Fundamental vibration experiment using smart sensor

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1. INTRODUCTION

Nowadays, the aging problems of civil infrastructure in industrialized countries are highly concerned. Development of reliable and efficient evaluating method of integrity of structures considering the cost, practicability, safety is increasingly urgent. Using sensors to monitor the response of structures is widely applied in structural health monitoring (SHM) field, both on laboratorial and in-service structures [1]. However, the deployment and maintenance of wired sensor system is costly, time-consuming. For this reason, smart sensor, which is wireless and has data processing capability, is expected as promising in application with its low-cost, wireless power supply and easy to install properties.

In this study, smart sensor Imote2 (Fig. 1), which has the strongest self data process capability so far, is applied in a vibration test for detecting natural frequency of simple structure in laboratorial experiment so as to develop a new structural identification method.

2. SMART SENSOR SYSTEM AND IMOTE2

Several types of smart sensors are available currently with strong performance in monitoring structural response such as acceleration, strain and even temperature, sound and light [2]. To be smart, these sensors are qualified with next capabilities: (1) wireless communication capability, which is attractive, and can transmit data through blue tooth or radio frequency (RF). (2) data process capability, which can do data conversion before RF transmission and reduce the transmitted information. (3) high data acquiring capabilities in many aspects [3]. Smart sensors can monitor several types of physical phenomena such as acceleration, strain, temperature, sound and light. However, smart sensor also has its limitations, such as the communication and processing speed, packet loss, data storage capability, and most importantly the power supply, which is battery-based.

Accelerometer is among the most commonly employed sensors which installed on smart sensor. Sometimes low sensitivity and high noise are problems in civil engineering application. It is reported that accelerometer installed on smart sensors is accurate enough for dynamic testing, but is not recommended for ambient vibration measurement [3]. In this study, Smart sensor Imote2, which has the strongest data process capability and biggest storage volume among current smart sensors, paired with one sensor node (Fig. 2) are applied on vibration response testing of a model in laboratory.

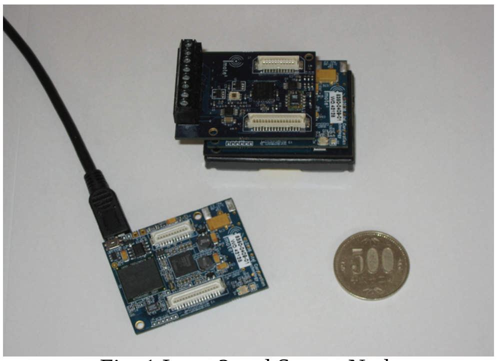

Fig. 1 Imote2 and Sensor Node

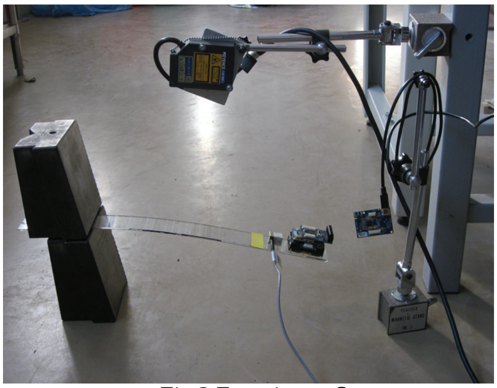

Fig.2 Experiment Setup

Structural responses are collected by the sensors installed on the battery board, and the data can be pre-calculated by processor of each sensor node, if necessary. Then the data will be transmitted to the receiver or shared by nearby sensor nodes through RF. The application program can be rewritten by install new application to Imote2, so the user can control Imote2 performance and apply desired applications.

3. VIBRATION MEASUREMENT TEST

3.1 EXPERIMENTAL SETUP

The model applied in laboratory test is consisted of a plastic cantilever. Sensors are installed on the free end (Fig. 2). The length, width and thickness of this plastic sheet are 36cm, 4cm and 0.6cm, respectively. Three types of sensors, Imote2, laser displacement sensor (Keyence LB-300) and strain gauge type accelerometer (Kyowa AS-2G), are applied in this experiment.

The model is excited by impulse using a hammer manually so each time the location and load of impulse is slightly different and the input is not measured. Imote2 sensor

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Table 1 Identified Frequency

	Imote2 (Accelerometer)				Strain Gage Accelerometer	Laser Disp. Sensor
Sampling Freq.(Hz)	10	20	50	100	100	100
1	2.811	2.916	3.159	3.561	2.737	2.737
2	2.857	2.885	3.090	3.612	2.737	2.737
3	2.646	2.864	3.170	3.577	2.732	2.737
4	2.851	2.916	3.152	3.493	2.737	2.737
5	2.785	2.940	3.142	3.541	2.737	2.737
Average	2.790	2.904	3.143	3.557	2.737	2.737

node and strain accelerometer are used to measure the vibration response while laser displacement sensor measures the displacement of the center point of the cantilever. Because of weight of Imote2 and AS-2G, the plastic cantilever has original deflection, as shown in Fig. 2.

3.2 DATA ACQUISITION AND ANALYSIS

In data acquisition process, the sampling frequencies of laser displacement sensor and strain accelerometer are 100Hz, and the sampling frequency of Imote2 is changed from 100Hz to 50Hz, 20Hz and 10Hz, that is, Imote2 sensor node collect data under four sampling frequency bands. For each case, 10sec vibration data is measured and the tests are repeated for 5 times.

In data acquiring procedure, XSniffer application under MS.NET is used to collect acceleration measurement by Imote2 [4]. Matlab program with the Data Acquisition Toolbox [5] is used for laser displacement sensor and strain gauge type sensor. For displacement measurement, LB-300 sensor head is connected to LB-1200 amplifier unit then NI USB-6008 acquired data to computer. For strain gauge accelerometer, data are sent to computer through amplifier unit and NI DAQ-6036E. After collecting data, time-history curve and its Fourier spectra are calculated. Peak of spectrum is extracted as a fundamental natural frequency of the cantilever.

3.3 COMPARISON OF RESULTS

The identified natural frequencies extracted from the Fourier spectra of collected data are shown in table 1. The Figs 3-6 show the vibration amplitude (left) and its Fourier spectra (right) by both strain gauge type accelerometer and Imote2 with 100Hz, 50Hz, 20Hz and 10Hz of sampling frequency.

The predominant frequencies identified by strain gauge type accelerometer and laser displacement sensor are exactly same, 2.737Hz, so this frequency can be recognized as having high accuracy and reliable. However, for the predominant frequencies identified by Imote2 under different sampling frequencies, it needs more investigation. At sampling frequency of 100Hz, the identified average frequency is 3.557Hz, which has a big gap of 30.0%, between the one identified by the other two types of sensors. And at sampling frequencies 50Hz, 20Hz and 10Hz, the identified average frequencies are 3.143Hz, 2.904Hz and 2.790Hz, the difference between other sensors are 14.8%, 6.1% and 1.9%,

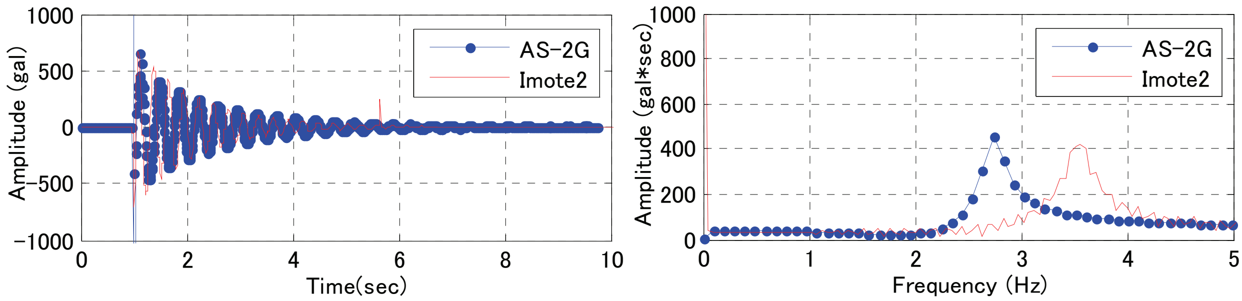

Fig. 3 Results from acceleration measurement (f_s of Imote2 is 100Hz)

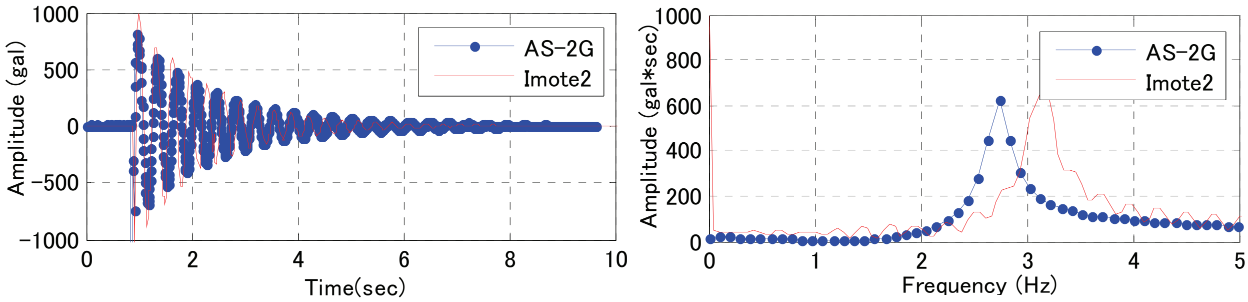

Fig. 4 Results from acceleration measurement (f_s of Imote2 is 50Hz)

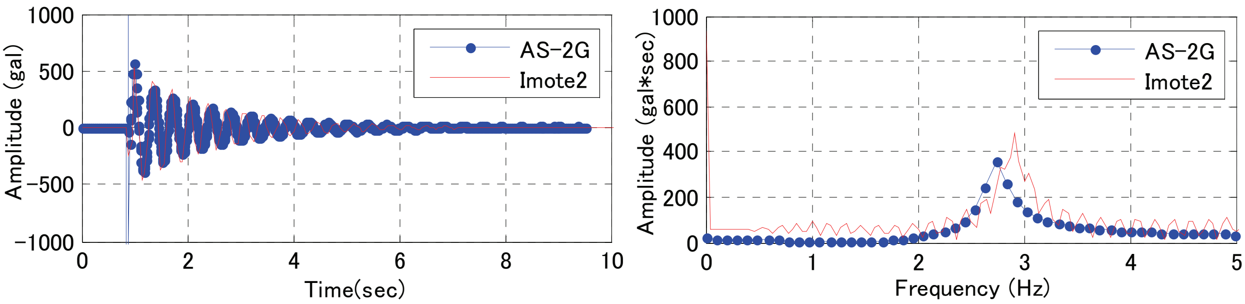

Fig. 5 Results from acceleration measurement (f_s of Imote2 is 20Hz)

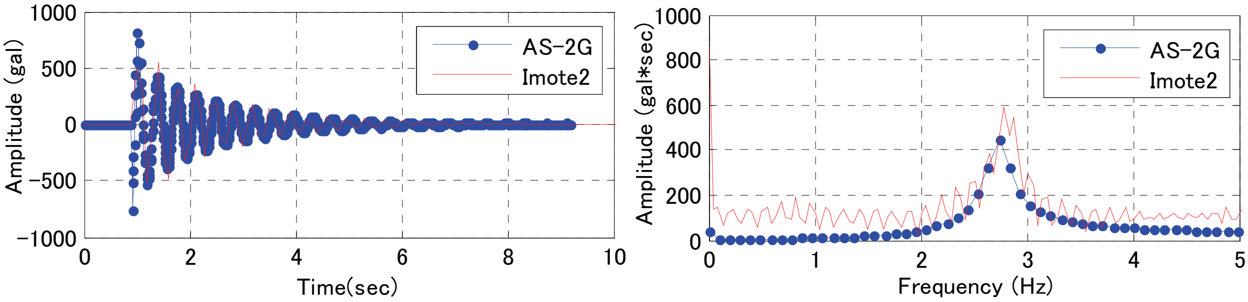

Fig. 6 Results from acceleration measurement (f_s of Imote2 is 10Hz)

respectively. It is hard to conclude that Imote2 has high accuracy contrast to the other two sensors, but it is understood from the Table 1 that the lower the sampling frequency, the closer it goes to accurate result.

The left-hand side of Figs 3-6 shows the vibration amplitudes. The peak amplitudes detected by Imote2 and strain gauge type accelerometer are at the same scale, if not exactly the same. Although measured at the same time, the two waves do not coincide well and have time delay. Larger sampling frequency of Imote2 gives larger time delay from comparison of figures.

The right-hand side of Figs 3-6 shows the Fourier spectra. The amplitude of peak frequencies of Imote2 is close to that of strain gauge accelerometer's peak. And the spectra by Imote2 have many peaks while the one from strain accelerometer is smooth. Most significant difference is that the peak frequencies of spectra shift to higher frequencies. From these phenomena, designated sampling frequency of Imote2 is doubted and it has time delay under the configuration in this study. Because Imote2 has data processing circuit on the sensor board and data transmitter board, it takes certain time to collect and transmit data. For the configuration of this study such processing time might be longer than sampling interval. In this study, Imote2 works with the application based on MS.NET provided by manufacture and higher processing speed can be realized by improving software approach. Tiny OS [6] is also applicable for smart sensors and it is widely recognized as compact operating system. The test may have better results if Tiny OS and compact data acquisition application is applied.

4. CONCLUSION

In this study, a fundamental experiment is designed to examine the practicability of smart sensor Imote2 for detecting vibration responses. Imote2 is utilized to detect vibration response at four sampling frequencies while laser displacement sensor and strain gauge type accelerometer are applied at the same time.

The detected response amplitude and identified frequencies by Imote2 and laser displacement sensor and strain gauge accelerometer are collected and analyzed. The results indicate the practicability of Imote2 in this method although the accuracy needs more discussion. However, problems are still to be solved. The sensing ability at different sampling frequencies, the deployment of multi nodes and applicability for ambient vibration are needed more investigation. Most importantly, the practicability of Imote2's utilization on real structures needs further on-site experiment investigation.

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