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Efficiency improvement of outer wall inspection using acoustic irradiation induced vibration from UAV
UAVからの音波照射加振を用いた外壁検査の効率改善

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1. Introduction

In Japan, all buildings that have passed 10 years are required to undergo an overall inspection, such as a hammering inspection. However, the cost burden of temporary scaffolding is heavy and not realistic. Therefore, in order to improve the efficiency of the outer wall inspection, the practical application of an inspection method that can be performed without contact from a long distance is expected. The noncontact acoustic inspection method[1-7] is an excellent method capable of detecting defects at the same level as a hammering inspection from a long distance, but has problems of angle dependency of the sound source and environmental noise. Since it was predicted that these problems could be solved by mounting the sound source itself on an unmanned aerial vehicle (UAV), a UAV actually mounted with a small planar sound source was prototyped. The applicability of the external wall inspection by the noncontact acoustic inspection method was examined using the mounted planar sound source, and it was confirmed mainly by laboratory experiments that high-speed inspection was possible. However, the large UAV was somewhat unstable in the low altitude of about 2 m, due to the wind generated by its own propeller. Therefore, an exploration experiment was actually carried out during UAV flight by suspending the outer wall specimen itself on another specimen (height 3m) using a large crane vehicle. Therefore, this time, we examined whether it would be possible to improve the efficiency of the outer wall inspection by acoustic irradiation induced vibration by actually flying the UAV with sound source.

2. Sound source mounted type UAV and outer wall specimen

Fig.1 shows an external view of a sound source mounted UAV (prototype). The base body is DJI's Matrice 600 Pro, which is equipped with a flat speaker (FPS 1030M3F1R), a sighting laser pointer and a laser rangefinder, and an FM receiver on the bottom of the aircraft. **Fig.2** shows the layout of the simulated defect sheet embedded in the outer wall specimen ($2\times1.6\times0.2$ m^3) manufactured for the verification experiment. As the simulated peeling defect, 0.5 mm thick foam sheets and 0.5 mm thick styrene sheets were used (the thickness of the adhesive tape was about 0.5 mm). Therefore, the burial depth of the sheet is about 9 mm from the tile surface, assuming that the distance from the base material (concrete) to the upper surface of the tile is 10 mm (depending on the mortar thickness and the penetration thickness of the tile). The size of one tile is about 45 × 95 mm^2.

Fig.1. Sound source mounted type UAV in flight.

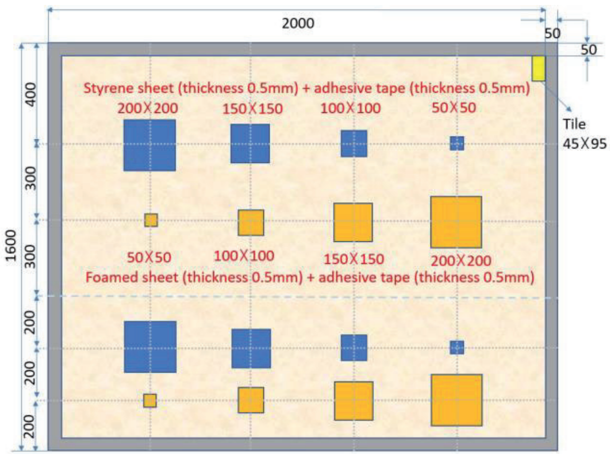

Fig.2. Arrangement of simulated defects of outer wall specimen. Styrene sheets and foamed sheets were used as simulated defects.

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3. Acoustic irradiation experiment

3.1 Experimental setup

Fig.3 shows the experimental setup during UAV flight. The sound source mounted type UAV was operated so as to face the central part of the outer wall specimen, and the distance to the tile surface was in the range of 3 to 5 m. The reason why the distance is not constant is that the UAV's aircraft position fluctuates due to the effects of the wind that occasionally blows. The scanning vibrometer (Polytec Corp., PSV-500 Xtra) measured vibration velocity distribution at a distance of approximately 11.2 m diagonally upward. The waveform used for acoustic irradiation induced vibration was a multitone burst wave[8] with a frequency range of 0.5 to 4 kHz, a pulse length of 3 ms (frequency interval : 200 Hz), and a total waveform length of 60 ms. The sound pressure during excitation is set to about 90 dB (Maximum value of Z characteristic) at a distance of 5 m.

3.2 Experimental result

The size of the measurement area was about 1.4 x 1.7 m^2, and 525 points (length 21 x width 25 points) were measured at intervals of about 70 mm in length and width. Since the movement of UAV was larger than originally expected, it was found that the conventional time-frequency gate may not be able to handle it. Therefore, a new time-frequency gate with a UAV (sound source) moving range of 3 to 5 m from the surface to be measured was applied. **Fig. 4** shows the vibration energy[9] in the range of 500 to 4000 Hz. From this figure, it can be seen that all the simulated defects targeted were detected (the defect of 50 mm^2 was excluded from measurement this time because the flexural resonance frequency is high at 10 kHz or higher). As a result, the measurement time was about 137 seconds.

4. Conclusion

We examined whether the outer wall can be inspected by the noncontact acoustic inspection method by acoustic irradiation induced vibration by actually flying the sound source mounted type UAV. From the experimental results, it was clarified that if a time-frequency gate considering the movement of UAV is applied, even if UAV sways under the influence of natural wind, it can detect peeling defects of about 100 to 200 mm^2 without any problems. From this result, it became clear that this method is extremely effective for actual outer wall inspection and that it is highly possible to improve the efficiency of inspection work. Therefore, we will continue to study for practical use.

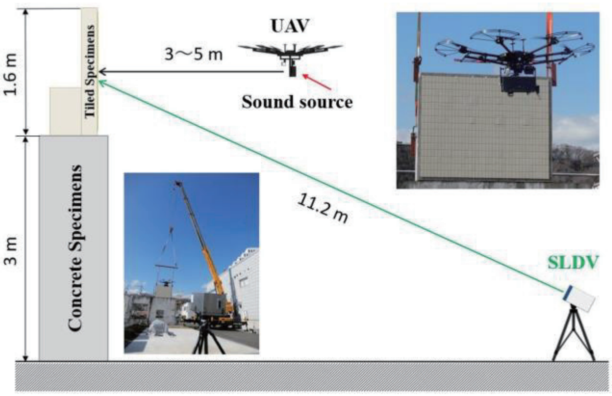

Fig.3. Experimental setup using UAV and LDV.

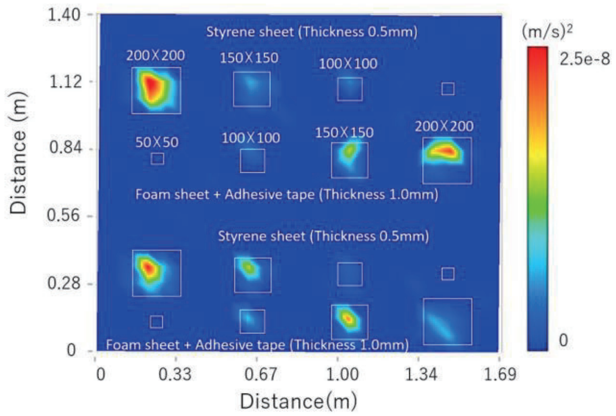

Fig.4. Experimental result using vibration energy (500-4000Hz).

Acknowledgment

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