Calibration of hydrophones in a closed acoustic vessel using optical method

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ABSTRACT

Optical method has been used in the calibration of hydrophones for many years. It is an absolute method for the calibration of free-field sensitivity of hydrophones. Usually, the calibration is carried out in an open water tank. In this paper, the calibration of a B&K8105 and TC4033 hydrophones in a closed acoustic vessel were described. The comparison results between the optical method and the reciprocal method were given and good agreements were achieved. It showed that the optical method had potential applications for the calibration of hydrophones in a pressure vessel in future.

Keywords: Calibration, Optical method, Closed acoustic vessel I-INCE Classification of Subjects Number(s):71.9

1. INTRODUCTION

The sound pressure is one of the most important quantities of underwater acoustics, which is usually measured by a hydrophone. As the most important terminal, hydrophones are widely used for underwater measurements such as ambient noise of the ocean and the radiated noise from the ships. In order to ensure the measurement accuracy, the hydrophone used must be calibrated. The primary calibration method used is the three-transducer reciprocal method based on the principle of reciprocity, which needs a reciprocal transducer. The absolute sensitivity of the hydrophone to be calibrated is determined through the measurements of transfer impedance from three transducer pairs. For a hydrophone used in deep water, the calibration is performed in a closed acoustic vessel by applying static hydraulic pressure to simulate the actual working depth. The calibration procedure is complex and difficult to carried out in a acoustic pressure vessel.

The optical method is an absolute method for the calibration of hydrophone sensitivities. It is very convenient to perform the calibration without disturbing the acoustic field. The applications of optical method became more and more widely. The National Physical Laboratory of UK keeps the primary reference of UK, which calibrates the hydrophones in the frequency range 0.5 MHz to 20MHz using optical method. The calibration technique using the optical method in the frequency range from 10 kHz to 600 kHz was investigated. Hangzhou Applied Acoustics Research has the optical standard facility for hydrophone calibrations in the frequency range 0.5MHz to 15MHz. The accurate calibrations of hydrophones in the frequency range 1 kHz to 200 kHz were achieved using optical method based on water surface reflection, which eliminated the acousto-optic interaction effect. All above calibrations using optical method were carried out in an open tank. In this paper, the optical calibration technique was present for the closed acoustic vessel. The calibration principle was introduced and an experiment facility was built. The calibration results of a B&K 8105 and a TC4033

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hydrophones were showed.

2. PRINCIPLE OF CALIBRATION

The calibration principle of hydrophones using optical method is shown in Figure 1. The auxiliary projector transmits sound waves into the water. A reflective and acoustic transparent pellicle is placed in the far field of the auxiliary transducer, where the plane wave assumption is made. The laser beam is incident to the pellicle and reflected back to the laser vibrometry and the magnitude of pellicle is measured. The motion of pellicle is in phase with the particle velocity in the water as long as the thickness of the pellicle is far less than the wave length. The particle velocity u can be obtained by the measurement of the pellicle vibration. According to the plane wave assumption, the sound pressure can be derived as $p=\rho cu$. Remove the pellicle and substitute the pellicle with the hydrophone. The open circuit voltage of the hydrophone e_{oc} then is measured with the transmission conditions the same as before. The sensitivity of the hydrophone can be calculated as :

$$M = e_{oc}/p = e_{oc} / (\rho cu).$$

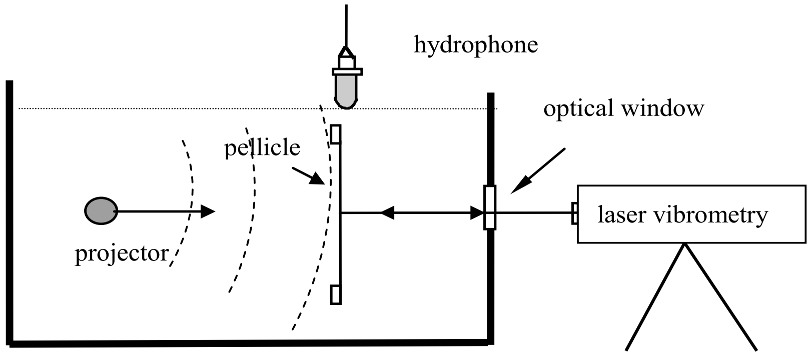

Figure 1 – Schematic diagram of calibration principle using optical method

3. CALIBRATION FACILITY AND RESULTS

3.1 Calibration facility

An experiment facility has been built for the calibration of the hydrophones. As is seen in Fig.2. The measurement facility has a signal transmission subsystem, a receiving subsystem, an optical subsystem and computer controlled subsystem. An signal generator Agilent 33250A, a power amplifier B&K2713 and a projector constitute the transmission subsystem which forms the acoustic field. The closed acoustic vessel is 7 m long and 2.5m in diameter, which has positioning systems and optical windows for laser incidence and observations. A preamplifier B&K2636, a digital filter NF3628 and a digital oscilloscope Agilent6014 forms the receiving subsystem, which measures the output signal from the hydrophone and the vibrometry. The optical subsystem includes a laser vibrometry Polytec OFV5000 and a reflective pellicle of the dimensions 1m long, 5mm wide and about 50μm thick. The pellicle is mounted on a U-shape frame. The generator, preamplifier, filter and oscilloscope are program controlled by the measurement software which accomplishes the data collection, storage, processing and results output.

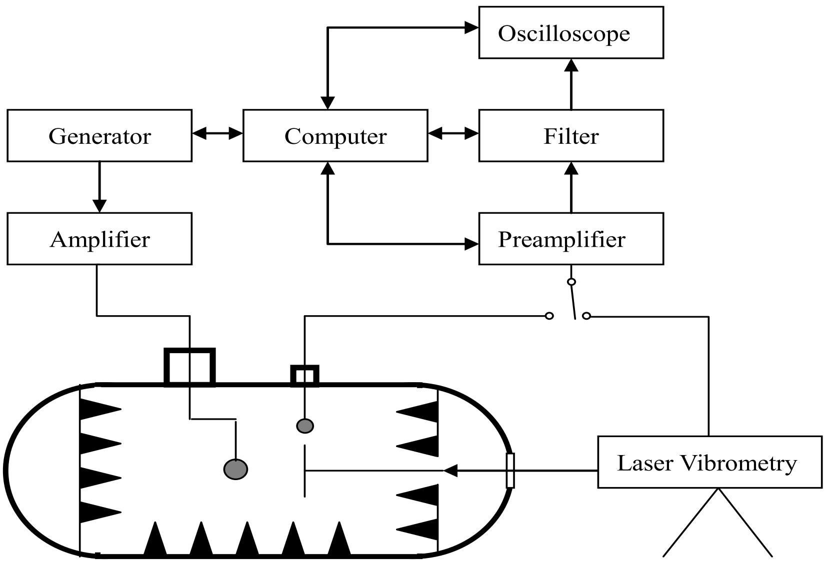

Figure 2 – Schematic diagram of the experiment facility

3.2 Margin Calibration results

A B&K8105 hydrophone and a TC4033 hydrophone are calibrated in the frequency range from 10 kHz to 200kHz using the calibration facility. The 1/3 octave frequency points are chosen during the calibration. The auxiliary projector is spherical transducer with a diameter 30mm. The distance between the projector and the pellicle is about 50cm. The laser head is about 2.2m away from the reflective pellicle. The calibration result are shown in FIG.3. and FIG.4. The results using the reciprocal method are given for comparison in order to validate the results.

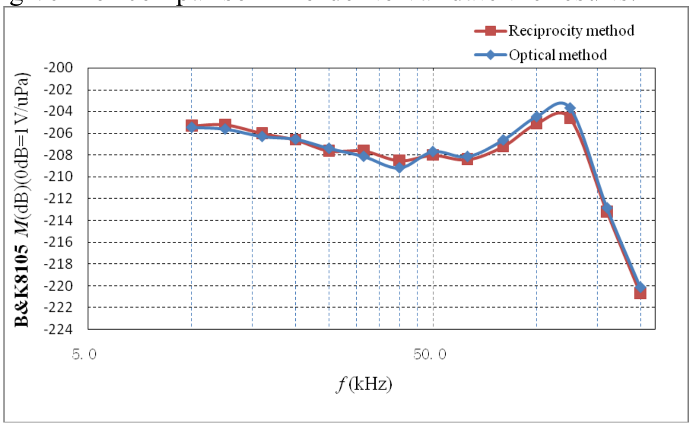

Figure 3 –Results comparison between the optical and reciprocal methods for B&K 8105

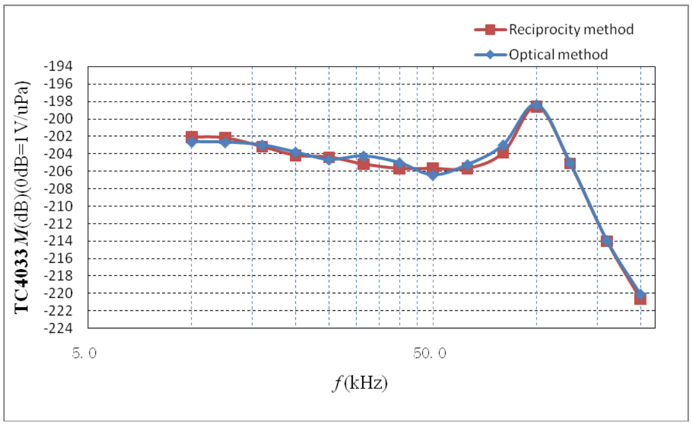

Figure 4 –Results comparison between the optical and reciprocal methods for TC4033

The calibration results using optical method are in good agreement with that of reciprocal method in the frequency range 10 kHz to 200 kHz for both hydrophones. The discrepancy varies from -0.7 dB to 0.9 dB.

4. CONCLUSIONS AND FUTURE WORK

The experiment results using the optical method in a closed acoustic vessel at normal atmosphere condition show that it is a superior calibration technique, which provides a potential way to calibrate hydrophones precisely at the static hydraulic pressure conditions. Compared to the reciprocal method it is more convenient and easy to carry out.

The calibration of hydrophones in a closed acoustic vessel at normal atmosphere is the first stage work. Further works shall be done in order to calibrate hydrophones at the static hydraulic pressure using the optical method, which includes the relationship between the effective refractive index of the water and the static hydraulic pressure and the technical details.

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