Advanced pipe inspection robot using rotating probe

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Abstract: Recently many plants' pipes and drains became old and many robots to inspect these pipes were developed in the past. Wired robots were put to practical use, but they had a heavy power supply and a signal wire. Therefore, new inspection robots using wireless radio communication system are considered useful for long complex pipes and long distance pipes including straight, vertical and bend line. But sending wireless radio signals isn't practical because the properties of the radio wave are affected by the shape and material of the pipes. For these reasons, we measured the properties of wireless radio signal with steel pipes and ceramic pipes and we developed a practical wireless radio communication system. On the other hand, the Indian Institute of Technology Kanpur has researched a rotating probe using piezo element for inspecting the inside of pipes with a touch sensor system. This time, we developed and tested a new inspection robot that had integrated both the inspection system using wireless radio communication and image transmission developed by Waseda University and the inspection system using the rotating probe developed by the Indian Institute of Technology. In this experiment, we confirmed that we could drive the robot by wireless radio communication system in the inside test pipe and collect the image and some signals from the rotating probe.

Keywords: Pipe, Inspection robot, Wireless radio communication, Rotating probe

I. INTRODUCTION

Recently many plants became old, so steel pipes, ceramic pipes(earthenware pipes), concrete pipes and plastic pipes used for transportation of water and gas also became old. And, these pipes become cracked because of deterioration and corrosion. Many robots to inspect these pipes were developed in the past, but they had a heavy power supply and a signal wire. As a result, these wires caused problems with the movement of the robot. Therefore in this research, our purpose was to develop a flexible drain inspection robot using a wireless radio communication system. In 2005 and 2007, the radio communication properties inside the pipe were measured in an actual pipe and the appropriate radio frequency was analyzed. As a result, in steel pipe with a diameter of 30cm, the inside image information could be transferred by using radio communication system of 2.4GHz and 5.2GHz for a distance of about 100m. In an actual frequency test earthenware pipe with a diameter of 25cm and length of 20m, it was confirmed that the inside image could be transmitted using a radio frequency of 5.2GHz. On the other hand, the Indian Institute of Technology Kanpur has researched a rotating probe using piezo element for inspecting the inside of pipe with a touch sensor system. We developed the robot with this technique and report that the robot could inspect the inside of the pipe using the inside image information and the rotating probe data with touch sensor.

II. PIPE TRANSMISSION SYSTEM

2.1 Transmission Test in Steel Pipe

Experiment condition using a 10m steel pipe with a diameter of 30cm is shown in Fig.1. In the experiment, we emitted a wireless radio signal from the steel pipe inlet and it was measured in the steel pipe outlet. In the results, we could know the transmission loss in the steel pipe. Fig.2 and Fig.3 shows the transmission loss at different antenna positions respectively for 2.4GHz and 5.2GHz band. The transmission loss from transmitting antenna input to receiving antenna output is 14±6dB for 2.4GHz and 23±6dB for 5.2GHz band.

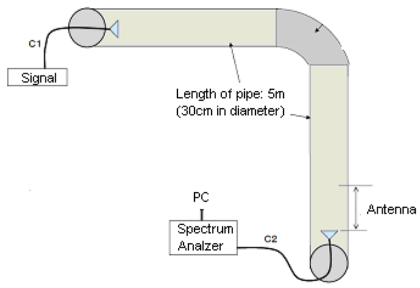

Fig.1. Wireless communication property measurement inside the steel pipe

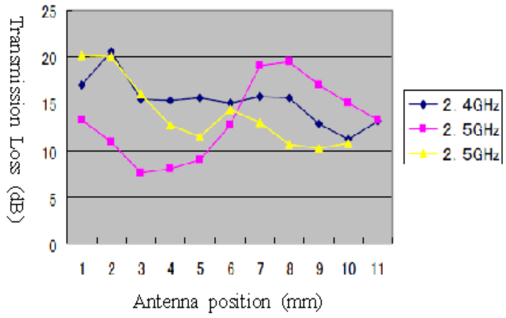

Fig.2. Transmission loss measured in steel pipe (2.4 GHz)

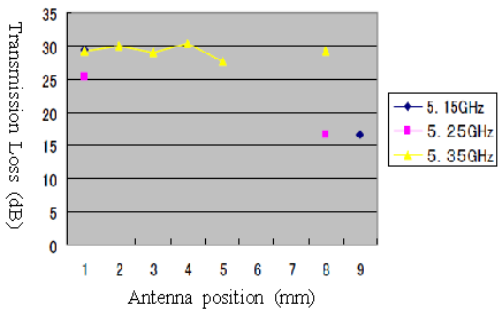

Fig.3. Transmission loss measured in steel pipe (5.2 GHz)

2.2 Transmission Test in Ceramic Pipe

Experiment condition using a 7m ceramic pipe with a diameter of 25cm is shown in Fig.4. This experiment inspected ceramic pipes using a similar method previously used for steel pipes. Transmission loss is 84±2.5dB for 2.4GHz and 52±1.5dB for 5.2GHz band. Fig.5 shows the relative electric field strength between ceramic pipe and free space. It is clear that 5.2GHz band has good performance in the ceramic pipe.

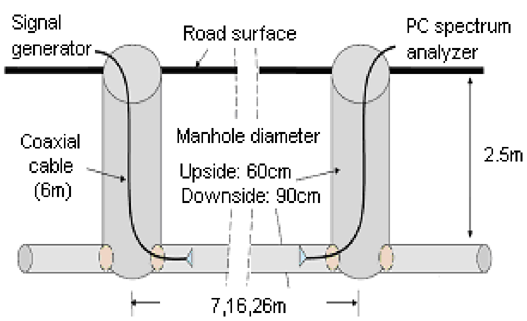

Fig.4. Wireless communication property measurement in the ceramic pipe

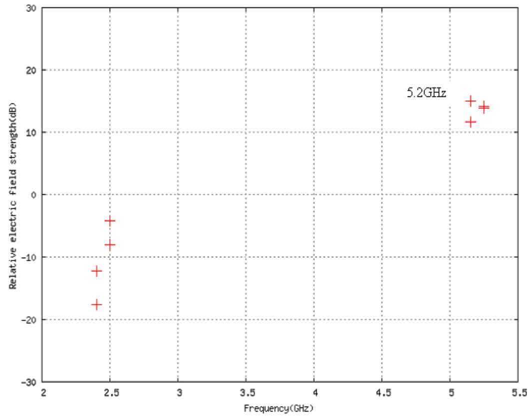

Fig.5. Wireless communication result in ceramic pipe

2.3 Transmission Test in Pipe using robot

Experiment condition using a 19m cleaned ceramic pipe with a diameter of 25cm and 30cm is shown in Fig.6. This experiment inspected transmission loss in ceramic pipes using previously tested robot and also inspected transmission loss in ground and space. And we clarified the relational equation between a pipe's diameter and the possible radio transmission distance in an earthenware pipe , as shown in Fig.7.

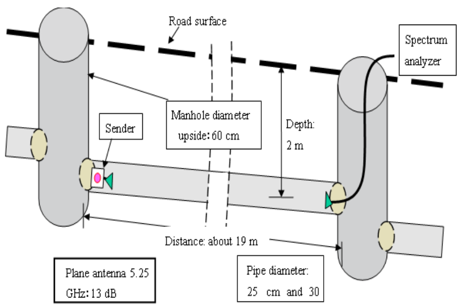

Fig.6. Transmission loss measurement system

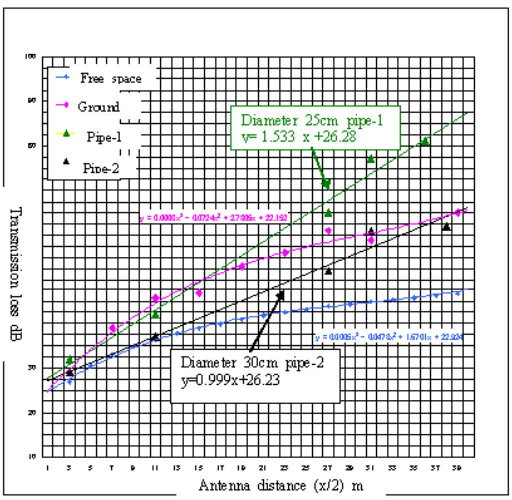

Fig.7. Transmission property

III. DEVELOPMENT OF ADVANCED INSPECTION ROBOT

From these results, we developed a drain pipe inspection robot equipped with practical wireless radio communication system. The robot was developed based on drain pipe inspection robot 'Mogurinko250' by Ishikawa Tekkousyo, as shown in Fig.8. This robot can be controlled by wireless radio communication in the inside pipe and can also transmit image information of the inside of the pipe in real time.

Specifications of this inspection robot:

- Size: length 370mm, width 180mm, height 160mm.
- Moving speed: 13.7m/min,
- Driving mode: double motor,
- Electric Power: rechargeable batteries 7.2V.
- Wireless frequency: apply to 2.4/5 GHz and Data transmission by 100 base-T Ethernet.
- USB Camera(300 thousand pixel)

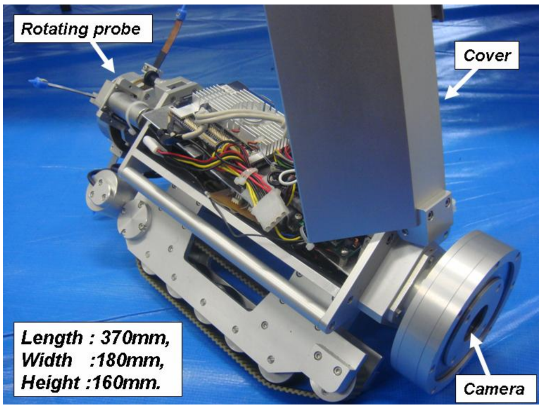

Fig.8. Inspection robot (Mogurinko)

IV. PIPE TOUCH SENSOR SYSTEM

4.1 Structure of Rotating Probe

The Indian Institute of Technology Kanpur has researched a rotating probe using piezo element for inspecting the inside of pipes with a touch sensor system. This time, a drain pipe inspection robot 'Mogurinko250' is equipped with this rotating probe and inspected the ceramic pipes. The four probes are equipped at the back of the robot. The rotating probe consisted of flexible steel and piezo film is positioned at the base of the probe. The steel strip can be used as cantilever. To control the cable of the rotating probe, a slipring was used, as shown in Fig.9.

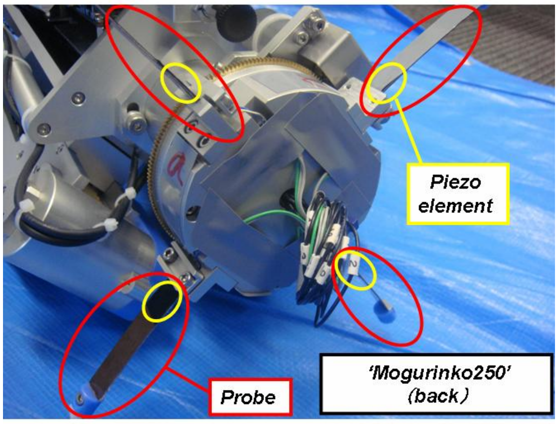

Fig.9. Rotating probe

4.2 Movement of Rotating Probe

When the rotating probe touched the defected area, the piezo film could detect the curve and change of the stress. This stress change of the piezo film can be measured as voltage change. Movement of rotating probe is shown Fig.10. First, four probes rotate and the probes approach the defect of the inside pipe. (Fig.10-①)Next, the probes start to touch the defect and its detected defect. (Fig.10-②,③) Afterward the probe moves away from the defect. (Fig.10-④)

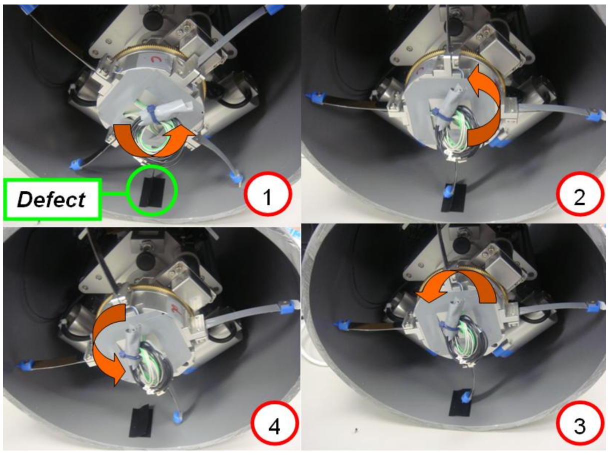

Fig.10. Movement of rotating probe

4.3 Rotating Probe Test in Vinyl Chloride Pipe

This experiment used a resting robot with a rotating probe in a clean vinyl chloride pipe with a 25cm diameter, as shown in Fig.11. Voltage change was measured in free rotation, and when the probe touched defects with heights and width of 5mm, 3mm and 1mm. The defects were made of slices of eraser.

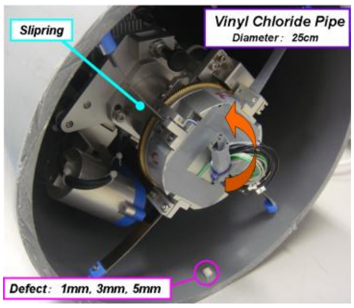

Fig.11. Voltage change measurement in the pipe

Detected voltage change was captured into the microcomputer by A/D converter. The main computer of the robot reads the data through serial transmission using the RS232C cable. The sampling cycle of the A/D converter is 0.01 seconds. These experimental results are shown in figure 12.

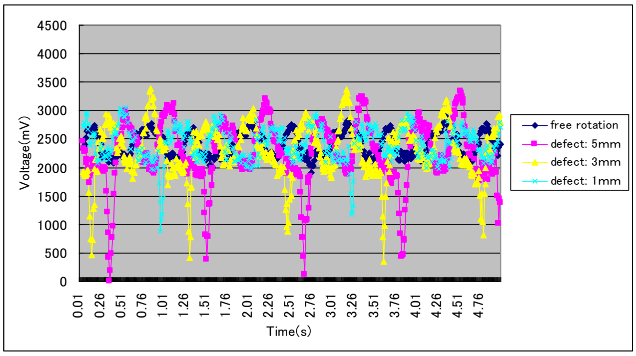

Fig.12. Voltage change using a resting robot

In this result, a probe could measure the defect of 5mm, 3mm and 1mm in the vinyl pipe. When a probe touched the defect, voltage showed a substantial decline. Therefore, we believe that four probes can be used to measure problems in inside pipes caused by corrosion, cracking and breakage. But, after a probe touched the defect, voltage change caused a strong rebound in the probe. For this reason we have to develop a probe using a harder substance.

4.4 Driving Test in Vinyl Chloride Pipe

Next, we carried out a test run with a robot equipped with a rotating probe. This experiment was used by a vinyl pipe, as shown in Fig.13.

Fig.13. Driving test

Fig.14 shows the relative voltage change by driving, and driving with a rotating probe in a vinyl chloride pipe.

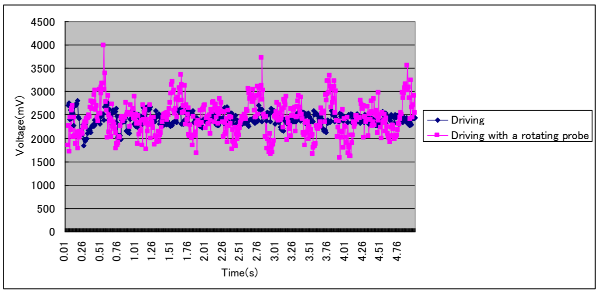

Fig.14. Voltage change in a driving robot

This results shows that the voltage change in driving with a rotating probe is greater than the change in driving with no rotating. This caused by vibration and small defects in the vinyl chloride pipe. In the future, we will try to improve the probe with no vibration and to inspect the real defect while driving.

V. CONCLUSION

In this paper, a rotating probe in vinyl chloride pipe was tested, and a new inspection robot system for drain pipe was developed. In future, we will analyze the image data and the probe data and research the best method for inspecting the defects and increasing the detection ability. In addition, we are going to do research on a smaller robot system and wireless radio communication system for small size's long drain pipe.

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