In-pipe Robot with Capability of Self Stabilization and Accurate Pipe Surface Cleaning

Luis A. Mateos and Markus Vincze

Abstract—After 50 years the connections between fresh water pipes (800-1000mm diameter) need to be repaired due to aging and dissolution of the filling material. Only in Vienna 3000km of pipes need to be improved, which requires a robotic solution. The main challenge is to accurately place the robot in the center of the pipe while overcoming the push back forces and vibrations caused in the cleaning process, so that the cleaning tool is able to focus on desired area of the pipe surface. This paper presents the overall design of an in-pipe cleaning robot DeWaLoP, which includes a suspension system to position itself as a rigid structure stably in the center of the pipe, while the II configuration of the robot arm is able to stabilize the cleaning tool in the cleaning process, to reduce the vibration and push back forces.

I. INTRODUCTION

Fresh water pipelines are prone to damages due to aging, excessive traffic and geological changes. Resulting from these damages, the pipe-joints may not be completely hermetic and water loss along the pipeline may occur. Leakage is not only a problem in terms of wasting an important resource, it also results in an economic loss in form of damages to the supplying system and to foundations of roads and buildings too [1] [2].

The installation or replacement of pipelines implicates high cost and use of heavy machinery, such as cranes. In addition, side effects may occur, such as constructions sites placed along streets, blocking pedestrian and traffic tracks [3]. The size of pipes transporting water between residential areas and industrial parks is normally ranged from 800mm to 1200mm in diameter, which make it possible for one man to enter. Consequently, human operators can access the pipe and attempt to clean and repair it, as shown in figure 1. Nevertheless, this creates a special situation that presents safety and health risk to the human operator [4]. Currently, the applications of robots for the maintenance of the pipeline utilities are considered as one of the most attractive solutions available. Nevertheless, to substitute skilled human operators, pipe redevelopment requires mechanisms with high degree of mobility, able to move along the pipeline, overcoming obstacles, extreme environments, and with high accuracy clean and repair specific areas of the pipe [5] [6] [7].

The most common method to clean the pipe is using water jet, as this method does not require accurate positioning of the robot inside the pipe. However, the water pressure has disadvantage of damaging the pipe-joint hemp pack which is caulked up with a lead ring. Thus, we adopt a cleaning method which is using wire brushes disks and grinding heads to remove the corrosion of the pipe by friction. By auto suspension system, our robot is able to fix its in-pipe position accurately to support the cleaning tool system to focus on specific areas.

II. RELATED WORK

In-pipe cleaning robots can be categorized to two types: 1) Pressure-based cleaning robots and 2) Tool-based cleaning robots. In this section, we present the typical in-pipe cleaning robots developed both from academia and industry.

A. Pressure-based cleaning methods

J. Saenz [8] presents a cleaning system able to work efficiently and control the pressure of the nozzle through a relative accurate positioning to the pipe wall. They commented "A common risk when cleaning with high pressure water is the possible damage to the surface from overly applied pressure. This risk can be minimized with such a cleaning system where the cleaning parameters can be carefully controlled and monitored". Even if the pressure can be controlled, for cleaning pipe-joint this is not recommended, due to the pressure exerted by the water, pushing the hermetic seal of the pipe-joint.

B. Tool-based cleaning - Impact abrasion methods

1) GRISLEE - Gasmain Repair and Inspection System for Live Environment: The GRISLEE is designed to be modular, so different kinds of in situ repairs are possible. The cleaning system consists of flails, which expand when rotates and cleans the surface by impact abrasion method. The system has a compact size, and is able to work in different pipe sizes [9].

2) Umbrella mechanism: The umbrella mechanism consists of a structure able to increase its height in order to adapt to different pipe diameters. The cleaning system is similar to an umbrella kind open-and-close mechanism, which makes the robot highly adaptable to different pipe sizes [10].

Commercial cleaning system such as Robocutter [11], KASRO robot [12], OptiCut [13] and IMS Turbo cutter [14] are smaller robots but use similar design like the umbrella mechanism. Lacking of stability, due to the push back effects and vibration caused in the cleaning process.

C. Tool-based cleaning - Cutting methods

mechanism is an arm consisting of small cutting plates. The arm is located on the front of the robot, perpendicular to the pipe’s horizontal with the same length as the inner-pipe’s diameter. From this configuration, the cleaning method consists of rotating the arm, milling all corrosion while the robot moves inside the pipe. Although the mechanism is able to remove strongly incrusted corrosion. The drawback of this configuration is the low flexibility of the cleaning tool to pipe displacement. In other words, the cleaning mechanism will damage the pipe if the pipes are not perfectly aligned.

C. D. Jung [16] proposes an in-pipe cleaning robot with the 6-link sliding mechanism which can be adjusted to fit into the inner face of the pipe using pneumatic pressure. The proposed in-pipe cleaning robot have self forward/backward movement as well as rotation movement of brush. However, the disk cleans all over the in-pipe wall without being able to focus on a specific area.

In contrast to the state-of-the-art cleaning mechanisms, DeWaLoP in-pipe robot is able to fix itself stably in a specific location using self suspension system. Independently from the main body of the robot, the cleaning tool is flexibly configured which can be adjusted in a cylindrical 3D space, able to move up to 100mm in the pipe’s horizontal axis, and reach to the surface of the pipe with diameter in the range of 800mm to 1000mm.

Besides its high positioning capability and flexibility, the cleaning mechanism is able to overcome vibrations and jump back forces from the cleaning tool with its integrated suspension system, mimicking the reaction of a human operator when such events happens.

REFERENCES