Ultrasound in Convective Flux in Gases, Axial Tomography and Cartesian Scanning

Carlos Gonzalez¹, Rodney Reyna²

¹Department of Applied Physics, Engineering Faculty, Central University of Venezuela, Caracas, República Bolivariana de Venezuela; Phone: 582126051734, Fax: 582126053197; e-mail: carlos.gonzalez@ucv.ve

²Departament of General Education in Basic Sciences, Simon Bolivar University, Caracas, República Bolivariana de Venezuela; e-mail: rodneyrey@hotmail.com

Abstract

This work aims to develop an experimental system of acquisition of data and algorithms for the processing of acoustic signal, in order to detect the contrast of temperature in convective flows of air in the vicinity of a surface at raised temperature, related to ambient temperature. The basis for determining the temperature of gas using ultrasound is the proportionality of the speed of sound in gas, with the square root of the temperature. Both pulse-echo and transmission methods are used for the determination of the time that it takes an acoustic pulse across the region of interest. The data inversion is performed via the inverse Radon transform, similarly to computerized x-ray axial tomography. As a preliminary result, images of convective flow columns produced by heaters elements are shown. In the second part of this research, pulse echo phase lag techniques are used for the study of the effect of convective flux over flat surfaces with temperature contrast. A Cartesian scanner is used to sweep the acoustic beam over the surface with normal incidence, at constant distance from it. In this case the thermo acoustic image is obtained directly, showing significant differences depending on whether the surface is horizontal or vertical. Unexpected spatial and temperature sensitivity was obtained. Images using phase lag information allows detection of small veins in ceramic tiles scanned over the flat side. In conclusion we have that the thermo graphic image obtained by acoustic means reveals the presence convective flow and quantifies its temperature. The developed technique complements conventional thermography and facilitates its interpretation.

Keywords: acoustic thermography, acoustic-imaging

1. Introduction

Many authors have used the inverse radon transform [1] and other methods of data inversion to obtain CT of nozzles [2] [3], with the aim of obtaining the temperature and velocity distributions. In this work we consider a steady laminar flow system, for the determination of morphology and distribution of temperature in a convective flow. Such flow, produced by heating elements, is shown in Figure 1. These heating elements are soaked with oil for visualization only. As is well known, the speed of sound in gases is proportional to the square root of the temperature. This allows determining temperature changes from the local change of sound velocity. For the reconstruction of the data, the cross-section of pipes is sweep with sound waves in order to determine the temperature distribution of the gas. In the second part of this article an ultrasonic beam is directed perpendicularly on a flat surface with temperature contrast. Echo signal phase shift is processed in order to obtain the temperature distributions.
of the gas layer close to the surface. These images are compared with conventional thermographic images.

2. Acoustic and thermal tomography

The arrangements of heating elements are shown in Figure 1. A 40 kHz ultrasonic beam is sweep transversely to the columns of hot air. A second transducer placed frontally to the first transducer, detects the transmitted acoustic signal. Phase shift of the acoustic signal is detected. This phase shift reflects local temperature changes in air. The settlement is moving in the transverse direction, to completely sweep the jets, then spins a predetermined angle and performs another scan. This procedure is repeated until 180° sweep is completed.

![Figure 1. Columns of hot air produced by the heating elements. Oil is used for the visualization of the convective, quasi stationary and laminar flow.](image)

The results of applying the inverse radon transform to the data obtained as indicated above, are shown in Figure 2.

![Figure 2. Thermo acoustic CT for three and four columns of hot air.](image)

3. Thermal and acoustical image using Cartesian sweep by reflection

A 40 kHz acoustic beam strikes perpendicularly through air, on a flat, vertical surface with temperature contrast. By a Cartesian sweeping on the surface with the ultrasonic beam, phase
shift is detected and analyzed similarly to the previous case. The phase shift is related to changes of speed of sound, which allows determining near surface air temperature changes.

Figure 3. Experimental arrangements consisting of a ceramic tile, a heating element (to be placed behind the tile) and a circular spacer for calibration and reference purposes.

Figure 4 shows the conventional thermograph obtained with the heater element behind the tiles.

Figure 4. Thermograph corresponding to the assemblies in figure 3 with the heater element on the rear.

Figure 5 shows the image obtained by scanning the beam acoustic using reflections.

Figure 5. Images of the tile with rear heating element
The thermal effect of changes in thickness of the tile due to the grid, is clearly seen when the tile is analyzed acoustically from the flat side. See figures 5 and 6.

4. Conclusions

A technique for obtaining thermal imaging has been developed using the phase shift of transmitted and reflected sound waves in air. The results reflect both the morphology and the temperature distribution of air layers. Experimental results show that spatial resolution reflects the scanning step size and sensitivity in the detection of the phase shift. The proposed procedure might be applied to more complex surfaces applying at least two sweeps, one of them with no thermal contrast. The difference of the values of phase shift would reflect the temperature contrast in the air layer near the surface under study.

5. References

