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Ultrasonic Standing Wave Investigations

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Abstract. Cavitation activity as produced by sound waves in a liquid is a useful phenomenon. It has been successfully applied as a cleaning process. To increase equipment efficiency in this operation, tests were made to determine if standing wave formation affected the intensity of cavitation. This was accomplished by varying the liquid depth in multiples of the sound wave length. The results indicate that standing wave formation has a positive effect but only to a very small degree.

Theory

Ultrasonic cavitation is a process involving the formation of local cavities in a liquid as a result of the reduction of total pressure (1). These cavities are filled with gases dissolved in the liquid and are produced whenever the instantaneous pressure falls below vapor pressure. Collapse of such cavities produces very large impulse pressures on the order of 1500 atmospheres, which may cause considerable mechanical damage to neighboring solid surfaces. If the collapsing bubble is close to a metal surface, the impact causes mechanical destruction so that the metal becomes pitted or eaten away. At the present time this erosive action cannot be fully explained.

The theory tested in this experiment was based on the idea that, when the liquid under cavitation had a depth that was a multiple of the wavelength of incident sound waves, standing waves should form in the liquid. This would result in sound energy being reflected back into the liquid from the liquid-air interface. The resulting rise in energy density would cause an increase in cavitation activity.

The theory discussed in the previous paragraph is in contradiction to qualitative ideas expressed by Carlin, who states (2), "Ultrasonic waves will be attenuated by any medium that has viscosity. Since the amount of ultrasonic attenuation is a function of the size of the signal and since the reflections of energy cause a rise in the internal signal intensity, it may be qualitatively stated that the greater the amount of reflection in a part, the greater will be the attenuation of energy within it. Thus for a fixed amount of incident ultrasonic power, if the reflections become larger the losses become greater."

It was hoped that this experiment would provide information that would enable one to decide between the above-mentioned theories.

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Equipment

Apparatus for this experiment consisted of a glass-walled tank, 8 x 9 x 14 inches deep, attached to a ⅜ inch stainless steel diaphragm. On the outer face of the diaphragm was attached a magneto-striction transducer. The liquid used was degassed water at 100° F. The incident signal was of 400 watts power, and had a frequency of 21.5 KC.

Measurement Methods and Procedure

Cavitation activity was measured by the amount of graphite coating removed from flat ceramic rings 1⅝ inches in diameter with a surface width of ¼ inch. The method of measuring the amount of graphite removed from a ring involved the use of a light-sensitive device. This device measures the amount of light reflected from the surface of the ring. The test ring is a natural white color when completely clean, and a glossy black when graphite coated. The measuring device is calibrated to read directly in percentages with a clean test ring being 100 percent. The test rings were placed in three layers of three rings each, one above the other, in half wavelength steps as measured from the bottom of the tank. The liquid level was varied over one wavelength in quarter wavelengths steps. This resulted in five sets of data, three at nodal points and two at antinodes. Two tests were made, first with decreasing liquid depth and second with increasing liquid depth. The exposure time of the rings was one minute.

Calculation of the incident signal wavelength was accomplished by plotting the values for the velocity of sound in degassed water versus temperature as given by the *Handbook of Physics and Chemistry*. Extension of the curve produced to the range of 100 degrees gave the desired velocity value. The calculated wavelength is 2.8 inches, for a frequency of 21.5 Kilocycles.

To determine when standing waves were present, optical systems were employed in the hope that the waves might be viewed directly and photographed. The striation system as described by Carlin (3), and the diffraction system as described by Willard (4) were constructed. These systems failed to produce any visual evidence that waves were present. It was concluded that failure to view any wave forms was not an indication that waves were not present but that the frequency being used and its resultant long wave length were not sufficient to produce a detectable change in the incident light. In the previously cited data by Willard, the frequencies in use were from 5 to 15 Megacycles, and the wavelengths, therefore, were extremely short. Short wavelengths such as these are easily detected by optical methods.

Upon failure of optical wave detection, the experiment progressed on the theory that the diaphragm of the testing tank would correspond to the antinode position in the sound wave train, the diaphragm being an area of maximum displacement. All following calculations and measurements were made on this basis.

Results

The results of the experiment were obtained by averaging all readings obtained from the rings for each liquid level change. Numerically the results were as follows: uppermost node position 42.5%, uppermost antinode position 42%, middle node position 49.5%, lowest antinode position 45.4%, and lowest node position 56%. It will be noted that there is a general rise in percentages from node to node position. This is due to the decrease in liquid quantity above the rings and the resulting increase in sound energy density. This general rise in percent does not account for the decrease in percent found at the antinode positions, and since the only other variable present was the variation in liquid level, it was concluded that in instances when the liquid level was a multiple of the incident wavelength cavitation activity was increased.

Conclusions

Immediate application of these findings is not warranted, as the average cavitation activity change is only 6%. These results do suggest that further experiments concerning standing wave formation could possibly be beneficial. In instances where high frequency sound waves are employed to produce cavitation these results are of little value, for the extremely short wavelengths encountered do not easily lend themselves to minute, accurate adjustments. Normal liquid agitation from cavitation action causes variations of the liquid depth greater than the wavelengths encountered, and therefore liquid level control is virtually impossible. Cavitation can be produced at frequencies of 10 KC and in this area the long wavelengths encountered lend themselves to reasonably accurate adjustment. It is in this area that the results may be applied most beneficially.

References

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