MILITARY TECHNICAL COLLEGE

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THE EFFECT OF WATER GAP AND PRESSURE WAVE REFLECTING SURFACE ON CAVITATION EROSION OF CYLINDER LINERS

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ABSTRACT

Vibratory cavitation formation and collapse and consequent material damage are controlled mainly by the driving pressure amplitude. This amplitude is the sum of the generated pressure wave amplitude and the reflected pressure wave amplitude from cylinder block surface.

A series of vibratory cavitation erosion tests at different water gaps were carried out at vibration frequencies ranged from 1.85 to 6.4 kHz. Also a series of tests using a rubber disc to act as an absorbing surface instead of the normal brass bottom of test liquid container were conducted.

It was found that the erosion rate increases due to the proximity of a reflecting surface, and by suitable treatment of the reflecting surface, this increasing can be eliminated.

EXPERIMENTAL WORK

The effect of the gap between the vibrating surface(cylinder liner) and the reflecting surface (jacket surface) on cavitation erosion of cylinder liner has been studied in the present research by conducting a series of tests at different water gaps using a test liquid container with brass bottom. This series covered water gaps mainly from 0.5 cm. to 10 cm. The tests were carried out at frequencies of 1.85,3.4,4.7 and 6.4 kHz, at vibration amplitudes of 215, 72, 40, 23 µm respectively. The cast iron alloy specimens, supplied by one of Diesel engine makers, were tested at all four frequencies, and the aluminium specimens at only the first two frequencies. These vibration frequencies covering the important range of

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vibration frequencies for most Diesel engines.
The effect of pressure wave reflecting surface on cavitation damage was studied by conducting a series of erosion tests using a rubber disc at the bottom of test liquid container to act as an absorbing surface instead of the normal brass bottom of the container. The tests were carried out at the same conditions as before and were conducted at, different water gaps until the effect of the gap on the erosion became negligible. At frequencies of 1.85 and 3.4 kHz aluminium specimens were tested and at frequencies of 4.7 and 6.4 kHz cast iron alloy specimens were tested. A complete description of the test rig, test specimen preparation, and test procedures can be found elsewhere [1,2] .

RESULTS AND ANALYSIS

The effect of water gap on total weight loss (T.W.L), steady state rate of weight loss (E), and maximum depth of penetrtion (M.P.D.) is shown in figures 1,2,3,4,5 & 6 with brass bottom test liquid container. This effect also is shown in figures 3, 4, 5 and 6 with rubber bottom test liquid container. Figures 1,2,3,4,5 and 6 show that the relationship between total weight loss, steady state rate of weight loss, or maximum depth of penetration and water gap can all be divided into two zones. The first zone is where the deterioration changes with the change in water gap and is for gaps less than 11/f cm., where f is the frequency in kHz. The second zone is where the deterioration is approximately constant with the change in water gap and is for gaps greater than 11/f cm., a though there is a transition zone around the change over gap of 11/f cm. In the first zone, the cast iron alloy total weight loss, steady state rate of weight loss and maximum depth of penetration are inversely proportional to the gap, to the power $1.93/f^{0.65}$, $1.55/f^{0.35}$ and 0.5 respectively.

With rubber reflecting surface, the effect of water gap ($t < 11/f$ cm) on cavitation erosion is nearly eliminated at the four different vibration frequencies.

DISCUSSION AND CONCLUSIONS

These results illustrate the following features:

1. Test specimen eroded area, total weight loss, steady state rate of weight loss and the maximum depth of penetration at the end of the test decrease with increasing water gap up to about 11/f cm., and have a negligible change for any further increase in gap.
2. At a water gap of less than 11/f cm, the cast iron alloy total weight loss, steady state rate of weight loss and maximum depth of penetration are inversely proportional to the gap to the power $\simeq 0.94$ (average value), $\simeq 1.03$, (average value), and 0.5 respectively.

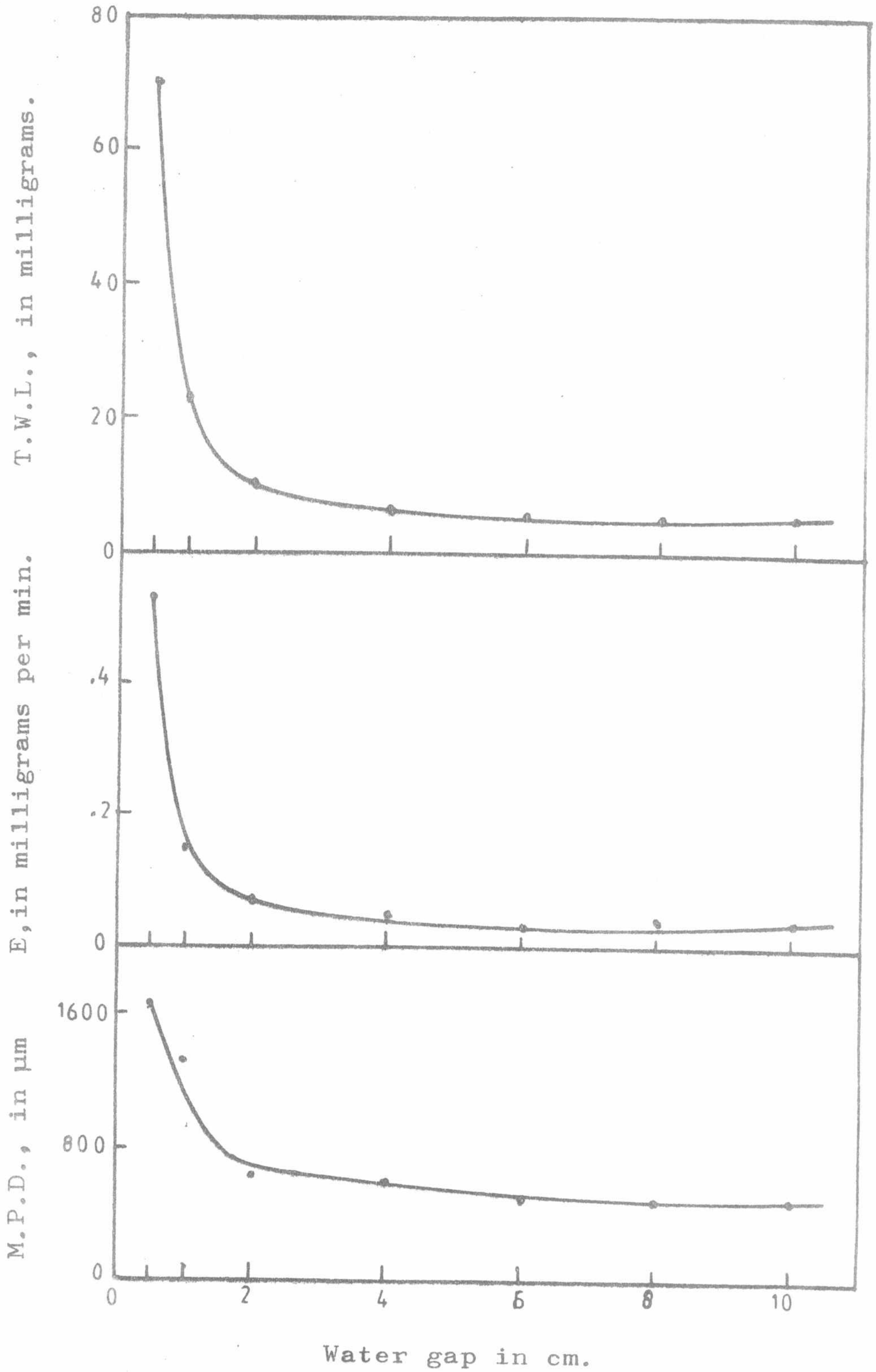

Fig. (1) The effect of water gap on erosion of cast iron alloy at frequency of 1.85 kHz

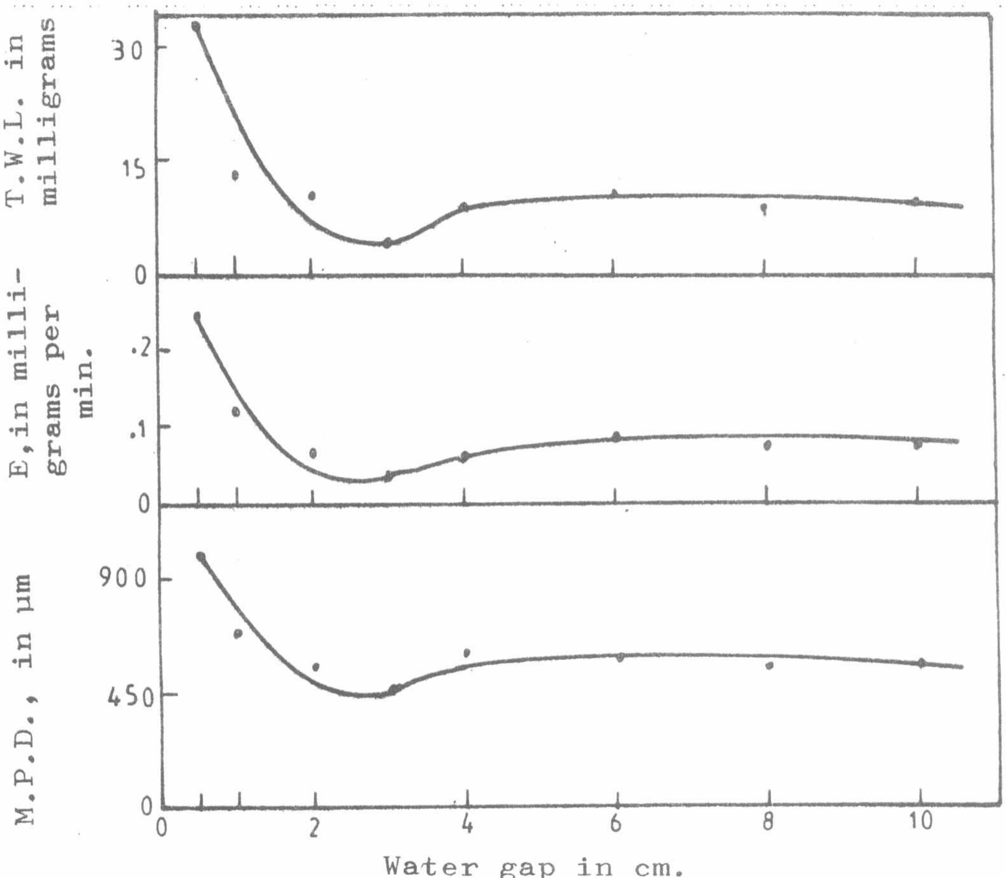

Fig.(2) The effect of water gap on erosion of cast iron alloy at frequency of 3.4 kHz.

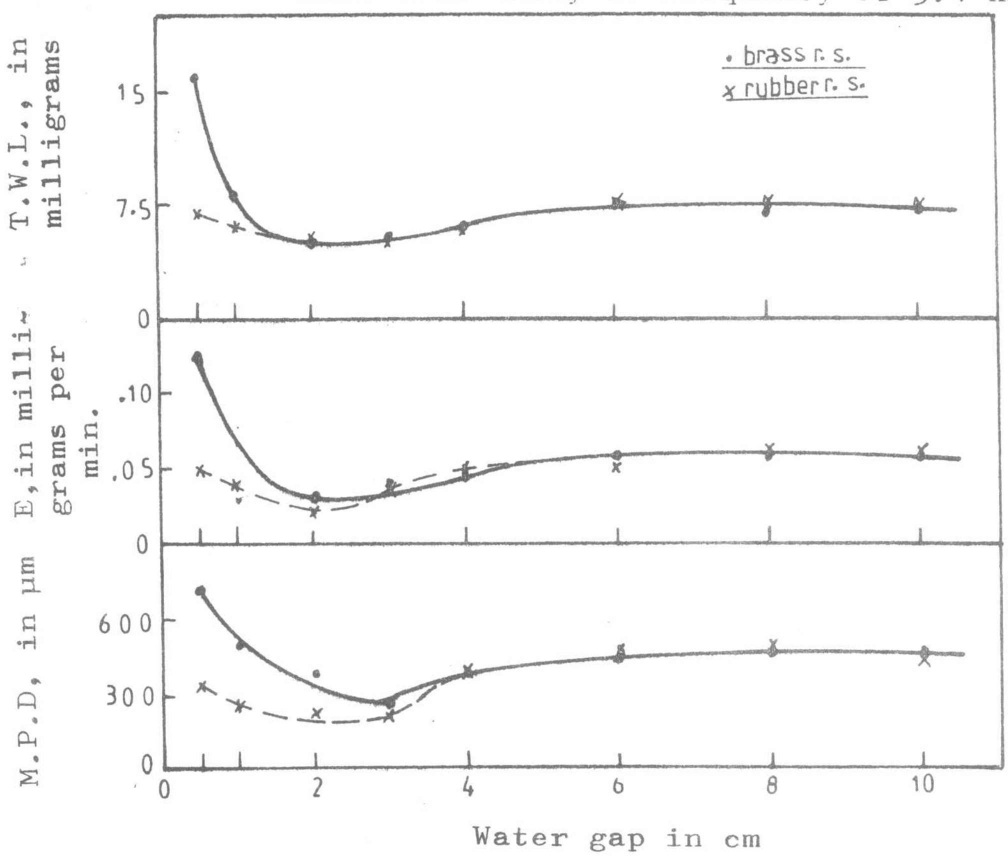

Fig. (3) The effect of water gap on erosion of cast iron alloy at frequency of 4.7 kHz.

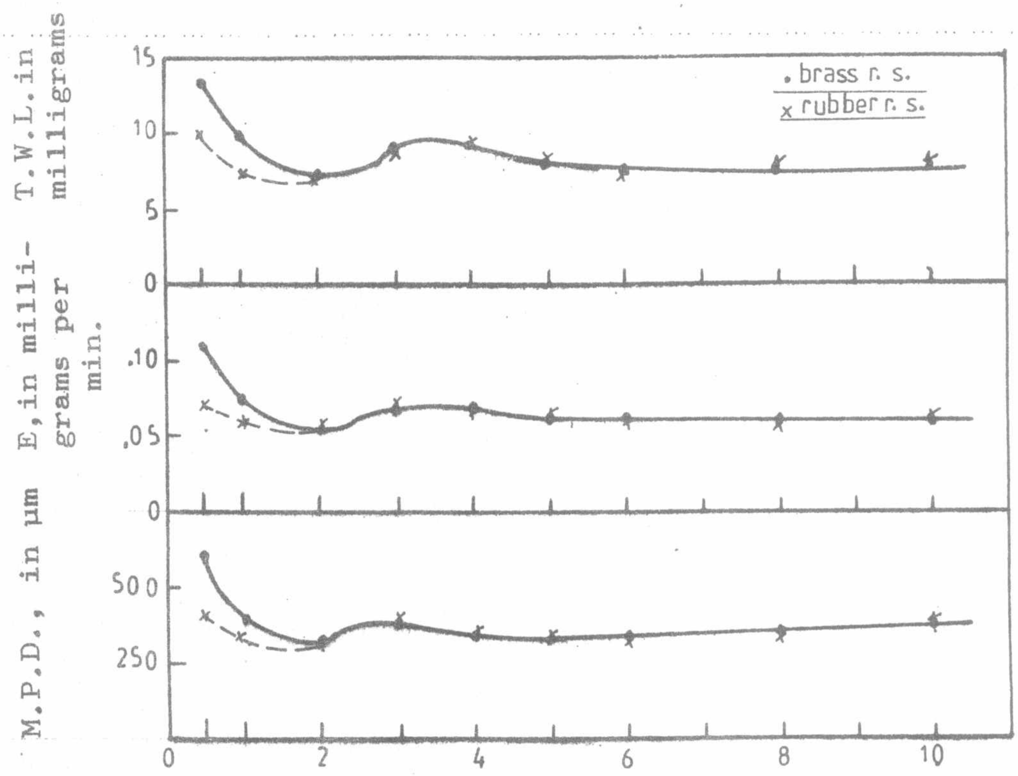

Fig. (4) The effect of water gap on erosion of cast iron alloy at frequency of 6.4 kHz.

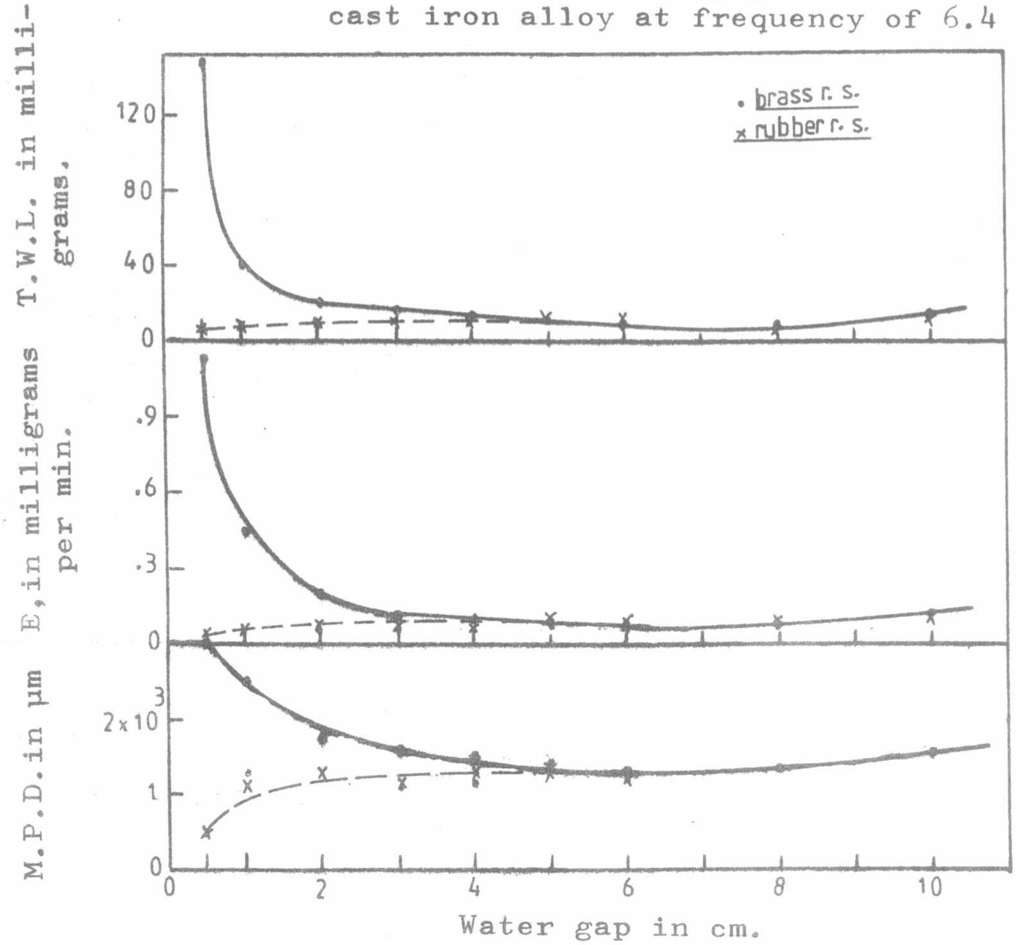

Fig. (5) The effect of erosion of aluminium at frequency of 1.85 kHz.

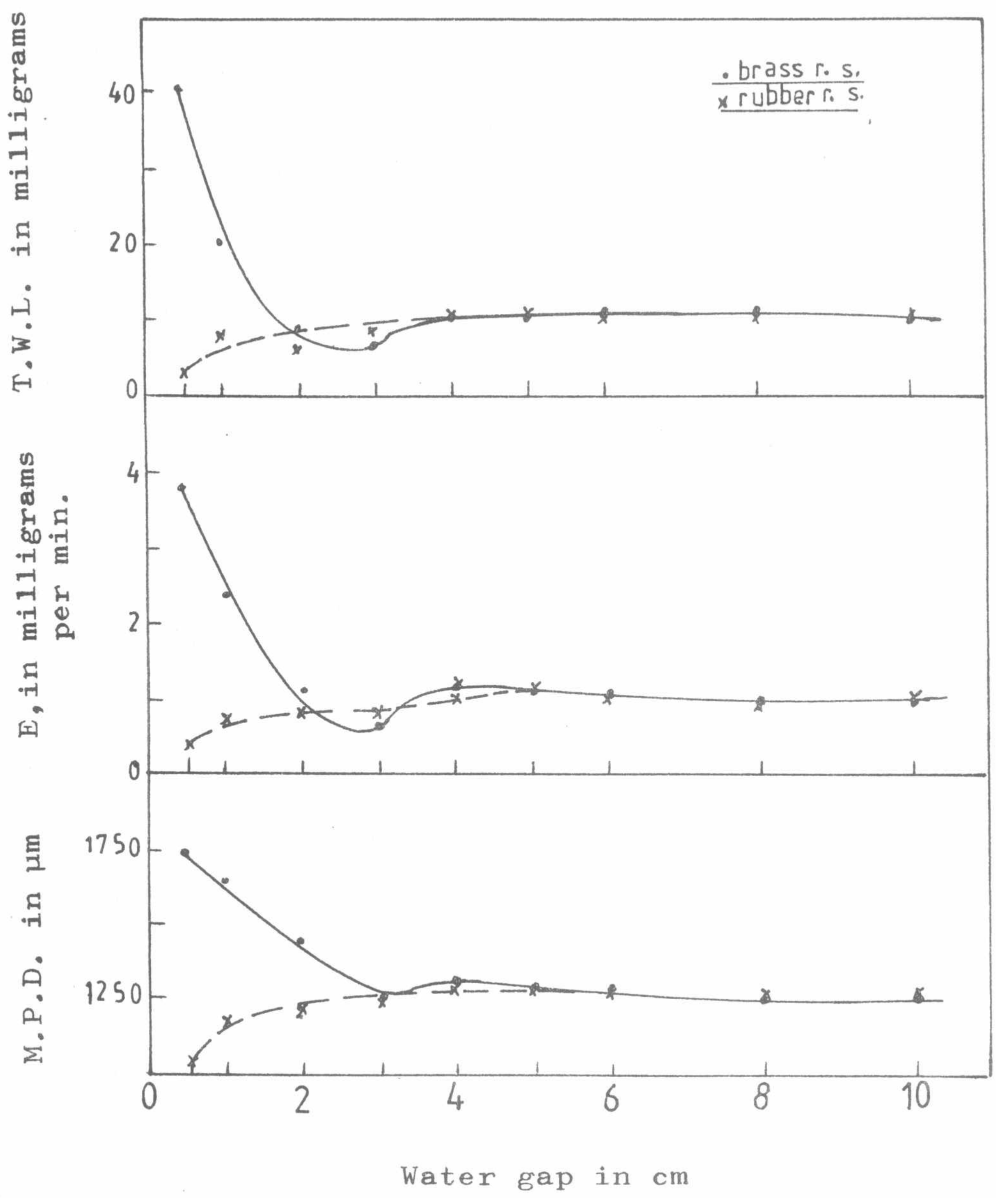

Fig.(6) The effect of water gap on erosion of aluminium at frequency of 3.4 kHz.

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3. With the rubber disc at the bottm of test liquid container, there is a negligible change in material deterioration with changing water gap. But by decreasing the gap below 1.0 cm, there is slight decrease in specimen deterioration with frequencies of 1.85 and 3.4 kHz, no change at a frequency of 4.7 kHz and a slight increase at a frequency of 6.4 kHz.
4. The effect of the water gap on aluminium erosion is similar to that of cast iron alloy.

It is generally understood that cavitation formation and collapse and consequent material damage are controlled mainly by the driving pressure amplitude at the test specimen face when the other test conditions remain constant. The amplitude of the driving pressure is the sum of the generated pressure wave amplitude and the reflected pressure wave amplitude from the test liquid container base. The reflected pressure wave amplitude depends on the generated wave amplitude, the water gap, the reflecting coefficent of the base, the damping factors of the fluid and the driving frequency. Therefore above a certain value of water gap the amplitude of the reflected pressure wave at the test speciment face becomes nrgligible so that a further increase in gap has no effect on the driving pressure amplitude.

The present results are in general agreement with Robinson[3] and Thiruvengadam[4] except for Thiruvengadam's finding at small gaps (0.3 wave lengths) which appearently conflicts with the finding reported here, namely that damage increase at small gaps. The decrease in damage observed by Thiruvengadam could be because the gap at 0.3 wave length in his work corresponds to the beginning of the transition zone around 11/f cm. (the wave length is not stated). The present results also showed a decrease around this gap which was however followed by a rapid increase as the water gap was decreased further. This discrepancy could also be because the conditions at high frequencies (e.g. 15 kHz) are different than in the frequency range of the present tests.

The effect of water gap on total weight loss and steady state rate of weight loss, depends on the driving frequency, such that its influence decreases with increasing driving frequency. This suggest that the rate of material deterioration is non linear and reaches a limiting value according to its mechanical properties. The effect of water gap on maximum depth of penetration is frequency independent because it is less sensitive to the change in gap than the weight loss.

With the rubber disc at the bottom of the test liquid container the effect of decreasing the gap below 11/f cm. on cavitation erosion has been reduced with all driving frequencies due to damping the incident pressure wave. This damping reduces the amplitude of the reflected pressure wave, the amplitude of the driving pressure at the test specimen face and consequently cavitation thrust forces.

As a result of these investigations, the reduction of cavitation attack on cylinder liners can be made by increasing the minimum water gap between the liner and the water jacket (or adjacent liner). If the increase in the gap is limited by other design considerations, the adverse effect of pressure reflection can be reduced by suitable absorbing surface treatment.

REFERENCES

1. Moustafa, S.M. "Cavitation erosion of cylinder liners" Ph.D. thesis, Southampton university, England, 1981.

2. Moustafa, S.M., "The effect of vibra tion on cavitation erosion of cylinder liners". Proceedings of the second fluid mechanics and hydraulic conference, El-Mansoura, Egypt, 1983, pp. 269-295.

3. Robinson, L.E., Holmes, B.A. and Lieth, W.G.,"Progress report on standardization of the vibratory-cavitation test". Trans, ASME, 80, 1957 , pp. 103-107.

4. Thiruvengadam, A. and Preiser, H.S. "On testing materials for cavitation damage resistance". Jr. Ship research, 1964, pp. 39-57.