Experiments with Kundt's tube

Erica MACHO-STADLER, Maria Jesús ELEJALDE-GARCÍA

Department of Applied Physics 1, Bilbao Faculty of Engineering (University of the Basque Country UPV/EHU), Plaza Ingeniero Torres Quevedo 1, E 48013 Bilbao, Spain

Abstract. We present some lab science experiments that are intended to be performed by undergraduate university students of scientic and technological disciplines. We come out with an experimental study of waves in Kundt's tube by varying the absorption characteristics of its closed end. The measurement of the resonant frequencies permits to determine the speed of sound in the tube. The impedance tube-standing wave method (ISO-10534-1) is applied to study the normal absorption coefficient of acoustics insulators. The setup includes basic lab equipment available in the undergraduate laboratory: a tube, a speaker, a microphone, a digital function generator and an oscilloscope.

1 Introduction

The Kundt's tube permits to investigate the propagation of sound waves in a tube. A loudspeaker produces an acoustic wave, which travels down the pipe and reflects from its end. The phase interference between the incident and reflected waves results in the formation of a standing wave pattern in the pipe.

If a sample of absorbing material is placed at the end of the tube, some of the incident sound energy is absorbed by the sample, then the incident and reflected waves have different amplitudes. The total sound field in the pipe is the superposition of a standing wave and a wave travelling in the tube-axis direction.

In this work, we propose to perform an experimental study of standing waves in Kundt's tube varying the absorption characteristics of its closed end. The proposal is suitable for undergraduate students of engineering, architecture and other scientific fields that need a good understanding of vibrations and waves and materials' properties.

2 Theory

Sound waves striking a surface are either reflected or absorbed. The amount of energy reflected or absorbed depends on acoustic properties of the surface.

In a Kundt's tube, one of the tube ends is bounded by a sound source ($x=0$) and the other by a sample ($x=L$). A plane sound wave propagates along the tube axis. If a progressive wave is impeded by a barrier, it can be reflected at that location. If the tube has boundaries on both sides, standing waves and resonance phenomena will occur [1].

2.1 Resonant frequencies

In general, not all the multiple waves reflected between the ends of the tube will be in phase, and the amplitude of the wave pattern will be small. However, at certain frequencies, all the reflected waves are in phase, resulting in a very high amplitude standing wave. These frequencies are called resonant frequencies. Resonant frequencies depend on the length of the tube and the speed of sound in. The resonance states also depend on whether the ends of the tube are open or closed.

2.2 *Normal absorption coefficient*

If a sample of absorbing material is placed at the end of the tube, some of the incident sound energy is absorbed by the sample, then the incident and reflected waves have different amplitudes. The total sound field in the pipe is the superposition of a standing wave and a wave travelling in the tube-axis direction. The ISO-10534-1 provides an experimental method for calculating the absorption coefficient of the sample [2]. This experimental procedure can be easily reproduced by using ordinary equipment in undergraduate laboratories.

3 Experimental

The PASCO WA-9612 Resonance System has been used [3]. This equipment includes a plastic tube (inside diameter 31.4 mm, overall length 0.90 m), a speaker, a miniature microphone that can be mounted on the end of the probe arm, a digital function generator capable of driving the speaker and an oscilloscope.

The absorption characteristics of the closed end have been varied using four acoustic sound insulators.

4 Results

4.1 *Resonant frequencies*

The study of the resonant frequencies shows similar results in all the experiments. This is an expected result because the resonant frequencies depend on the length of the tube and the speed of sound but not on the characteristics of the closed end.

4.2 *Normal absorption coefficient*

The results obtained for the normal absorption coefficient versus frequency show that studied materials are very good sound absorbers from approximately 2000 Hz to 5000 Hz.

For comparison, the sound absorption coefficient of the same samples has been measured using a commercial system. This comparison is imperative because no “reference” sound absorbing material exists with which to contrast the experimental data.

5 Conclusion

The design and study of undergraduate laboratory courses is an area of increasing interest in the physics education community. In this work, an experimental study of standing waves in Kundt’s tube varying the absorption characteristics of its closed end is described and checked for four acoustics insulators. The experimental set up uses material available in the teaching laboratory. These experiments permit students to deepen their knowledge of the science of sound and materials’ properties.

References

[1] M. Möser, *Engineering Acoustics. An introduction to noise control*, Springer-Verlag, Berlin, 2009.

[2] ISO 10534-1 1996 Acoustics—Determination of Sound Absorption Coefficient and Impedance in Impedance Tubes: 1. Method Using Standing Wave Ratio (International Standard Organization, Switzerland)

[3] PASCO Resonance Tube Manual, https://www.pasco.com/file_downloads/Downloads_Manuals/Resonance-Tube-Manual-WA-9612.pdf