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SOME MEASUREMENTS OF ACCELERATION
PRODUCED BY SOUND PRESSURES

Charles W. Remaley - 1613-1

ABSTRACT

This paper contains the results of an experiment performed to determine the effects of sound pressure on acceleration of a test specimen. Particular attention is given to determining the resonant frequency and amplitude of acceleration of the test specimen as a function of mass, sound pressure and frequency.

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SOME MEASUREMENTS OF ACCELERATION PRODUCED BY SOUND PRESSURES

PURPOSE OF EXPERIMENT

There has been a general desire for some time to know the effects of sound pressure on mass acceleration. The purpose of the experiment described herein was to determine the effects of mounting a test specimen on plates of varying mass. Close attention was given to determining the resonant frequency of the test specimen and the amplitude of acceleration as a function of frequency. The test specimen was a dome-shaped cover of die-forged 61S-T6 aluminum having a 17-1/4-inch spherical radius, a bolt circle diameter of 23-1/2 inches, and a nominal thickness of 3/8 inch.

EXPERIMENTAL PROCEDURE

The block diagram of the experimental setup is depicted in Figure 1. A detailed description of the acoustical testing facility used in this experiment will be found in the Appendix.

The power source was a Westinghouse Type HI-500 amplifier driven by a Westinghouse Type HI-40 amplifier. This system provided 500 watts of audio power to the speakers. The driver amplifier was sinusoidally modulated by a Hewlett-Packard Model 205A Audio Signal Generator. This power system is shown in Figure 2. The frequency spectrum used was from 1000 to 5000 cps. The Endevco Model 2213 accelerometers were mounted as shown in Figure 3. The accelerometers were placed at 40-degree angular intervals and at a radius of 0, 2, 3, 4, 6, 7, 8, 10, and 12 inches from the geometrical center of the test specimen. Steel mounting plates 28 by 30 inches and of varying thicknesses were used to support the specimen and provide several different mass conditions. These steel plates weighed 120, 238, and 475 pounds and were of 1/2-, 1-, and 2-inch thickness, respectively. The specimen was bolted to the plate (Figure 4) and was mounted in the center of the chamber (Figure 5).

The microphonic sensitivity of the accelerometers was determined by subjecting each accelerometer to 140 db of sound pressure. The output was recorded and analyzed. There was no observable output below 2000 cps. In the range from 2000 to 5000 cps, the output varied from 0.1 to 0.3 g. The output voltage from the accelerometers was fed into two 6-channel cathode followers and then into Ballantine Laboratories Model 300 Electronic Voltmeters as shown in Figure 6. A six-pole switch on the cathode followers enabled the operator to select the appropriate accelerometer.

A trial run, during which the input power was held constant, produced 60 g's acceleration at 1850 cps. The results indicated that, as power input was held constant, the sound pressure fluctuated as the frequency was varied. It was decided to run each test series with constant sound pressure levels. With this technique, the specimen response for each run was independent of the sound pressure level.

A total of four complete frequency runs were made, one of the specimen alone and one for each of the plate and specimen assemblies. For all frequency runs the sound pressures were held constant within the limit of the equipment. The frequency was varied gradually

until a significant output was observed; this output was then recorded and sweeping was continued. The entire spectrum from 1000 to 5000 cps was swept in this manner until all significant output was recorded. The output from the voltmeters was changed to g's to facilitate comparison of acceleration under varying mass conditions. The results of the frequency runs are shown in Figures 7 through 10. The output in g's at one station for all four mass conditions is shown in Figures 11 through 13.

Data for only three stations are shown on the figures; this was done so that the results might be seen more easily. The stations selected were typical of the output from all stations.

ACCURACY OF EXPERIMENTAL EQUIPMENT

Several factors limited the accuracy of this experiment. One of the most critical factors was the exact location of the sound pressure pickup and the angle of incidence of sound waves across the cartridge face of the pickup. Another important point was the inability to determine the exact frequency or band of energy which caused the output from the sound pickup. With a known input frequency it is difficult to determine the frequency of the energy causing the acceleration observed. It is possible that the energy prevailing in the chamber might be composed of 80 per cent fundamental frequency and 20 per cent harmonic frequency. Under this condition the harmonic could be causing a major portion of the acceleration and/or sound pressures observed due to resonant conditions.

Another experiment with fewer variables and more exhaustive analysis of the phenomena observed would result in more valid and repeatable information. This would require more time and equipment but the results would justify the expenditure of additional time and effort.

EXPERIMENTAL RESULTS AND CONCLUSIONS

The resonant frequency of the test specimen was approximately 1850 cps. Changes in the total mass of the test specimen had little observable effect on the resonant frequency. The amplitude of acceleration was found to be a function of the total mass of the specimen under test. The increase in amplitude, by a factor of 2.3, when the total mass was 200 pounds can be explained in part by the re-enforcement of the fundamental frequency of resonance of the test specimen. This re-enforcement was caused by the natural frequency of the 1/2-inch plate, for this mode of vibration, being a sub-harmonic of the test specimen resonant frequency which provided considerable re-enforcement of the acceleration observed. This was verified by calculation of the resonant frequency of the plate in this particular mode of vibration using the Rayleigh-Ritz method of frequency determination.

Since one would expect that the test specimen alone would exhibit higher acceleration than it would attached to larger masses, some explanation is needed to justify the difference of 24 g's at the resonant frequency. Some of the difference was due to the necessary inversion of the test specimen when it was tested alone. This inversion was necessary due to the shape of the specimen and the mounting system used. As a result of this inversion, the test specimen was in a position of lower sound pressures and resulting lower accelerations than would have resulted if it had been mounted in a reverse position.

RECOMMENDATIONS

It is strongly recommended that a series of experiments be conducted to more fully evaluate the properties of the existing reverberant chamber. Specifically, tests are recommended between 100 and 6000 cps using both sinusoidal and random modulation of the amplifier system. During this testing, the output of the pressure pickup should be filtered by means of narrow band-pass filters to determine the actual frequency peaks of energy in the chamber with any given input frequency. This would provide a positive means of determining the principle

frequency of the energy in the chamber as a function of the input frequency. By sweeping the entire range of the frequency spectrum from 100 to 6000 cps in very narrow bands of 1/10 octave or less, significant harmonic energy present in the chamber would be detected each time the frequency input is changed.

It is further recommended that this entire procedure be repeated with the sound pressure pickup at several different locations in the empty chamber and with a specimen mounted in the chamber. It is realized that this procedure would take considerable time; however, this would provide accurate knowledge of the peaks and nodes within the chamber as a function of frequency. These data would be of material aid in the design of a full-scale reverberant chamber.

CHARLES W. REMALEY - 1613-1

Case No. 693.00
July 17, 1957

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Fig. 1 -- Block diagram of power and instrumentation

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Fig. 2 -- View of power system

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Fig. 13 -- Graph of output at station "8" all conditions

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SOUND PRESSURES IN A 15 CUBIC FOOT REVERBERANT
CHAMBER USING MAXIMUM POWER INPUT (200 WATTS)

Fig. 14 -- Graph of sound pressures in empty chamber

APPENDIX

DESCRIPTION OF ACCOUSTICAL TESTING FACILITY

This test was conducted in a reverberant chamber having a volume of 15 cubic feet, the interior surfaces of which were highly reflective. These surfaces were 1/4-inch aluminum plate attached to a rigid wooden structure. This chamber was designed as a small scale - model sonic exciter to determine the feasibility of full-scale acoustic testing facilities. Experiments, conducted in October and November 1956, indicated that over-all sound levels of 140 ± 10 db (0 db ref: 0.0002 dyne per sq cm) were attainable at 1000 cps but were slightly less at higher frequencies (Figure 14). The input to the speakers was measured by means of a Sensitive Research Instrument Company Model DLW Wattmeter. The sound pressure was measured by a Massa Model M-141C Blast and Pressure Gage which was connected to a General Radio Type 759-B Sound Level Meter.

The acoustic power was generated by Electro-Voice 848HF Compound Diffraction Projector type loudspeakers. Eight of these units were utilized in a configuration such that two stacked speakers were used on each of the four sides of the chamber as shown in Figure 5. These loudspeakers had a low frequency cutoff of 100 cycles and had a mechanical cross-over frequency of 1000 cycles. The power handling capacity of each speaker was 25 watts of sinusoidal input at 400 cycles. A number of speaker combinations were tried, both in phase and unphase. The circuit connection which resulted in the greater sound pressures was all speakers phased and in series, parallel combination for the best impedance match. Since the speakers were mounted in two parallel planes and were mutually perpendicular to those adjoining, the greatest sound re-enforcement occurs at 1000 cps. At this frequency, the geometrical center of the chamber is essentially one wave length from all speakers and all interior surfaces of the chamber. This approaches the desired goal of everywhere equal sound pressure.