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"A REVIEW ON HYDRODYNAMIC CAVITATION"

A noble approach for waste water treatment.

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Abstract *— Waste water treatment is practiced using a number of physical, physico-chemical and biological methods of treatment. Quality of waste water can be defined by the presence various biodegradable and non-biodegradable pollutants, out of which Chemical Oxygen Demand (COD) has been considered as one of the major pollutants in the industrial effluent.*
In order to achieve desired level of COD reduction, numbers of conventional processes are available but because of their low efficiency these processes are nowadays being replaced by advanced oxidation processes (AOPs). Different AOPs such as Fenton, electro-Fenton, and electro-oxidation etc. have been observed to give better results in terms of COD reduction but at the same time they are associated with other operational restrictions such as huge chemical requirement and excessive sludge generation.
Hydrodynamic cavitation has emerged as promising technology for COD reduction as it does not require chemicals and sludge generation is also very less in this process. This process results in sudden drop and increase of pressure in a liquid, which creates cavities and bubbles followed by sudden and violent collapse. This process results in generation of shock waves leading to generation of hydroxyl free radical. This hydroxyl free radical causes the development of localized forces which have destructive effects on the solids in dispersions, emulsions and slurries affecting particle size and distribution resulting to reduction in COD.
Therefore, through this review paper an attempt will be made to combine hydrodynamic cavitation with one on the AOP so that on the one hand, overall efficiency of the COD removal can be improved and on the other hand, chemical requirement and sludge generation can be reduced.

Keywords - Hydrodynamic Cavitation, Advanced Oxidation Process (AOPs), COD removal.

I. INTRODUCTION

Chemical Oxygen Demand (COD) is one of the major pollutants in the industrial effluent. In order to achieve desired level of COD reduction, numbers of conventional processes are available such as physical, chemical, biological process. In case used of chemical process, chemical consumption and capital cost is high. Biological processes take more time and generate high sludge. Hydrodynamic cavitation has emerged as promising technology for COD reduction as it does not require chemicals and sludge generation is also very less in this process.. If hydrodynamic cavitation process is use alone it gives less efficiency. In order to achieve desired level of COD reduction, number of conventional processes is available but because of their low efficiency these processes are nowadays being replaced by advanced oxidation processes (AOPs).

1. Cavitation

Cavitation can be simply defined as a physicochemical process employing oxidation mechanism coupled with physical breakage or thermal decomposition using cavitating device for degradation of chemical species. [2]
Cavitation is usually divided in to two classes of force behavior:

1) Inertial Cavitation
2) Non Inertial Cavitation

Inertial Cavitation: Inertial Cavitation is the process where void or bubble in a liquid rapidly collapses, producing a shock wave. Inertial cavitation occurs in control valves, pumps, impellers and propellers.
Non Inertial Cavitation: Non Inertial Cavitation is the process in which a bubble in a fluid is forced to oscillate in a size or shape due to some form of energy input, such as an acoustic field. Such Cavitation is often employed in ultrasonic cleaning baths and can also be observed in pumps, propellers, etc.

Vapour bubbles occurs due to following condition.
1) The pressure of the liquid is lower than the vapour pressure. (A change from the liquid state to gaseous state is known as vaporization. (Depends pressure and temperature.) These accumulated vapors exert a pressure on the liquid surface this known as vapour pressure. In other word we can say the pressure at which the liquid is converted in to vapours.)
2) In a region of higher pressure sudden collapse of vapour bubbles

Flow chart of cavitation with classification. [2]

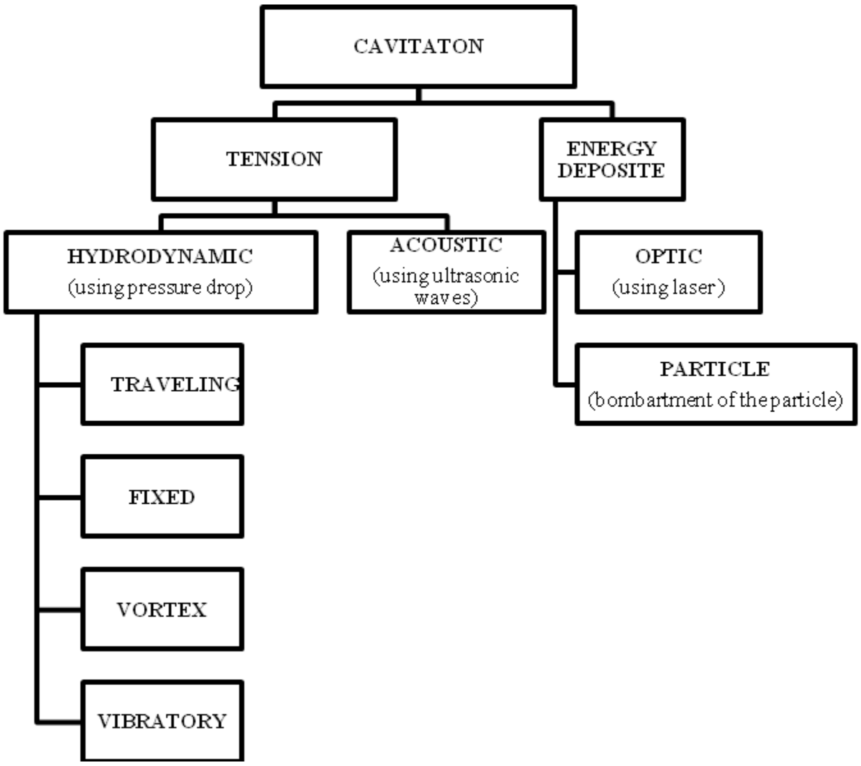

Figure: 1 Classification of cavitation

1.1 Tension cavitation:

Cavitation is the process of formation of voids and clouds of bubbles in liquids under tension [18].

1.1.1 Hydrodynamic cavitation

This process results in sudden drop and increase of pressure in a liquid, which creates cavities and bubbles followed by sudden and violent collapse. This process results in generation of shock waves leading to generation of hydroxyl free radical. This hydroxyl free radical causes the development of localized forces which have destructive effects on the solids in dispersions, emulsions and slurries affecting particle size and distribution resulting to reduction in COD.

Advantages of hydrodynamic cavitation

- Less sludge generation
- Less chemical consumption
- Less time required
- Eco-friendly way to reduce the pollution load of wastewater.

Disadvantages of hydrodynamic cavitation

- More energy required

Factors affecting hydrodynamic cavitation: [1]

- Inlet pressure.
- Diameter of the, constriction.
- Properties of the liquid.
- Percentage of free area for the flow

Hydrodynamic cavitation again divided in four parts according to their movement.

1.1.1.1 Traveling cavitation:

Travelling cavitation means it is composed of individual transient cavities or bubble that from in the liquid and move with the liquid. As they expand, shrink and then collapses.[18] this cavities appear at the low pressure points within the fluid , usually along the solid boundary or in a high turbulence region .

1.1.2.2 Fixed cavitation:

Fixed cavitation is the situation where the liquid. Flow separates from the boundary of an immersed body. And form a cavity fixed to the boundary. This fixed cavity sometime looks like highly turbulent boiling surface [18].the maximum cavity length depends on the pressure field.

1.1.2.3 Vortex cavitation:

Vortex cavitation forms in through high shear zones in side vortices. Since vortex cavitation often occurs on the blade tips of ships propellers, it is also called tip cavitation .Cavitation occurs in a vertical movement of liquid is known as vortex cavitation [18].

1.1.2.4 Vibratory cavitation:

In vibratory cavitation each individual fluid element does not passed through the cavitation zone only once. Since the fluid velocity is so low, a given element of liquid is exposed to many cycles of cavitation rather than only one. The blade of a rapidly rotating propeller any surface vibrating in the liquid with sufficient acceleration.[18]

1.1.2 Acoustic cavitation:

The phenomenon of growth and collapse of micro bubble under an ultrasonic field is known as acoustic cavitation.

1.2 Energy deposite cavitation:

These Cavitations are achieved in nature by local energy deposited rather than by tension in liquid [13].

1.2.1 Optic cavitation:

The most common method to generate optic cavitation involves the focusing of short pulsed lasers in a transparent liquid media. Light absorbed heats up the liquid beyond its boiling temperature in a time span of microsecond to millisecond (depending on the optical intensity).

1.2.2 Partical cavitation:

High speed jet of fluid impact on a liquid on a fixed surface. Cavitation damage on a valve plate for an axial piston hydraulic pump. That is the consequences of forces acting upon the liquid.

If hydrodynamic cavitation process is use alone it gives less efficiency.[18] In order to achieve desired level of COD reduction, number of conventional processes is available but because of their low efficiency these processes are nowadays being replaced by advanced oxidation processes (AOPs)[16]. Different AOPs such as Fenton, electro-Fenton, and electro-oxidation etc. have been observed to give better results in terms of COD reduction but at the same time they are associated with other operational restrictions such as huge chemical requirement and excessive sludge generation. Both the methods have their own advantages and disadvantages.

2. Mechanism of hydrodynamic cavitation:

The process of hydrodynamic generation of cavitation bubbles is shown schematically in the figure. The cavitation process begins with a flowing stream of material. A high pressure, P_1 is generated in chamber 1 by a localized flow constriction at point 2. In this localized flow constriction, the velocity of the flow increases. This causes the hydrostatic pressure to drop to a pressure below the saturated vapour pressure of the liquid phase flow. This phenomenon creates the physical conditions necessary for the development of cavitation bubbles in the stream. A high velocity jet (point 3) is formed by the localized flow constriction that becomes saturated with cavitation bubbles at point 4. This cavitating jet penetrates into the second chamber 5, which is under a hydrostatic pressure of P_2.

This hydrostatic pressure initiates a violent collapse of the cavitation bubbles, which results in the energy accumulated by the bubbles during the growth process being transferred to the flowing material. It is important to note that the higher the velocity of the cavitating jet at point 3, the higher is the hydrostatic pressure P_2 in region 5. With respect to higher values of P_2, maintaining a low pressure in the cavitating jet is required for the development of cavitation bubbles, and this is only possible by increasing the velocity of this jet in the localized flow constriction at point 2.

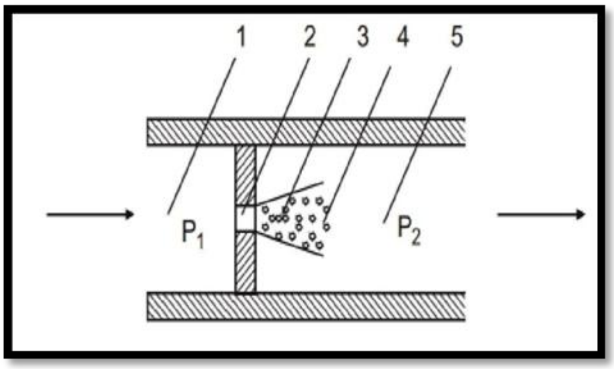

Fig.2- (Schematic illustrating the generation of cavitation in a fluid)

The idea of using the energy from collapsing cavitation bubbles to intensify material processing led to the creation of controlled flow cavitation devices. Hydrodynamic cavitation can be purposefully created in these devices through a variety of different designs and configurations.

The most effective designs are easy to use in the laboratory as well as industrial applications and are known as static hydrodynamic cavitation mixers or reactors. Cavitation devices each, containing a bluff body, a flow-through transit channel and a local constriction for the liquid flow. In order to control and specify the required structure of the cavitation bubble field, the bluff body may have various shapes. This results in the flow-through transit channel having various shapes which produce a local constriction of the flow around the baffle. The flow-through transit channel may also have a cross-section that has one linear section and a circular or irregularly shaped cross section, such as a semi-circle.

Fluids are fed into a hydrodynamic cavitation device with the aid of a pump. The type of pump selected is determined by the physicochemical properties of the fluid medium and the hydrodynamic parameters necessary to accomplish cavitation.

3. Performance

Marta korniluk and janusz ozonek both are observed the decrease in COD and TOC values for the landfill leachate samples in the function of cavitation time. In can be seen that only 6.7% of COD and 5.1% of TOC was removed after 30 min of cavitations.[6]

It is likely that changes in operational conditions such as the cavitation time or the pressure applied would allow obtaining more effective results. In addition, the modification of flow conditions and geometry of the cavitation reactor, particularly the arrangement of holes on the orifice plates, could result in more preferable effects.

II. Conclusion:

Hydrodynamic Cavitation is eco- friendly way to reduce the pollution load of waste water. Sludge generation is very less because of less chemical consumption. The visibility, flexibility in the design and on-line measuring devices of the new cavitation loop will be a step forward in the understanding of the Phenomenon of hydrodynamic cavitation. The extended experimental procedures And optimization of the technique with the new cavitation loop will determine the Real potential of this technique for its application as an AOP for wastewater Treatment, confirming or refuting the promising results that have been obtained so far. [12]

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