Advanced Pipe Inspection Robot using Rotating Probe and Image Processing

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Abstract: Recently many drain pipes used for transportation of water and gas at the plants have become old. These pipes have many defects caused by corrosion and cracking and they cause serious accidents because of leakage, fire and blasts. Therefore, to forestall these accidents, we believe it is important to do drain pipe inspections and maintenance using drain pipe inspection robots.

'Rotating probe' and 'Image processing' are used for the method of inspecting pipe in this research. Then, the development of the Pipe Inspection Robot measures the irregularity and the form of the defect in pipe. Therefore, this robot using the rotating probe of this touch sensor is profitable.

Keywords: Drain pipes, Pipe inspection robot, Rotating probe, Image processing

I. INTRODUCTION

Recently many drain pipes used for transportation of water and gas at the plants have become old. These pipes have many defects caused by corrosion and cracking and they cause serious accidents because of leakage, fire and blasts. Therefore, to forestall these accidents, we believe it is important to do drain pipe inspections and maintenance using drain pipe inspection robots. A lot of pipe inspection robot that uses image processing has been developed up to now. However, whether it is a defect or a pattern might not be understood only from the image processing. Then, the presence of the defect is confirmed with a touch sensor. In this research, the composition of the robot is described, and the image processing, the explanation of the rotating probe, and the outcome of an experiment are described. Subsequently, I describe the future plans.

First of all, the video shooting in pipe is done as a flow of the system of the picture processing. Next, the confirmation and the correction of a center point are done. Finally the developed figure of the video image is made by development of the image and correcting the seam. The recording cameras of the image processing are 300,000 pixels CCD.

Next, the probe (sensor) that enabled the defect detection was developed. The performance experiment of the sensor is installed in the rotational mechanism of 'Mogurinko 250' by 'Ishikawa iron works Ltd'. In separate research, the Indian Institutes of Techonology Kanpur has researched a rotating probe using piezo element for inspecting the inside of pipes with a touch sensor system. It explains the composition and the operation of the probe, and the outcome of an experiment in the made pipe model is shown.

II. ROBOT STRUCTURE

In this research, the robot of 'Mogurinko 250' by 'Ishikawa iron works Ltd' was used. This robot has CCD camera in the front and the rotating probe was installed in the back. Fig.1 shows the appearance diagram.

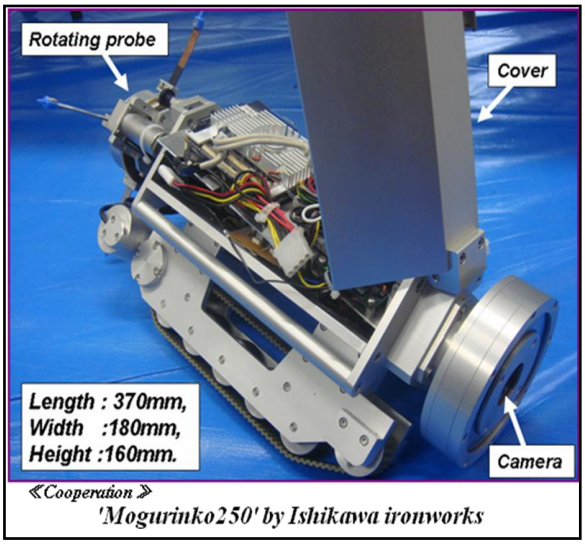

Fig.1 The appearance diagram of robot

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)

III. IMAGE PROCESSING METHOD

The image processing to be a center point correction of pipe and develop of the image, it is very difficult to recognize the defect based on video in pipe. Then, the image is converted from circular image to zonal image and the inside of pipe is vertically seen. It becomes easy to recognize the defect by processing it like that.

3.1 Center Point Correction

The obtained video doesn't necessarily have the center of the pipe at the center of the image. Accordingly, the center of the pipe is found and it is necessary to process the image centering on the point.

Center point correction method is ' Hough transformation method ' and ' Least squares method '[1]. Fig.2 is the second order polynomial approximation.

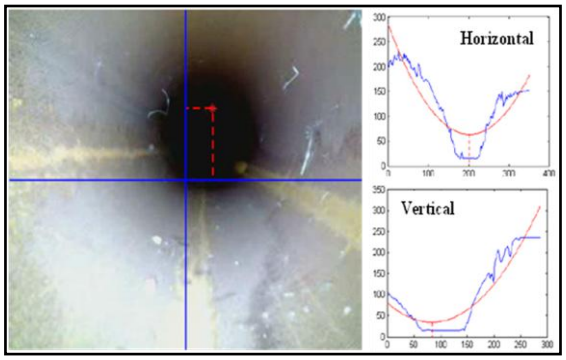

Fig.2 Least-squares method

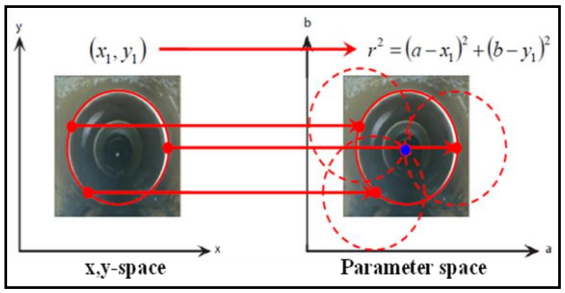

Fig.3 Hough transformation method

3.2 Zonal Image Making

When a center point is found, circular image is developed to the zonal image. The acquired image is taken by perspective. Therefore, the correction is put, and a circular image is converted to a zonal image.

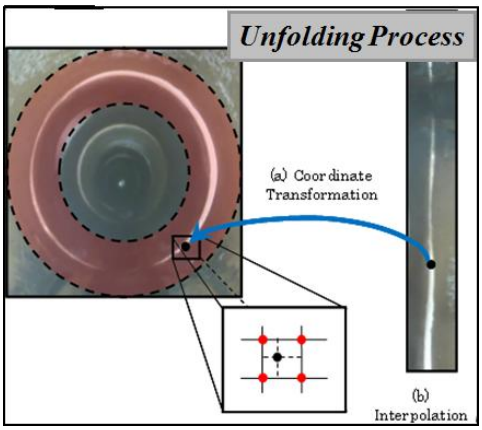

Fig.4 Zonal image making

3.3 Development Image Making

When an arbitrary zonal image is made, a zonal image is continuously made. And, the image of development in pipe is made by joining it.

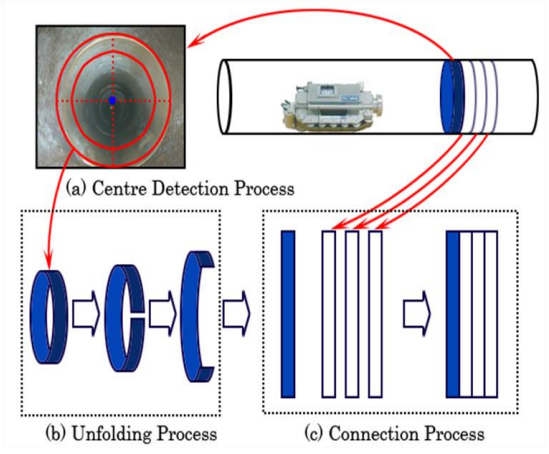

Fig.5 Development Image

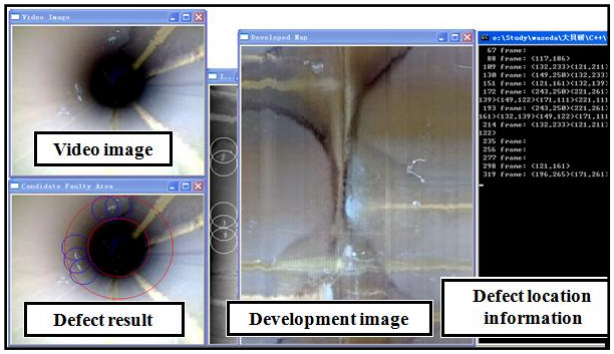

Fig.6 Image processing result

IV. ROTATING PROBE METHOD

4.1 Structure of Rotating Probe

The probe consists of spring 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 steel strip was used, as shown in Fig.7

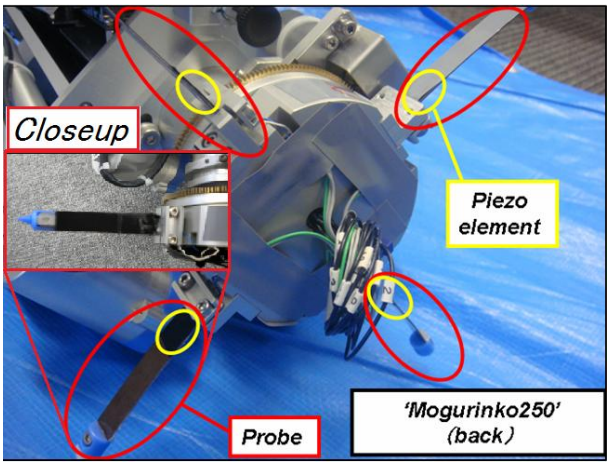

Fig.7 Rotating probe

4.2 Operating Principles of Rotation 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.8.

First, four probes rotate and the probes approach the defect of the inside pipe. (Fig.8-①)Next, the probes start to touch the defect and its detected defect. (Fig.8-②.③) Afterward the probe moves away from the defect. (Fig.8-④)

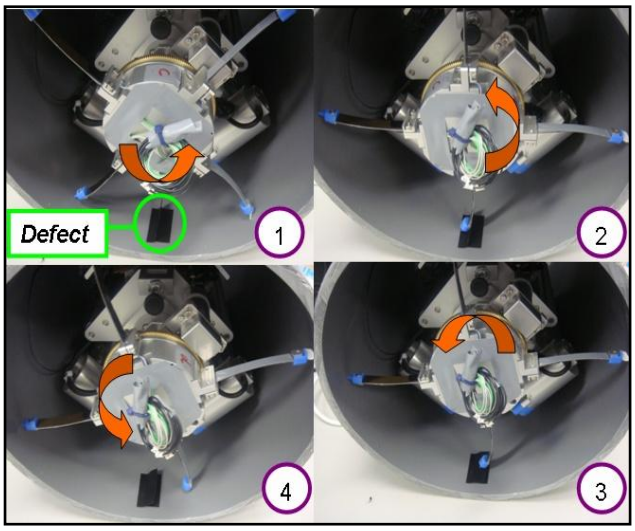

Fig.8 Movement of rotating probe

V. Performance experiment of Probe

This experiment used a resting robot with a rotating probe in a clean vinyl chloride pipe with a 25cm diameter, as shown in Fig.9. The defects were made of slices of eraser.

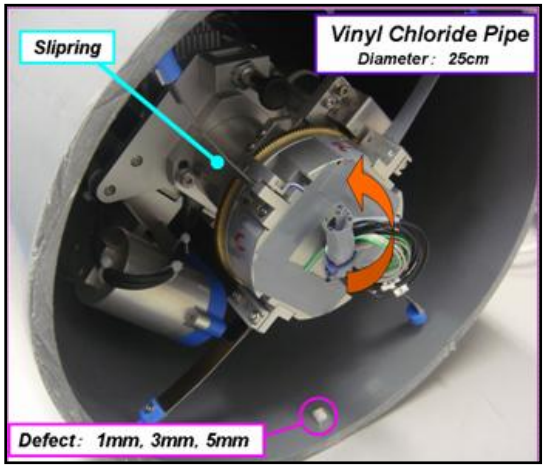

Fig.9 Experiment Conditions

5.1 Data Capture Method

The voltage change happens from bending of the probe. The voltage change is taken into the microcomputer. And, it displays it in CPU of the robot by using serial communications. The sampling period at this time is 0.01 seconds. The microcomputer used H83664tiny microcomputer. Fig.10 shows the appearance diagram of microcomputer.

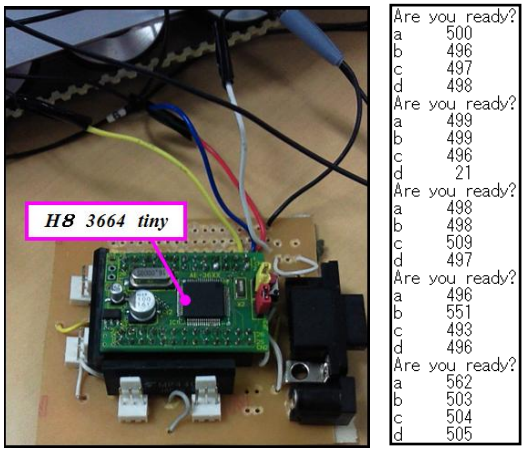

Fig.10 The appearance diagram of microcomputer.

5.2 Experiment Method

The experiment doesn't drive the robot, and operate only the rotation probe. And probe touched to the defect of experimental object. What voltage change happens is measured as a result.

Table.1 shows the experimental condition.

Table.1 Experimental condition.

Experiment 1 (Fundamental feature of Probe)	Defect form : Cube , Cuboid (Height : 10mm , 6mm , 3mm , Width : 10mm)
Experiment 2 (Detection of continuous defect)	Defect form : Five cubes (Height : 10mm , Width : 10mm)
Experiment 3 (Change on defect)	Defect form : Three cuboid (cube) (Height : 10mm , Width : 50mm , 30mm , 10mm)
Experiment 4 (Change according to form)	Defect form : Semicircular (Diameter : 40mm , 30mm , 20mm) Defect form : Equilateral triangle (Sides : 20mm)
Experiment 5 (Damage experiment)	Defect form : Concave type (Width : 10mm , 6mm , 3mm)

5.3 Experimental Environment

Figure of each experimental condition is enumerated as follows.

- Experiment 4

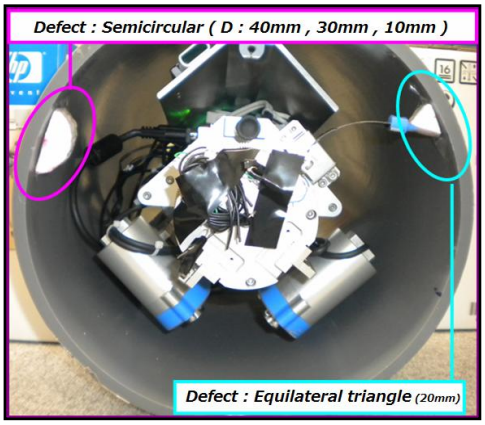

Fig.11 Defect form: Semicircular and Equilateral triangle

- Experiment 5

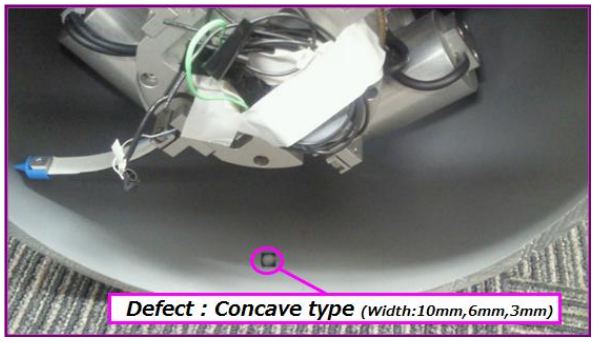

Fig.12 Defect form: Concave type

5.4 Experimental Results

The Table.2 and Table.3 shows the outcome of an experiment.

Table.2 Experimental Results (Size)

Condition of defect	Voltage [mV]
Defect type : Cube(Height:10mm)	More than 3,000
Defect type :Cube(Height:6mm,3mm)	About 2,700
Defect type : Concave(Width:10mm)	About 900
Defect type : Concave(Width:6mm)	About 1,700
Defect type : Concave(Width:3mm)	About 1,900

Table.3 Experimental Results (Form)

Condition of defect	Voltage change
Defect type : Cuboid (Width:50mm,30mm,10mm)	▪ Irregularity on defect surface ▪ Width of defect
Defect type : Semicircular (Diameter:40mm,30mm,20mm)	▪ Smoothly increase, and decreases.
Defect type : Equilateral triangle (Sides:20mm)	▪ Fixed part and the tip of the probe. (Two times)

VI. AUTOMATIC DEFECT RECOGNITION METHOD

Automatic defect recognition method was made based on these outcomes of experiments. Fig.13 shows the algorithm of automatic defect recognition method.

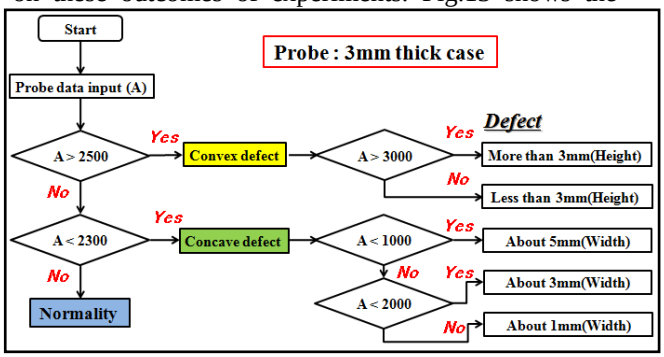

Fig.13 Pipe inspection algorithm

VII. CONCLUSION

In this paper, a rotating probe in vinyl chloride pipe was tested, and a new inspection robot system for drain pipe was developed. Moreover, the image was processed, a circular image was developing, and it was possible to make it to a plane image. In the future, these two researches are combined, and the defect diagnostic system with good accuracy will be made. And, it actually experiments in pipe.

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REFERENCES

[1] Zhicheng Wang, Harutoshi Ogai, Shigeyuki Takahiro, "Real-time Generation of Developed View for Sewer Pipe Based on Web Camera Video", The 15th International Symposium on Artificial Life and Robotics 2010, CD-ROM, papers,OS3-4,2010,Beppu,Japan.
[2]Kentarou Nishijima, Yixiang Sun, Rupesh Kumar Srivastava, Harutoshi Ogai and Bishakh Bhattacharya, "Advanced Pipe Inspection Robot using Rotating Probe", The 15th International Symposium on Artificial Life and Robotics 2010, CD-ROM, papers,OS3-2,2010,Beppu,Japan.