NDT Inspection Mobile Robot with Spiral Driven Mechanism in Pipes

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***Abstract* -- This paper describes an NDT inspection mobile robot to drive 100m away with inspection module in 10cm pipes. A spiral driven mechanism was adopted to obtain a high traction force. The inspection module was made with a camera and four laser sensors. This module can find out 1mm size defects with a laser image sensor and recognize damages of the pipes using the camera. The mobile robot was tested in a real scale pipe mock-up and verified the function of mobility and accuracy.**

***Index Terms*--Spiral driven mechanism, In-pipe inspection robot, NDT (Non-Destructive Test), Small pipes.**

I. INTRODUCTION

Pipes are the fundamental components of infrastructure facilities such as thermal/nuclear power plants, an oil refinery, service water supply/drain, chemical plants and so on. A malfunction in pipes is caused by aging, fatigue and stress corrosion cracking.

Cracking and deterioration of the pipe cause rupture of the pipe. Therefore, to avoid these problems, periodical inspection of the pipes is required. However, the limitation of the pipe space and a complicated passage prevents a full length inspection of the inner pipes. Generally, NDT inspections are carried out outside the pipes for finding defects using an X-ray or ultrasonic sensors. Reliability of the pipe inspections can't be assured and dismantling/reassembling of the insulations of the pipes took a longer maintenance time and higher labor charge. To solve these problems, a lot of researches and developments have been performed for an inspection mobile robot to find defects by moving inside [1-5].

To inspect long distance of over 100m for small size pipes diameter is one of the important research targets. This system carries an image acquisition camera and laser sensors for measuring the diameter and checking defects in the piping. The driving mechanism of the spiral movement method was applied to maximize the motive power of the mobile robot. Traction for a long-distance running test of the mobile robot is performed in the manufactured 100m mock-up pipes.

II. A MOBILE ROBOTIC INSPECTION SYSTEM

A. Configuration of In-pipe Inspection System

Fig. 1 shows the overall configuration of a mobile robotic inspection system. This system is composed of a camera module and two mobile robots. Mobile robot 1 towed a camera module and electric wire of 40m length. To compensate the traction force decreased by friction force between the cable and pipe, mobile robot 2 is connected to the back of the cable. It is then possible for the entire system to pull a section for 100m or longer. Mobile robots '1' and '2' include a power line communication unit, power supply unit, a motor driver, and a sensor processing unit. A camera module consists of a laser sensor, lighting, and high-resolution camera.

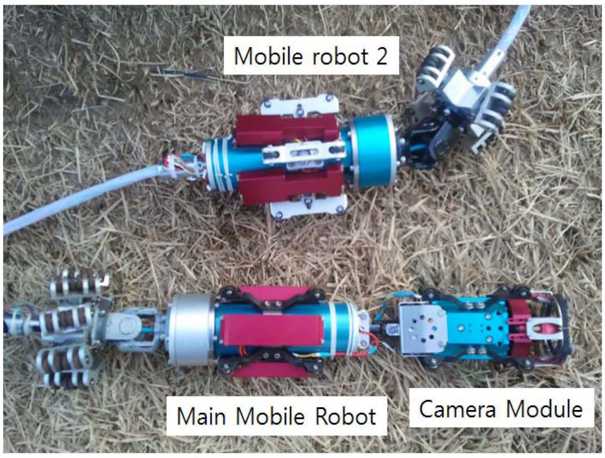


Fig.1 Configuration of in-pipe inspection system.

B. In-pipe mobile robot with spiral driven mechanism

The size of the motor used in the mobile robot is small, so the torque of motor is limited. This paper proposes a method of driving to rotate auxiliary wheels at certain inclined angle to overcome this problem.

Fig. 2 shows a detailed design of the in-pipe mobile robot. The output part of the motor and driving wheel was connected using a universal joint to move easily bent area. A motor output portion and a universal joint was designed using a hollow type mechanism to prevent a twisting of the connecting wire. Each driving wheel has 8 roller assemblies in contact with the pipe at the inner surface. There are 4 rollers supporting one point, the roller assembly was designed such that 32 rollers are hold in the pipe. The roller assembly is supported by a spring with some margin displacement to overcome obstacles or irregular boundaries in the pipe.

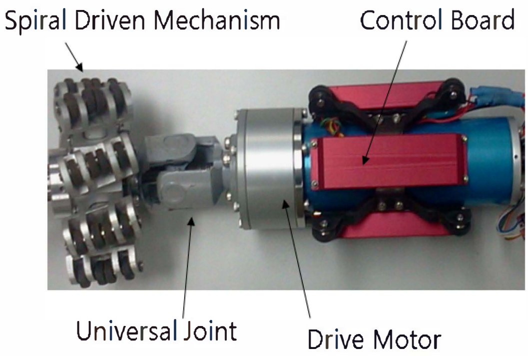


Fig.2. In-pipe mobile robot with spiral driven mechanism.

III. CAMERA MODULE

A. *In-pipe Inspection using Camera Module*

Fig. 3 is a camera module to be mounted on a mobile robot. The camera module consists of a high-resolution camera system for the transfer and acquisition of the video, lighting for visual inspection, quantity expression distance measuring sensor for measuring the distance traveled, communication units for power line communication, power units, a processor board for sensor data processing, and communication/control. The external frame was applied a skeleton structure to reduce the weight in dividing into a lot of structure parts. A spring structure is applied to minimize the shaking caused by deflection when the robot move the inner space of the pipe. The universal joint was applied between the camera module and the mobile robot in order to pass smoothly not only in straight sections but also at bent tube points.

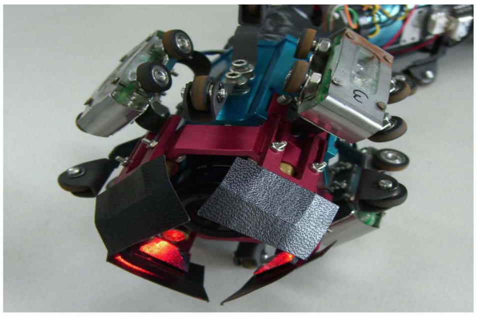
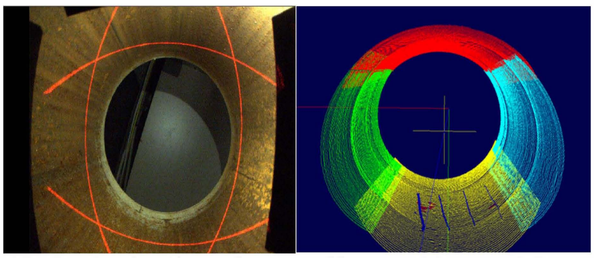


Fig.3. Inspection Module mounted camera and laser sensor.

Fig. 4 shows the visual inspection screen used to reconstruct the pipe interior with a laser sensor and camera. Fig. 4(b) shows the detected defects inside pipes.



(a) View for visual inspection. (b) result of detecting defects.
Fig.4. Inspection results using camera module.

B. *Driving test*

Fig. 5 shows a test set of 100m for a long-distance running test of the mobile robot. The mobile robot was verified for a long-range mobility in a pipe.

Fig.5. Pipe mock-up for driving test.

IV. CONCLUSIONS

This paper described the research and development of a compact mobile robot system for inspecting the inside of small diameter piping under 10cm. Non-destructive inspection module was developed with laser sensors and a camera. The camera module detected defects inside pipes successfully for 1mm. A spiral driven mechanism was adopted to maximize the driving force. A mock-up of the pipes was manufactured and a test was carried out with the developed in-pipe mobile robot. The mobile robot system travelled up to 100m distance of the pipe, which showed applicability in the field of plant industry.

ACKNOWLEDGMENT

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