

DEVELOPMENT OF WIRELESS REMOTE-CONTROLLED TESTING MACHINE FOR VERTICAL CONCRETE WALL

Tatsuya Iwamoto* , Shunpei Furui[†], Isamu Inoue^{††} and Kazuya Mori^{†††}

* Ariake National College of Technology,
150 Higashihagio-Machi, Omuta, Fukuoka 836-8585, Japan
e-mail: tiwamoto@ariake-nct.ac.jp, web page: www.ariake-nct.ac.jp

[†]ARIAKE Shipyard, Universal Shipbuilding Corporation,
1, Oaza-ariake, Nagasu-machi Tamana-gun, Kumamoto 869-0013, Japan

^{††}Fujitsu Limited,
Shiodome City Center, 1-5-2 Higashi-Shimbashi, Minato-ku, Tokyo 105-7123, Japan

^{†††}Department of Industrial Science, Kumamoto University,
2-39-1 Kurokami, Kumamoto, Kumamoto 860-8585 Japan

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Abstract: A lot of concrete structures are deteriorating to dangerous levels throughout Japan. These concrete structures need to be inspected regularly to be sure that they are safe enough to be used. The inspection method of these concrete structures is typically the impact acoustic method.

In the impact acoustic method the worker taps the concrete on the surface with hammer. So it is necessary to set up scaffolding to access vertical structures for inspection. However, setting up of high scaffolding is not economical in time and money. Moreover setting up scaffolding is difficult on very high concrete walls. So we developed a wireless remote-controlled testing machine for vertical concrete walls. This testing machine adheres to the concrete wall by two sets of suction cups, and climbs the concrete wall by the alternating motion of the two sets of suction cups. The power is supplied by lithium polymer batteries.

The impact acoustic method is used in this testing machine. This testing machine has a hammer for the impact and a microphone for the acquisition of the impact sound. The weight and the dimension of the testing machine are about 13 kg and 1.39 m by 1.39 m, respectively. This testing machine climbs the concrete wall at a speed of one meter a minute. The testing efficiency of this machine is about 10 min/m².

1 INTRODUCTION

A lot of concrete structures are deteriorating to dangerous levels throughout Japan. These concrete structures need to be inspected regularly to be sure that they are safe enough to be used. The typical inspection method for these concrete structures is the impact acoustic method carried out by workers. However, the impact acoustic method done by workers is not economical in terms of time and money

because it takes a lot of time and effort to set up scaffolding so developing more economical method is desired.

Wall-climbing robots have lately attracted attention to solve the problem because wall-climbing robots don't require scaffolding. Some wall-climbing robots have already been developed that test concrete nondestructively^[1] ~^[10]. Typically these robots are characterized as light weight with low traction for climbing.

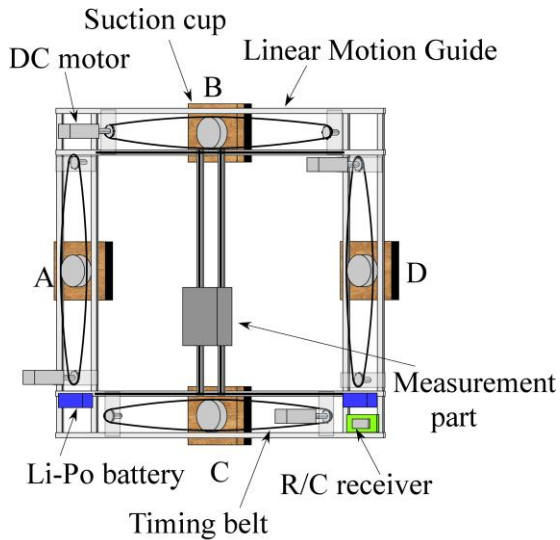


Figure 1: Schematic diagram of a testing machine



Figure 2: The appearance of a testing machine

However, using the impact acoustic method, strong traction is necessary to keep the robot attached to the structure because there is a reaction to each impact.

The purpose of this study is the development of a testing machine that can move the walls of any angle, and mounting the inspection device of the concrete wall.

2 REMOTE-CONTROLLED TESTING MACHINE

We developed a remote-controlled testing machine for vertical concrete walls as shown in Fig. 1. The appearance of the developed testing machine is shown in Fig. 2. This developed testing machine strongly attaches to the concrete wall by four suction cups and has an impact device for the impact acoustic method. The weight and the dimensions of the testing machine are about 13 kg and 139 cm by 139 cm by 11 cm, respectively. The testing machine consists of an adsorption part, an actuator part, a control part, and a measurement part. The details of each part are as follows.

2.1 Adsorption part

The composition of an adsorption part is shown in Fig. 3. Negative pressure is generated by the fan for cleaners. In order to increase the adhesion between the wall and the

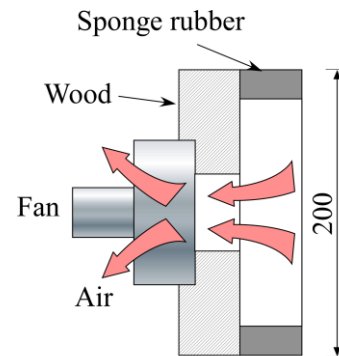


Figure 3: Schematic diagram of a adsorption part

Table 1: Results of pressure measurement

Wall type	NR	EPDM
Textured Paint	-3.06	-3.24
Siding	-2.96	-3.10
Tile	-3.09	-3.15

gauge pressure[kPa]

back side is attached sponge. In the selection of the sponge rubber, compare the type NR and EPDM type were selected higher adhesion. Table 1 shows the results of a preliminary experiment. Table 1 shows the negative pressure in the suction cup when using the sponge, respectively. The experimental result showed that an EPDM type had a high negative pressure and less dispersion on every wall. Then, the sponge rubber of the EPDM type is selected suction cup sealing material.

2.2 Actuator part

The composition of an actuator part is shown in Fig. 4. Drive system is a combination of a linear guide and a timing belt. Fixed to the suction cups the timing belt, timing pulley to rotate at both ends. DC motor is attached to one of the timing pulley, the suction cup can be moved to any position.

Two suction cups A and C or two suction cups B and D are synchronized as shown in Fig. 1. The two sets of suction cups move in relation to each other to create linear motions. This machine can climb concrete walls by the alternating motion of these two sets of suction cups. The power is supplied by lithium polymer batteries.

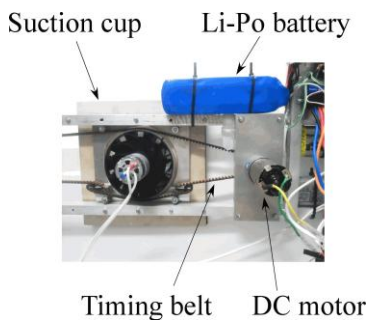


Figure 4: The composition of an actuator part

2.3 Control system

The control system is shown in Fig. 5. The control unit is composed in the radio control system and the motor driver.

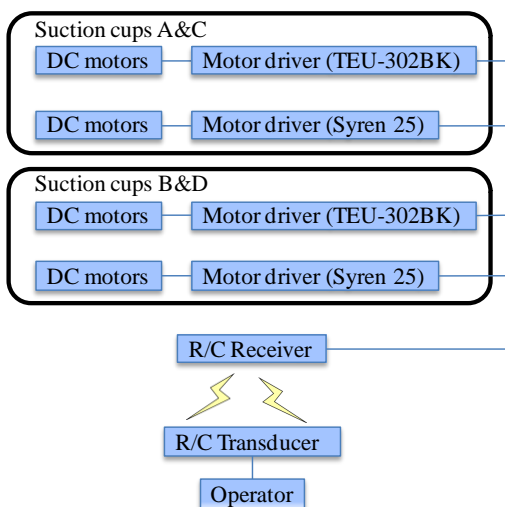


Figure 5: Schematic diagram of a control system

Four channels AM radio control system (Futaba Corporation) is used as a radio control system. As the motor driver for fans, SyRen 25A regenerative motor driver (Dimension Engineering LLC.), as the motor driver for actuator, Electronic Speed Controller TEU-302BK (Tamiya, Inc), were used. Each motor driver is controlled by RC system. One channel of receiver is assigned two suction cups A and C or two suction cups B and D, respectively.

2.4 Measuring part

The measuring equipment is shown in Fig. 6. The measuring system is shown in Fig. 7. A CCD camera, a microphone, and an accelerometer can be carried as a measuring device. This testing machine has a hammer for the impact, a CCD camera for the visual inspection, a microphone for the acquisition of the impact sound. The measurement value is converted into an electrical signal and transmitted to a computer through a wireless LAN.

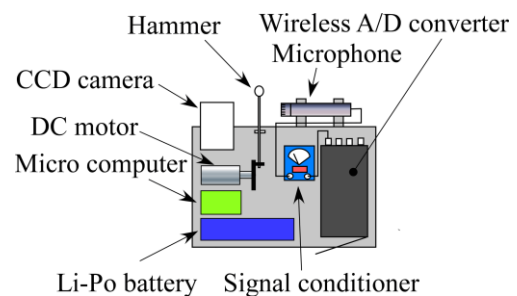


Figure 6: Schematic diagram of a measurement part

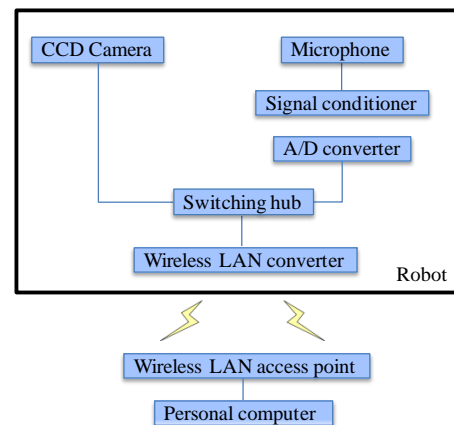
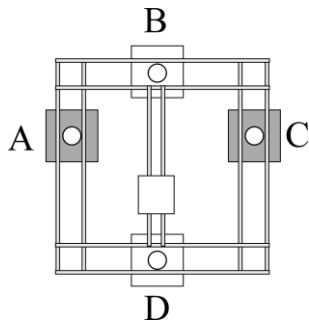
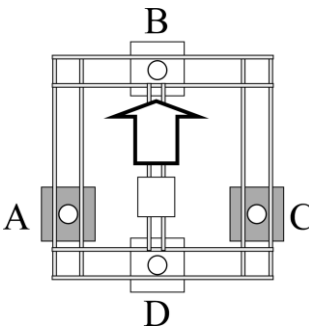


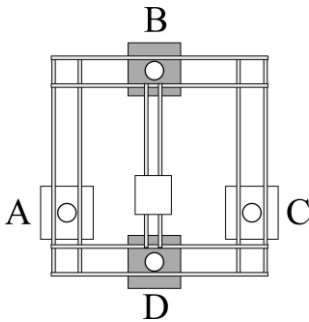
Figure 7: Schematic diagram of a measuring system



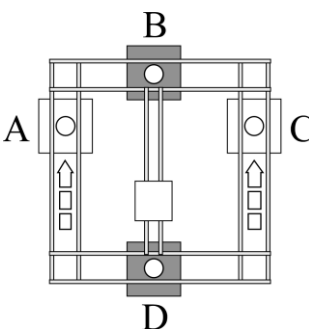
(1) Suction cups A&C power-on



(2) A main part is moved upwards



(3) Suction cups B&D power-on



(4) Suction cups is moved upwards

Figure 8: Mechanism of movement

3 MECHANISM OF MOVEMENT

The move method of the upward direction is shown in Fig. 8. First, (1) the suction cups the A and C power-on and adsorption to wall, (2) A main part is moved upwards. (3) Suction cups B and D power-on (4) suction cups A and C moving upward. The downward movement is possible in reverse operation. It is also possible to move the operation of the left-right direction similarly. This testing machine climbs concrete walls at a speed of one meter a minute. The testing efficiency of this machine is about 10 min/m².

4 VERIFICATION OF WIRELESS MEASUREMENT

For verification of wireless measurement system, an impact acoustic test was carried out on the test specimen. a schematic diagram of the test specimen in Figure 9. The test specimen is pasted tiles to concrete plate of 600mm × 330mm × 48mm. the polypropylene disc, 180mm in diameter, is embedded at a center of the test piece. An impact acoustic test was carried out on two points of the test specimen. As a delamination part, point C is the center of the polypropylene disc. A point A is outside the polypropylene disc, does not delamination. Sampling frequency is 50 kHz.

The experimental results are shown in Figure 10. In comparing the results of point A and point C, a clear peak can be observed in

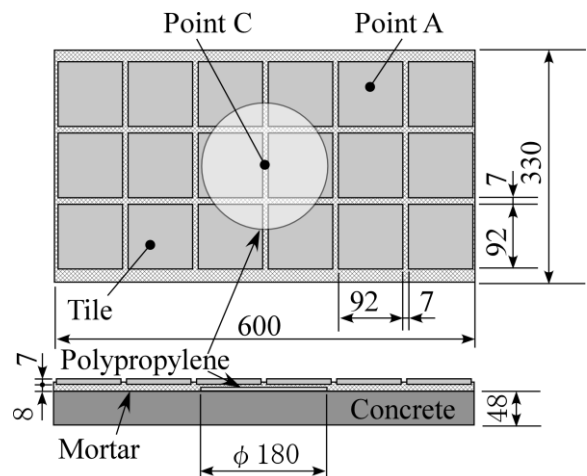


Figure 9: Schematic diagram of a control test specimen

about 3 kHz at point C. It seems that this peak is a frequency of the bending vibration in a delamination part. On the other hand, a clear peak is not observed at point A. Thus, validity of the wireless measurement system has been confirmed.

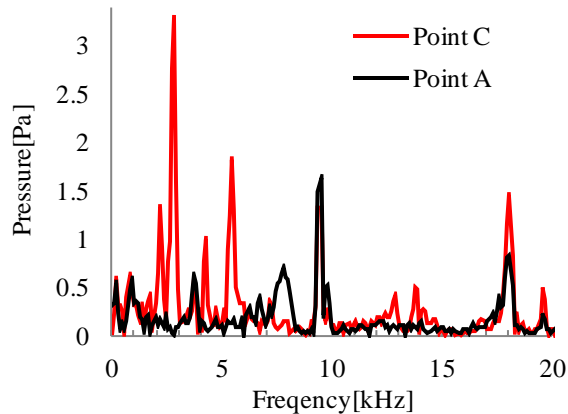


Figure 10: Results of an impact acoustic test

5 CONCLUSIONS

In this study, we developed a testing machine that can move the walls of any angle, and mounting the inspection device of the concrete wall. As a result, we obtain the following results.

(1) Using the four suction cups, the testing machine was developed that can move the walls of any angle. Then, in the experiment in the vertical wall, its performance was confirmed.

(2) A impact acoustic test equipment that can be mounted test equipment was developed, its operation has been confirmed, its motion has been confirmed. An accelerometer can be replaced by a microphone, the device can be easily impact echo method.

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