Study of the Factors Influencing the Speed of Sound in Low-Pressure Air Based on the Doppler Effect

Lu, Guanyu (School: Suzhou High School Of Jiangsu Province)

This study investigates the properties of the speed of sound (SOS) in low-pressure air through dynamic observations of the Doppler Effect. A sound recorder is mounted on a rotor, which rotates in a vacuum kettle where the pressure, temperature, and humidity are under control. It is found that when the in-kettle pressure ranges from 0.1 to 0.01 bar, for sound wave of 1000-Hz frequency, the change in humidity has little influence on SOS; meanwhile, SOS decreases as the pressure decreases, as is predicted by the classical theory of acoustics; The first impression given by regression analysis shows a linear relationship between SOS and the square root of air pressure, in accord with the theory under ordinary air, but further analysis indicates that SOS may actually be proportional to the fourth root of air pressure; Furthermore, with some vacuum degrees, SOS sometimes has a negative correlation with temperature, different from the theory under ordinary air. It is pointed out based on the nature of wave motions that the experimental results may be related to air compressibility and continuity, i.e., linked to its microstructure. Possible applications are also discussed. Examples include some special-purpose sensors for parameter extractions from extreme conditions, such as for space station connection or in a high temperature reactor. Unlike other methods that confront problems like low signal-to-noise ratio (SNR), in Doppler analysis the frequency shift in sound is usually reliable and robust, which enables long-distance measurement that ordinary sensors cannot achieve.