Experimental Study of Effects of Ultrasonic Waves on Heat Distribution in Gaseous Medium

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Abstract

The effect of ultrasonically generated forced convection on heat distribution in gaseous medium was experimentally investigated. In the experiment, as an ultrasound source, a piezoelectric transducer which has 28 KHz resonance frequency was used. Transducer was placed behind heat source and ran in sweeping mode from frequency 28 985 Hz to 27 397 Hz at about 20W power. 50 Ω chrome-nickel resistance heater wire of a hairdryer was used under 220V AC voltage as a heat source and its power is adjusted about 100W by a dimmer. The experiments were carried out two set-ups; one of them is in open environment and other is indoor environment. To observe distribution of heat that is generated by heat source, thermal distribution on A3 sized paper that was placed in test environment was monitored by FLIR A20 thermal camera. When both heat source and fan with heat source were running, the heat distributions induced by ultrasound were compared with that of other. It can be concluded that ultrasonic waves could have a positive effect on heat distribution in gaseous medium and it carries heat in propagating direction of itself.

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1. Introduction

In this study, it has been investigated that effect of ultrasonically generated acoustic flow on heat convection in gaseous medium. It is a preliminary study for orientation of heat convection by means of acoustic flow produced by ultrasonic waves. Visual results about heat orientation via ultrasonically generated acoustic flow experimentally achieved.

The idea behind study is, as acoustic flow moves air molecules, it will carry heated molecules on flow direction. Acoustic flow was investigated firstly by Rayleigh (Rayleigh, 1881). The velocity equations of acoustic flow were generated (Westervelt, 1954). The approximate solutions were developed for flow calculation by Nyborg (Nyborg, 1998). The enhancement of heat transfer via acoustic flow in enclosures was numerically carried out by the researchers (Aktaş et al., 2005). The acoustic flow in a water-filled rectangle enclosure based on position, dimension and frequency of ultrasound was numerically investigated by Tang (Tang and Hu, 2014). Fig. 1 shows the acoustic flow model generated at 10 KHz.

2. Methodology

2.1. Sample and Data Collection

In this study we aim to see effect of ultrasonic waves on heat distribution on gaseous mediums. In this study, two different experimental setups were used: Open volume and closed volume. A piezoelectric transducer (ultrasound source), a heater resistance (heat source), an A3 paper (imaging plane) and thermal camera (imaging device) were used in both setups. The heater was a chromium-nickel alloy wire having electric resistance of 50 Ω. A dimmer is connected to heater and run at about 100W power under 220V A.C.

The ultrasound source was a 100 W-piezoelectric transducer having resonance frequency of 28000 Hz which is used in ultrasonic washers generally. The piezoelectric transducer was driven at a frequency range between 28985 Hz and 27397 Hz with a power of approximately 20 W. Microcontroller generated square wave signal was driven transformer via MOSFET to run piezoelectric transducer. The thermal camera was a FLIR A20 in this study.

The heat source was placed in front of the ultrasound source and this combination was also placed under the vertical standing A3 paper in both setups. Temperature distribution on the A3 paper was monitored and recorded via thermal camera. Temperature distribution on the A3 paper gives information about heat transfer. Fig. 2 shows the open volume set up. In the open set up, volume was insulated from outer environment and heat was captured. Fig. 3 shows the closed volume set up. In the closed set up, the open setup was confined with cardboard and its one surface was enveloped with a transparent folio with the purpose of thermal imaging.
According to the list given below, the open volume experiments were performed.

1- Only heater runs
2- Both heater and ultrasound run

Closed volume experiments were performed in the following.
1- Only heater runs
2- Both heater and ultrasound run
3- Both heater and fan run
In total, we carried out five experiments for the open and the closed setups. Each of open setup experiments duration was 300 seconds and each of closed setup experiments duration was 210 seconds. During experiments temperature distribution on A3 paper was recorded by thermal camera.

2.2. Analyses and Results

Data recorded by thermal camera was analyzed by “Thermacam Researcher” software that is developed by FLIR. On open volume setup experiment results, thermal images at 30., 180., and 300. seconds were generated by the software. The open volume setup experiments were discussed in the following.

- Open volume setup experiments results

Fig. 4 shows the thermal view of A3 paper on the open volume setup before the experiments. Fig. 5 shows the thermal view of A3 paper on open setup, while heater only runs for 30., 180., and 300. seconds respectively. Fig. 6 the thermal view of A3 paper on the open setup, while both heater and ultrasound run for 30., 180., and 300. seconds respectively.

Fig. 4. Thermal view of A3 paper on the open volume setup before experiments
Closed volume set up experiments results

Fig. 7 shows the thermal view of A3 paper for the closed volume set up before the experiments. Fig. 8 shows the thermal view of A3 paper on the closed set up, while heater only runs for 30., 180., and 300. seconds respectively. Fig. 9 the thermal view of A3 paper on the closed set up, while both heater and ultrasound run for 30., 180., and 300. seconds respectively. Fig. 10 shows the thermal view of A3 paper on the open set up, while both heater and fan run for 30., 180., and 300. seconds respectively.
Fig. 7. Thermal view of A3 paper on the closed volume set up before the experiments

Fig. 8. Thermal view of A3 paper on the closed set up, while heater only runs for 30., 180., and 300. seconds respectively
Fig. 9. Thermal view of A3 paper on the closed set up, while both heater and ultrasound run for 30., 180., and 300. seconds respectively.

Fig. 10. Thermal view of A3 paper on the open set up, while both heater and fan run for 30., 180., and 300. seconds respectively.
Thermacam Researcher software is able to generate temperature histogram from selected area. We have chosen the area named as AR01 on software as shown Fig. 11. The temperature histogram on AR01 was produced during the last second of each experiment by the software.

![Fig. 11. AR01, Area chosen for calculations](image)

- Open volume set up temperature histogram

Fig. 12 shows the temperature histogram on AR01 on the open volume set up, while heater only runs for 210. seconds. Fig. 13 shows the temperature histogram on AR01 on the open volume set up, while both heater and ultrasound run for 210. seconds.

![Fig. 12. Temperature histogram on AR01 on the open volume set up, while heater only runs for 210. seconds.](image)
Fig. 13. Temperature histogram on AR01 on the open volume set up, while both heater and ultrasound run for 210. seconds.

- Closed volume set up histograms

Fig. 14 shows the temperature histogram on AR01 on the closed volume set up, while heater only runs for 210. seconds. Fig. 15 shows the temperature histogram on AR01 on the closed volume set up, while both heater and ultrasound run for 210. seconds. Fig. 16 shows the temperature histogram on AR01 on open volume set up, while heater and fan runs 210. seconds. According to temperature distribution histograms in these experiments, it is concluded that the measurement data using ultrasound in closed volume shows similarity the acoustic flow modeling by Tang and Hu (Tang and Hu, 2014).

Fig. 14. Temperature histogram on AR01 on the closed volume set up, while heater only runs for 210. seconds.

Fig. 15. Temperature histogram on AR01 on the open volume set up, while both heater and ultrasound run for 210. seconds.
3. Conclusion

In this study, the effect of ultrasonically generated forced convection (acoustic flow) on heat distribution in gaseous medium was experimentally investigated. The experimental data were processed via Thermacam researcher software. The temperature distribution histograms on A3 paper were produced for each experiment. According to temperature distribution histograms in this study, it was observed that there was a more homogeneous temperature distribution at the experiment in which ultrasound source runs in closed volume set up (see Fig. 15) than the experiment in which heat source runs in closed set up (see Fig. 14). It was also observed that there was a more homogeneous in temperature distribution in which a fan was used (see Fig. 16) than the experiment in which ultrasound source runs (see Fig. 15). The measurements in which ultrasound source runs, there are some visual data (Fig.6 & Fig.9) supporting the idea that temperature distribution was effected and formed by ultrasound.

References

Lord Rayleigh, (1884) On the Circulation of Air Observed in Kundt’s Tubes. Philosophical Transactions Royal Society A175, 1–21.