Quantitative evaluation of blast pressure in the atmosphere and direct measurement of infrasonic/acoustic wave propagation characteristics

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The space industry has grown as a national strategy of each country. In recent years, space industry is rapidly growing by supporting mainly as a country when private companies in the U,S and Europe get into the rocket industry. However, there are still many mysteries in the environment of the outer space near the Earth, for example vibration by infrasound waves from the ground can shake the upper atmosphere and affect the operation of satellites. For this reason, research on the Earth's upper atmosphere is becoming increasingly important. In this research, acoustic propagation characteristics are investigated and compared with the atmospheric model of acoustic wave propagation path and verified. In addition, to ensure rocket safety is essential and important issue for private rocket companies. The explosion of the rocket affects and damages not only for the surroundings by originating equipment but also from the splashing of the debris and destruction by the blast.

From the observed value detected by the acoustic wave sensors installed on the ground, the energy from explosion can be calculated and the influence of the blast on the distance from the blast hypocenter can be evaluated. We aimed to verify the acoustic propagation path of the blast using data obtained by unexpected rocket explosion, calculating the blast wind attenuation using numerical analysis, and to obtain the blast propagation process.

MOMO3rocket experiment is scheduled to be held in 2019. If it is successful, by using the sound sources of the firework blasts and the rocket launch, propagation characteristics of audible sound and infrastructure sound in middle to upper atmosphere, the comparison between the ground observation and the direct measurement data by rocket-mounted equipment can be determined and verified with the comparison between the ground observation and the direct measurement data, as well as comparison with the atmospheric model of acoustic propagation path.

For MOMO2 rocket experiments conducted in Taiki Town, Hokkaido, we installed multiple sensors at multiple points on ground. Sensors used for ground observation were Nano loggers, SAYA infrasound sensors, condenser microphones, IC recorders and cameras, and placed at nine points in the range between 50 m and 4 km from the launch point. A set of the same type of condenser microphone for rocket experiment was also installed at 600 m on ground. Figure, shows the positional relationship of each observation point.

IST (Interstellar Technologies) launched the Momo2 rocket at 5:30 on June 30, 2018 but failed to maintain thrust due to engine trouble and crashed and the launch experiment was failed. Although the original purpose could not be achieved due to the rocket trouble, we succeeded in observing the blast pressure of the rocket by conducting simultaneous ground observation. Measurement result by a sensor with the highest precision near the blast hypocenter is shown in the figure. The blast over pressure observed at 50 m from the launch/blast point was a pressure change of 170 Pa(p-p). The blast pressure values were also recorded at all observation points.

The attenuation curve of blast pressure obtained at every observed point is shown in the figure. The

attenuation of the sound pressure is comparatively gentle compared to the case [1] at the time of rocket firing, and it can be understood that the low frequency sound characteristic was affected.

Using the observed blast pressure as the energy per unit area, estimate the energy of this explosion from the total area of the space. The sound intensity is the energy amount passing through the unit area per unit time and is expressed by the following equation.
$I_{(t)} = P^2_{(t)} / \rho c$ [W/m^2], where $P_{(t)}$ is sound pressure, ρ is air density, and c is sound velocity. Here, we assumed that $P_{(t)}$=P$_0$sin ωt [Pa]. Hence we can estimate total energy which is given by $E = 4\pi r^2 \int I_{(t)}$ dt [J]. From the above formula, it is found that the energy at the 50 m point which is not much affected by the attenuation is 0.0084 kg in terms of TNT, this the explosion scale was weaker than expected by the reported video images.

From now on, we would like to calculate more quantitative data by carrying out numerical analysis using by precious blast pressure data. Also we will prepare for MOMO3 experiment planned to be launched in 2019.

References
[1] Kihara Oshiro, direct measurement of sound wave propagation characteristics in the development and middle-upper atmosphere of the S-310-41 Rocket equipped with PDI, FY2013 Kochi University of Technology graduate research report, 2013.

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