A STUDY OF ULTRASONIC CAVITATION IN SOME ORGANIC AND INORGANIC LIQUIDS

THESIS

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CHAPTER I

INTRODUCTION

Ultrasonic investigation of liquids can be carried out in three principal fields; non-linear propagation, cavitation and relaxation. Cavitation, which is the phenomenon to be studied here, was defined as the process of expansion and subsequent collapse of minute gas bubbles suspended in a liquid.

Flynn[1] defined ultrasonic cavitation as a physical phenomenon in which the motion of bubbles generated by a sound field bring about typical physical effects. Cavitation can be produced in liquids by several procedures such as boiling, passing steam into cold liquids, rotary hydraulic apparatus, or subjecting liquids to strong ultrasonic fields.

The first theoretical explanation of ultrasonic cavitation was offered by Lord Rayleigh[2]. He examined theoretically the behaviour of an incompressible fluid in which he imagined a spherical void to be suddenly formed. He calculated the force developed by the collapse of this spherical void. According to Rayleigh's treatment, the time required for complete collapse of the bubble was given by :

$$t = 0.915 \, (\rho / P_o)^{1/2} \, r_m$$

where ρ is the density of the liquid, P_o is the hydraulic pressure expressed in dynes/cm^2, and r_m is the maximum bubble radius just before collapse.

Willard(3) applied step by step process for the full development of cavitation induced by ultrasonic energy. He observed three steps for the cavitation process; the initiation step of cavitation, the catastrophic step, and the bubble formation step.

Types of Cavitation :

Ultrasonic cavitation occurs in liquids due to the presence of gases or impurities in the liquid which will serve as a nucleus for bubble formation.

Iyengar and Richardson(4), distinguished two types of cavitation bubbles; gas filled bubbles, and vapour filled bubbles. They showed that gas filled bubbles grow to visible size and then remain stable, while vapour filled bubbles expand and collapse explosively in a sound field. They also showed that, when a liquid contains dissolved gases, they will diffuse into the growing nucleus and give rise to gaseous cavitation. During the progress of this cavitation, vapour-filled bubbles are also seen to grow and collapse so that the two types of cavitation can exist together.

Strasberg(5), assumed that the bubbles that appear at the onset of cavitation are either gas filled cavities or vapour filled cavities. These two types are distinct in appearance and involve different physical mechanisms. The permanent gaseous cavities are formed by diffusion of dissolved gas out of the liquid into the nucleus. Under certain conditions, vapour-filled cavities can be formed by the explosive expansion of the nucleus during one, or at most, few cycles of the sound wave.

Webster(5) showed that acoustic cavitation in a liquid containing dissolved gas is characterized by the appearance of both sporadic short-lived ruptures of the liquid, and visible, permanent gas bubbles. The two types of cavity formation have been observed to proceed concurrently; both have their origin nuclei consisting of microscopic gas bubbles. Either formation process requires a threshold sound intensity for excitation. The threshold pressure depend on the physical properties of the liquid and the sound field.

Flynn[1], assumed that when a sound field is put on, the nuclei may be set into various types of motion. They may pulsate linearly or non linearly. They may also expand to some maximum radius and contract very rapidly. He observed two types of cavities and represented them as :

1- Transient cavities, where the pressure within each cavity is less than the ambient equilibrium pressure in the liquid and this pressure remains constant as the cavity contracts. It may break up, on collapse, into many smaller bubbles.

2- Stable cavities, where cavities oscillate non-linearly about their equilibrium radius. Such bubbles may shed clouds of smaller bubbles and then continue to oscillate about a smaller equilibrium radius. It may also be convenient to define two kinds of transient cavities;

(a) Gaseous transient cavity, in which the relative amounts of gas and vapour remain fixed during pulsation. In this bubble, there is no evaporation or condensation at the interface and the pressure of the cavity contents is that of a mixture of two non-condensing components.

(b) Vaporous transient cavity, in which the relative amounts of gas and vapour may change during a pulsation.

Effects of Cavitation :

Ultrasonic cavitation in liquids can result in several phenomena such as :

Sonoluminescence, which is the weak emission of light from engassed liquids cavitated by intense ultrasonic waves. The origin of sonoluminescence have been discussed by many authors[7,8]. They indicated the dependence of sonoluminescence on cavitation process. The origin of sonoluminescence was suggested to be due to the rise in temperature following adiabatic compression of the cavitating bubbles[9,10].

Chemical Reactions : Cavitation may have two effects on chemical reactions. The first is to accelerate the chemical reaction by a rate depending on the generation of cavities in the liquid. Moreover, cavitation may result in certain chemical reactions which would not take place in the absence of cavitation[11,12].

Depolymerization ; Thomas[13] and Groobeman[14] suggested that the degradation of polymers can result from the subjection of the long chain molecules to shearing forces imparted by the solvent flow that results from cavitation. Alternatively, the molecules may act as, cavitation nuclei and sustain the collapse of the bubbles.

Erosion; Plesset and Ellis[15], studied the effects of cavitation generated by standing acoustic waves on the surface of metals. They reported that, cavitation damage to metal surfaces is attributed to mechanical stress arising from the motion of a bubble. The rate of erosion of metal surfaces is influenced by the ultrasonic cavitation process.

Ultrasonic Cleaning : The most important and widely used high power technique is ultrasonic cleaning, which has been used with great efficiency to clean small and intricate mechanical parts such as watch mechanisms and precision gears. The cleaning action is mainly due to the phenomenon of cavitation. The molecules in the liquid become agitated and tiny bubbles continually build up and collapse. The power required to maintain cavitation varies with different liquids.

Object of Present Study :

The study of bubble formation in liquids or cavitation has been a topic of continued research, not only because of its contribution to the knowledge of physical properties of liquids but also because of its applicability.

Although large amount of work has been carried out to study the dynamic behaviour of the cavitating bubbles in a sound field, yet few data were reported on the physical parameters affecting the onset of cavitation, the physical phenomenon associated with ultrasonic cavitation and specially on the effect of adding traces of volatile liquids to act as cavitation nuclei.

The liquids studied here were chosen so that a wide range of parameters affecting the threshold pressure of cavitation could be investigated.

In order to achieve a better understanding of the cavitation phenomenon and the effect of adding impurities to the liquid, such as different salts, on the cavitation threshold pressure, the work under report is carried out.

CHAPTER II

REVIEW OF LITERATURE

Origin of Cavitation

Ultrasonic cavitation needs a nucleus for its production. A nucleus may be a small bubble already, existing in the liquid, or a small pocket of gas in a crack in the wall of the vessel containing the liquid. Dust particles present in the liquid are good nuclei, as well as any defect or void in the structure of the liquid. These nuclei remain in a quiescent state until some thermal, mechanical, or chemical change occur and upset their equilibrium. Ultrasonic waves which consist of pressure fluctuations upset the equilibrium of the cavities formed in the liquid and the bubbles will grow in size till they reach a maximum size, and then collapse.

Connolly and Fox(15), concluded that :

a) Cavitation occurs in a liquid only when gases are present in the form of nuclei. These gases may be the vapour of the liquid.

b) Nuclei grow to visible size under the action of ultrasonic waves, only if the sound pressure amplitude exceeds