phenomenon, is called "cavitation reaction". Cavitation, which is implemented for chemical reaction can be formed in hydrodynamic way or by emitting ultrasonic wave into liquid media. Hydrodynamic cavitation flow is term used for that kind of cavitation in which flowing of liquid through narrow passage or flow conduit and corresponding pressure drop below a critical value is responsible for activation of suspended nucleolus to grow explosively. Hence," Hydrodynamic Cavitation Reaction Flow" implies that cavitation which is formed by hydrodynamic ways is utilized for chemical reaction. Two kinds of hydrodynamic reactors are generally used for chemical reaction enhancement by cavitations. These kinds are Venturi tubes & Orifices.

In this research, "experimental study of hydrodynamic cavitation of venturi type for chemical reaction of water solutions" will be studied. At the first stage, hydrodynamic cavitation reactors of single and tandem-venturies types for water treatment purpose have been designed based on presented one-dimensional analytical approach. The idea of using tandem-venturies has been developed for augmentation of chemical reaction effect. It has been shown analytically that this type of venturi can be encountered with higher potential for chemical reaction effect. An experimental setup for implementing single venturi and tandem-venturies has been designed and constructed. The geometry of proposed test section (venturies) for constructed

experimental setup was obtained from a computer code, which is written based on one-dimensional analytical approach. At the next stage, cavitation flow in single and tandem-venturies has been studied. It has been shown that decreasing cavitation number (increasing inlet pressure or decreasing backpressure) leads to increasing of cavitation size in single venturi or down stream venturi of tandem arrangement. In addition, choked flow rate and system pressure loss are also increased for both single and tandem-venturies. The light intensity comparison technique has been used for cavitation size measurement in each case. The results show reasonable agreement between experiment and one dimensional theory for predicting average flow parameters such as cavitation size, flow rate, system pressure loss, and etc for design purpose of reactor. Moreover unsteady behavior of cavitation flow which is missed in theoretical approach is studied experimentally. Therefore, unsteady fluctuation of cavitation flow has been studied using high-speed photography and light intensity comparison technique. Then fluctuation frequencies and amplitudes have been obtained and frequencies components have been filtered by Fast Fourier Transform (FFT) method for de-noising. Eventually fluctuation patterns have been modeled with sinusoidal polynomial successfully. The results show that, frequency of fluctuation increases while cavitation number decreased. Amplitude of fluctuation decreases when cavitation number decreases from higher cavitation numbers to moderate numbers and then increases again as cavitation number decreases further from moderate values to lower cavitation numbers. It has been shown that operating pressure has minor effect on frequency and amplitude of fluctuation in comparison with major effect of cavitation number. It has been observed experimentally that at lower cavitation numbers, separation, shedding and collapsing of cloud-like cavities due to re-entrant jet mechanism is responsible for fluctuation. Eventually friction factor and diffuser loss coefficient of proposed venturi has been evaluated.

At the final stage of this research, hydrodynamic cavitation reaction mechanism has been studied for two groups of VOCs (Volatile organic compound) and non-VOCs substances. Methanol as a representative for first material group and m-Coloro Phenol and Nonyle Phenol for second category have been chosen. Chemical decomposition effect for methanol has been evaluated from effect of reaction products on solution PH. Gas chromatography method has been used for monitoring of Phenols decomposition during experiment. Since in the case of VOCs, reaction site is in gas phase region of collapsing cavities, solutes molecules incorporate directly in Pyrolysis reaction takes place in harsh conditions inside collapsing cavities. Therefore, reasonable chemical reaction rate has been observed in this case. It has been shown that decreasing cavitation number and/or increasing operating pressure, can intensify rate of chemical reaction.

For non-VOCs groups, since chemical reaction site is in bulk liquid or in thin liquid interfacial region around cavities, solute molecules do not take apart in direct chemical reactions arise in collapsing cavities. In fact, hydroxyl radicals, which are generated in Pyrolysis reaction of water molecules in gas phase, are responsible for chemical degradation of non-VOCs molecules. It has been shown that in this case, the rate of reaction is not significant at high and moderate cavitation number and it is very low at low cavitation number. The idea of using CAV-OX reactors is developed in this thesis in order to compensate low effectiveness of hydrodynamic reactor in handling with non-VOCs substances. Hydrogen peroxide as an oxidizer agent has been injected in experimental system. It has been shown that this modification bring reasonable reaction rate for decomposition of non-VOCs. Increasing injected amount of H_2O_2, shortening of injection time and decreasing cavitation number, all can rectify chemical reaction rate. Moreover, it has been shown that amount of injected H_2O_2 has major effect on rectifying chemical reaction rate compared to cavitation number.

Eventually, hydrodynamic cavitation reactor was assessed from energy consumption point of view for specific amount of decomposition. It has been found that increasing amount of injected oxidizer and shortening of injection duration lead to increasing in decomposition efficiency. Moreover, it has been shown that decreasing cavitation number and/or increasing operating pressure can improve decomposition of VOCs. However, it has been found that for non-VOCs, these parameters have reverse effect on decomposition efficiency than what observed in VOCs case, because of the reverse effect of these parameters cannot be compensated with positive effect of acceleration of chemical reaction rate.