Abstract of Doctoral Thesis

Title：Study on Traveling through Bent and Branch Pipes for Pipe Inspection Robots

Doctoral Program in Advanced Mechanical Engineering and Robotics
Graduate School of Science and Engineering, Ritsumeikan University

かこがわ　あつし
Kakogawa Atsushi

The study of pipe inspection robots, which can check inside dark and narrow pipelines instead of humans, has been expected last few years to survey the deterioration of the aging pipelines. Various kinds of pipe inspection robots have been studied and developed by several research and educational institutes and companies so far. However, existing studies consider that bent and branch pipes are one of the biggest obstacles; improvement for the mobility through them is a serious issue. It is recognized that a T-branch, where two pathways are perpendicular to each other, is the most difficult challenge among the branch pipes.

One of the possible factors which affect the mobility of the robot inside the pipelines is the contact state between the robot and the inner wall of the pipe. This state depends on the specific spatial constraints of the robot to expand in the pipes. Therefore, this thesis presents basic theory for passing through bent pipes and T-branches using a screw-driving pipe inspection robot as an articulated active joint type, which can be downsized easily, and a three modular pipe inspection robot as a coupled driven type, which can generate high traction force. Additionally, a description about the design and control method for both of them is included.

First of all, in the theory for passing through bent pipes, a common methodology which can be applied to both, the screw-driving type and the three modular type, is proposed. This is because contact points can be easily estimated in a continuous bent pipe. This common theory is also used for the design of the robot. On the other hand, contact points in the T-branch cannot be estimated easily as it is not continuous. Therefore, different theory for the screw-driving type and the three modular type in T-branch pipes is discussed.

Secondly, in the design of the screw-driving type, a new pathway selection mechanism, which enables pitch and yaw steerings using only a single motor, is proposed. The arm length and spring stiffness of the contractile mechanism is designed based on the spatial constraints obtained by the theory abovementioned. In the design of the three modular type, a new mechanism, called an underactuated parallelogram crawler, is proposed to solve the problem when the pipeline changes its diameter, which the existing robots have not been able to easily overcome. The gear ratio of the mechanism is designed using static analysis to get the ideal motion of the crawler. Control method for each module is proposed based on the spatial constraints obtained by the theory previously explained.

At last, experimental verifications of the screw-driving type and the three modular type are conducted in bent pipes and T-branches. From the results, performance of each robot type in both of them are comprehensively evaluated and future work is discussed. Even though problems left in the experiment of the T-branch, it was found that the robots can pass through the bent pipe efficiently.