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AN ACOUSTIC TECHNIQUE FOR DETECTING INCEPTION OF CAVITATION

by

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SUMMARY

Cavitation is one of the major problems encountered in the operation of hydraulic structures, turbines and pumping machinery. As these installations steadily increase in capacity and head, the problem of cavitation is assuming greater importance.

An acoustic technique to detect the inception of cavitation was employed in the studies conducted. It was observed that noise spectrum is influenced purely by cavitation only above a certain critical frequency. Any frequency above the critical frequency can be used to detect the inception of cavitation. The effect of back pressure on cavitation noise spectra, inception and dessinence of cavitation are also studied. Relative locations of points of inception are obtained by visual observations, acoustic methods and from curve relating, loss of head with the cavitation parameter, σ for a venturi set up. A comparison of the points indicate that the acoustic method gives the earliest indication of the onset of cavitation.

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INTRODUCTION An accurate method of detecting the inception of cavitation is necessary to demarcate the 'Cavitating' and 'Non-cavitating' regimes of flow in any hydraulic structure or machine and thereby specify conditions for 'Cavitation free' operation of such installations. In prototype structures where visual observations are not possible, it is desirable to have a technique to identify the presence of cavitation during its operation. It is well known that cavitation is associated with noise and vibration. Noise, being a basic consequence of cavitation, can very well lend itself as an indicator of inception of cavitation. Acoustic method is most suited for detecting cavitation in any flow situation, no matter whire cavitation occurs. This detecting technique does not interfere with the flow phenomena.

EQUIPMENT AND PROCEDURE A two dimensional, open circuit venturi set up consisting of a 10 h.p. pump, pressure and discharge regulating valves, venturimeter to measure the flow rate, contraction cone, test section and diffuser installed in a pipe line of 5 cms diameter has been used. (Fig.1) The Venturi test section 46 cms long is rectangular in cross section and of size 5 x 1.2 cms at the ends and 2.7 x 1.2 cms at the throat. The sides of the venturi test section are provided with transparent plexi glass to enable visual observation of the cavitation taking place. The cavitating specimen 1.9 cms long, 0.16 cms wide and having a depth of 1 cm is inserted with its midpoint 2.5 cms downstream of the throat exit. Another semi circular specimen of radius 1 cm and of thickness 0.16 cms was also used. The flow through the system is regulated by valve located on the upstream side of test section. The back pressure is regulated by valve located at the downstream side of the test section. Pressure tappings are provided one at 5 cms upstream and the other at 5 cms downstream of the test section. Manometers are provided to measure the discharge and the loss of head occuring in the test section.

Cavitation noise was measured using a Bruel-Kjar make frequency analyser. The analyser comprises of a pre-amplifier and a spectrometer. A Unidirectional microphone placed in front of the test section picked up the noise emitted at the test section and this was fed into the analyser. The analysing equipment has a frequency range of 20 to 31500 C/S.

In this venturi set up, it is possible to create cavitation in the test section to the desired degree. The back pressure could be varied using the downstream valve. At a particular degree of cavitation, the relative sound pressure levels at various frequencies were recorded. They were also measured at a particular frequency for different degrees of cavitation. Similar observations were carried out in centrifugal pumps also. In this case, the microphone was placed near the eye of the impeller and the degree of cavitation was varied by controlling the flow through the pump.

DISCUSSION OF RESULTS It is observed from figures 2,3 and 4 that the noise spectra run parallel beyond a certain frequency. The spectrum for lower σ lies above the spectrum for higher σ in this region. From this it can be inferred that the spectrum beyond the critical frequency is influenced only by cavitation.

The relative sound pressure levels recorded for different degrees of cavitation at frequencies above the critical frequency indicate that at the point of inception there is a marked rise of relative sound pressure level. (Fig.5) It is also evident from figure 5 that the point of inception indicated occurs at the same value of σ irrespective of the frequency chosen, provided it is above the critical frequency. There is an increase of steepness with which the relative sound pressure level rises at the point of inception with frequency, possibly indicating that higher frequencies are to be preferred for detecting inception of cavitation.

In these plots σ is defined as

$$\sigma = \frac{h_i - h_v}{V_i^2 / 2g}$$

where h_i, h_v, V_i and σ stand for pressure at inlet of test section in head of water, vapour pressure in head of water, velocity at inlet of test section, cavitation parameter respectively.

The parallelism of the noise spectra in the region beyond the critical frequency is observed from figures 2,3 and 4 irrespective of the boundary geometry of the flow. The geometry of flow was varied by running the experiment with a rectangular specimen, with a semi circular specimen and without any specimen.

In order to observe the effect of back pressure on the character of noise, the noise spectra were plotted for incipient cavitation at the test section for different positions of back pressure valve. The spectra obtained are presented in Fig.6. All the spectra were found to merge together beyond the critical frequency though they criss-cross in the range below the critical frequency. This is, as it should be, because all the spectra were corresponding to the same degree of cavitation i.e. incipient cavitation, irrespective of the prevailing back pressure.

The noise level curves for both inception and dessinence of cavitation are plotted in Fig.7 for different values of back pressure. The break in the curve is quite distinct both for inception and dessinence in all cases. However, the steepness with which the noise level rises is greater for incipient cavitation rather than for the dessinent cavitation for the same back pressure. The dessinent points indicated are found to be at a lower loss co-efficient in all the cases, irrespective of the back pressure. Loss co-efficient is defined as the ratio between overall pressure loss across the venturi and the kinetic pressure evaluated at the throat. Also the inception point for a given geometry is unaltered by the back pressure. The loss co-efficient was chosen for these plots in preference to since the former is claimed to be more sensitive to the cavitating conditions than the cavitation parameter.

To compare the inception points as obtained by visual observations, from a plot of σ with loss across venturi and by the acoustic method, σ values corresponding to inception by visual observation were always noted during the experiments. The relative locations of points of inception obtained by visual observation, by acoustic method and from a plot of σ versus loss across venturi are given in Fig.8 Similar trend was observed in the noise spectra due to cavitation in centrifugal pumps. Corresponding to performance fall off it was observed that there is a sharp rise of relative sound pressure level from which the point of inception could be clearly identified (5).

CONCLUSION The acoustic technique for detecting inception of cavitation is promising. It is adoptable for any flow situation, no matter where cavitation occurs. The detecting technique does not interfere with the flow phenomena. The results of the experiments indicate that

1. The noise spectrum is influenced purely by cavitation above a certain frequency. This may be termed as 'critical frequency'.

2. Irrespective of the boundary geometry, it is observed that the spectra run parallel beyond a critical frequency of 3000 C/S. Also it is evident that the spectrum for a lower σ lies above that of a higher one. This is so even for the flow under different back pressures.

3. Inception of cavitation can be detected by an increase in the relative sound pressure level at any frequency above the critical frequency obtained from cavitation noise spectra. The clear and marked change in relative sound pressure level at the point of inception leads to a definite and accurate method of determining the point of inception.

4. The same property of the relative sound pressure level plot can be utilised for identifying the point of desinent cavitation also. The points of inception and desinence do not depend on the back pressure. Loss co-efficient for desinent cavitation is lower than that for incipient cavitation.

5. The acoustic method gives the earliest indication of inception of cavitation.

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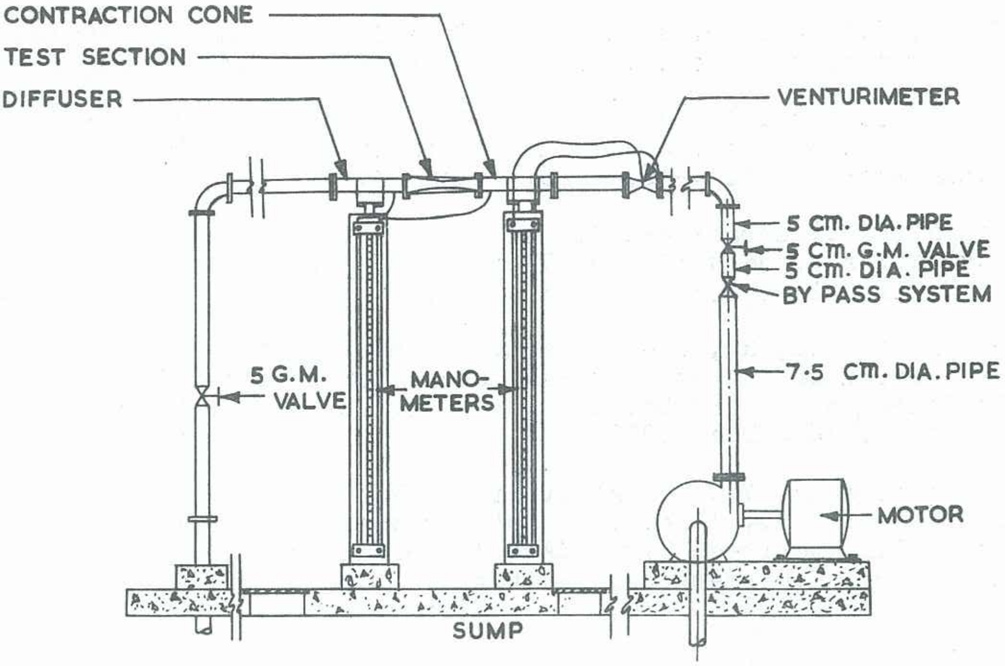

FIG. I VENTURI CAVITATION SET-UP.

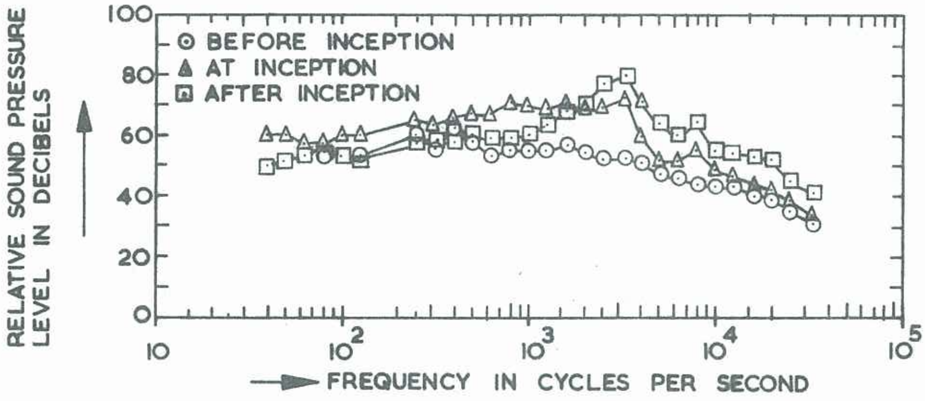

FIG. 2 NOISE SPECTRA DUE TO CAVITATION IN A VENTURI SETUP WITHOUT SPECIMEN.

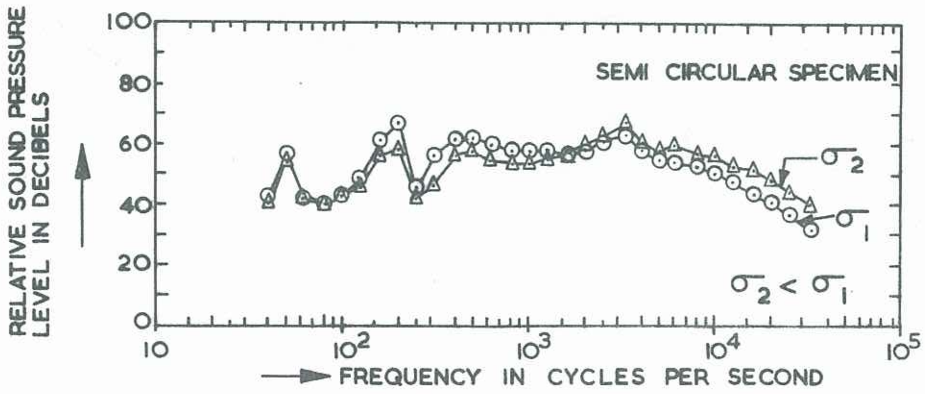

FIG. 3 NOISE SPECTRA DUE TO CAVITATION IN A CAVITATING VENTURI (σ_1, σ_2 POST INCEPTION) WITH SEMI-CIRCULAR SPECIMEN.

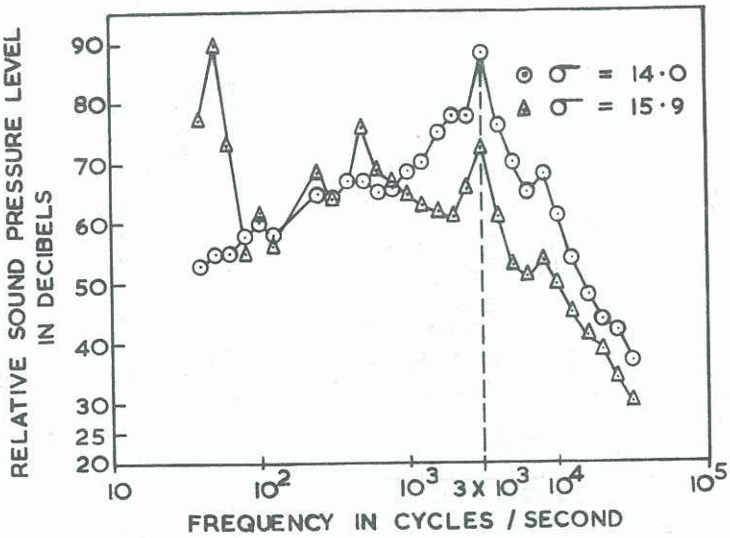

FIG. 4 NOISE SPECTRA DUE TO CAVITATION IN VENTURI SET-UP WITH SPECIMEN. (RECTANGULAR)

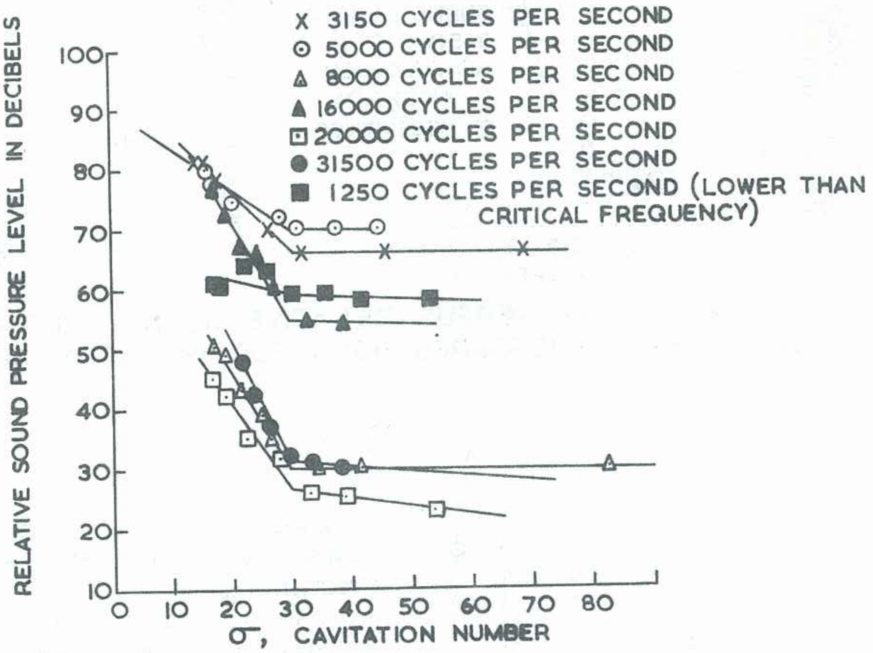

FIG. 5 LOCATION OF INCEPTION POINT USING VARIOUS FREQUENCIES.

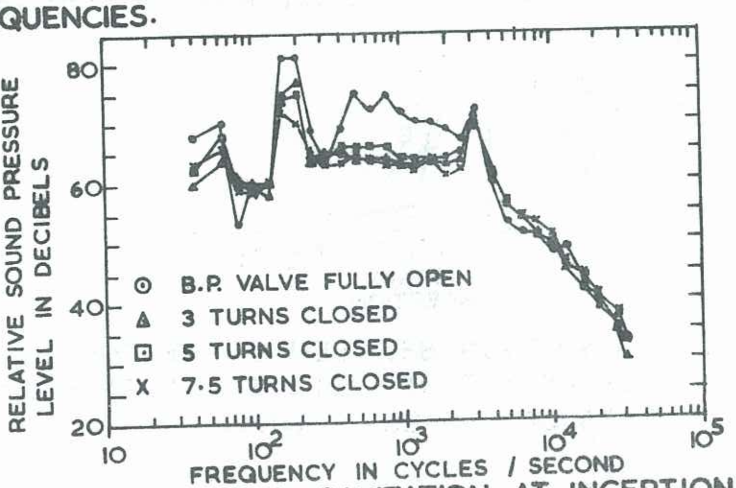

FIG. 6 NOISE SPECTRA DUE TO CAVITATION AT INCEPTION FOR DIFFERENT BACK PRESSURES.

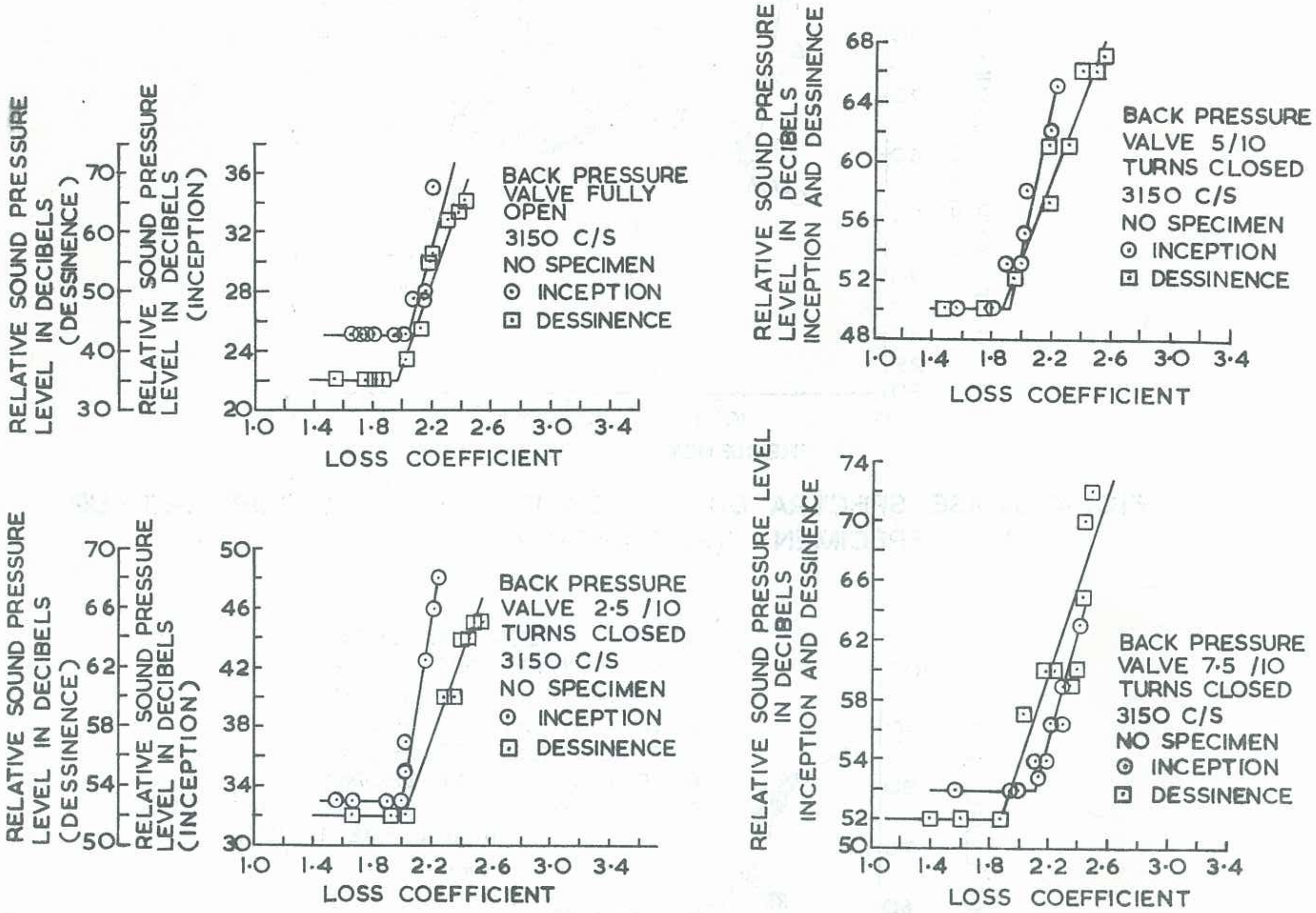

FIG. 7 LOSS COEFFICIENT VERSUS RELATIVE SOUND PRESSURE LEVEL FOR DIFFERENT BACK PRESSURES BOTH FOR INCEPTION AND DESSINENCE.

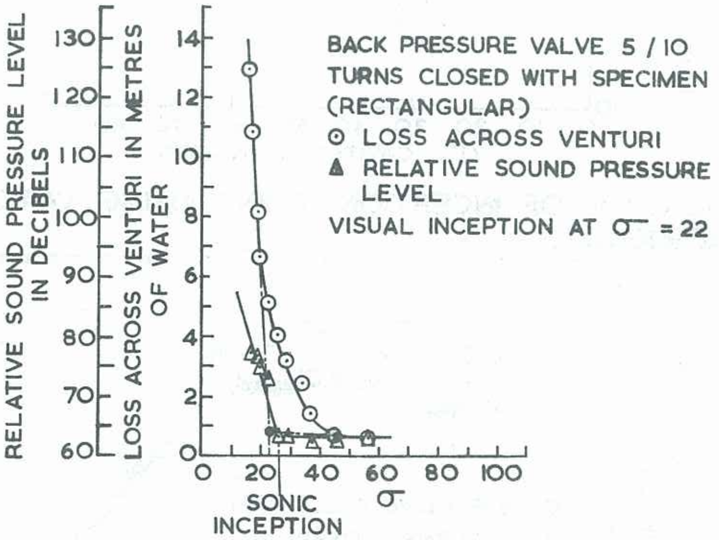

FIG. 8 COMPARISON BETWEEN σ VERSUS LOSS CURVES AND σ VERSUS RELATIVE SOUND PRESSURE LEVEL CURVES.