INTERNAL ROBOTIC TOOL FOR REMOTE WALL CONDITION ASSESEMENT AND INSPECTION OF RISING MAINS

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KEYWORDS

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ABSTRACT

Collaboration between Sydney Water Corporation (SWC) and the University of Technology Sydney (UTS) over the period 2017-2019 has resulted in two water mains wall inspection robots which are currently being successfully deployed in SWC water mains network, providing valuable non-destructive condition assessment for SWC maintenance and renewal program. These robots are not suitable for deployment into Sewer Rising mains, and two new robots are being designed with a specification requirement adapted to meet the needs of the Sewer Rising mains team at SWC.

Over the period 2020-21, The project involves the development and delivery of two deployable robotic tools designed for condition assessment of sewer rising mains, in cohorts including 250-450mm, and 450-750mm respectively. The robots have the capability to traverse and assess remaining pipe wall thickness and report the internal geometric condition of the main through 3D mapping and standard camera visuals. This information is relayed back to an operator in real-time and also recorded for later review.

INTRODUCTION

Sewer discharges result in effluent/sewerage leaking into local creeks/catchments from the associated network of sewer pipes, sewage pumping stations and sewer overflow structures. The NSW EPA regulates SWC's activities through a series of licences with strict, legally enforceable conditions with the objective to protect and minimise harm to the environment and public health from sewage discharges.

While coarse estimates of a pipeline integrity can be inferred from local environmental data, direct scanning of the pipe wall offers a conclusive measurement of remaining wall thickness, allowing accurate estimation of remaining asset life.

Generally, this is done by excavating and externally scanning the pipe wall, a costly and disruptive exercise, made even more challenging when logistics around sewage management need to be accounted for. A more cost-effective alternative is the internal inspection of larger sections of an asset from singular access points while the main is isolated.

It has been assessed that currently operating robotic devices developed between SWC and UTS for water mains condition assessment **[1,2]** can be suitably adapted and expanded to address the needs of assessing pipe wall thickness and the condition of cement lining geometry present in sewer rising mains. Providing these assessments will minimise the need for maintenance work to isolated pipe segments, which in turn will reduce the risk of financial and environmental impacts.

To help SWC capitalise on this opportunity, UTS and SWC are embarking on a project to develop two world-leading robotic condition assessment of rising mains that can traverse inside a dewatered rising main and non-destructively asses the remaining pipe wall thickness. They are fitted with additional sensing capability to also report on the internal pipe 3D geometries (cement lining or exposed bare metal), and standard camera visual streaming. This information is relayed back to an operator in real-time, and also recorded for later review. The first of two tools has been manufactured and was subjected to its first field test on a Sydney Water Rising Main asset in February 2021, as described in the manuscript (see Fig. 3).

Table 1 Specifications Summary Table

	Robot 1 (larger pipes range)	Robot 2 (smaller pipes range)
Scanning speeds (mm/s)	100	100
Diameter range (ID)	450mm-750mm	250mm - 450mm
Deployment range (m)	- Minimum: 100 - Ideally: 500	500
Thickness sensing	- Minimum: will be able to inspect crown and invert. - Ideally: more dense coverage	- Minimum: will be able to inspect crown and invert. - Ideally: more dense coverage
Pipe material	- Minimum: CI / CICL - Ideally: also DICL & MSCL	- Minimum: CI / CICL - Ideally: also DICL & MSCL
Sensing modalities	- PEC (wall thickness) - CCTV (internal video) - Above-water 3D (internal pipe/CL geometry)	- PEC (wall thickness) - CCTV (internal video) - Above-water 3D (internal pipe/CL geometry)
Water-proof rating	IP68 (1 meter for 1 hour)	IP68 (1 meter for 1 hour)
Inclination (degrees from horizontal)	Minimum: up to 15 degrees	Minimum: up to 15 degrees
Bends	Variable per diameter (cohorts from 254 to 762mm). Minimum bend vertical and horizontal for both robotic tools: 11.25°	
Entry mechanisms (options)	- Pump station - Discharge maintenance hole - Open pipe or blank flange (pit) - Reflux valves	- Pump station - Discharge maintenance hole - Open pipe or blank flange (pit) - Reflux valves
Weight (kg)	Max. 35kg	Max. 30kg
Tether specifications	- Live communication for operator - Safety rated for > 400kg - Low friction	- Live communication for operator - Safety rated for > 400kg - Low friction

HIGHLIGHTS

- UTS and SWC are developing two world-leading internal pipe scanning tools for metallic rising mains.
- Thickness maps over substantial lengths allow targeted renewal decisions.
- The robotic tool produces a wall thickness map 360° and up to 500m in length.
- The first robot targets larger Cast Iron Cement Lined (CICL) rising mains, range 450mm-750mm. Field deployment of the device has begun as on Febuary 2021.
- The second robotic tool targets a smaller range of CICL rising mains, 250-450mm rising mains. The device is at the design stage.
- The pipe material sensed by the robot is planned to be subsequently extended to Ductile Iron Cement Lined (DICL) and Mild Steel Cement Lined (MSCL).

PROCESS

Tool Design Specifications

An initial assessment of the SWC rising mains assets in terms of critical risk has been undertaken to understand the most effective sets of specifications to drive the robot design, included in Table 1. Altogether, the two proposed robotic inspection devices combined will be able to cover a diameter range of 250-750mm, hence covering:

- 70% of CI/CICL and 80% of CI/CICL/DICL/MSCL of the top 20 risk-assessed SWC pipelines.
- 56% of CI/CICL and 78% of CI/CICL/DICL/MSCL of the top 100 risk-assessed SWC pipelines.

Tool 1: 450-750mm

The first robotic tool has been designed, manufactured and tested. It consists of two bodies, the first being a locomotion body housing drive motors, a battery and various electronics. The second body is a sensing unit consisting of several Pulsed Eddy Current sensors on a compliant actuated expansion mechanism. The connection between these bodies allows for bending on the horizontal plane which is neccesary for the system to navigate horizontal bends in the pipes. The bending mechanism is passive and spring forces restore the robot to a linear orientation after navigating a bend.

Careful material selections have been made as to provide good chemical compatiability with 1% Sodium Hypochlorite (bleach). This is important as the tool will be cleaned and disinfected after each sewer deployment and should not exhibit material degredation which could affect functionality and its lifetime. Further to this, numerous static and dynamic o-rings, as well as rubber bellows have been incorporated to protect sensitive parts and components from fluid and disinfectant.

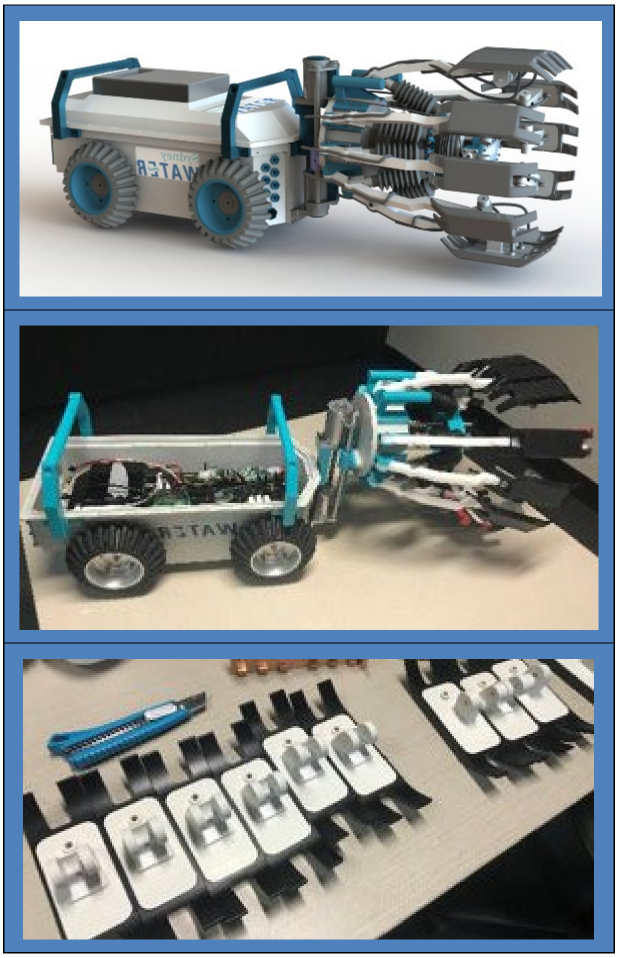

Figure 1 Robot 1 for diameters 450-750mm.

Tool 2: 250-450mm

The second robotic tool is currently nearing the completion of the design phase. As this tool is required to operate in significantly smaller pipes fitting all necessary electronics inside a smaller drive unit proved to be difficult without significantly increasing the length of this body. This is however undesirable since increasing the length of the drive body makes navigating tight bends, particularly in the smaller pipes, challenging and practically impossible for tighter bends.

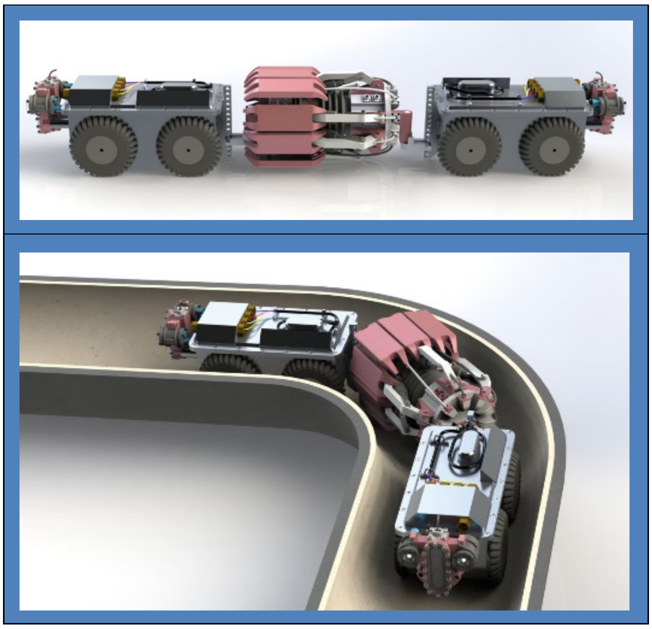

Figure 2 Robot 2 for diameters 250-450m.

An alternative arrangement has been investigated which consists of two driving units on each side of the sensing body. Introducing two drive carts allows the electronics to be distributed which maintains a relatively short length of each body. Universal joints are incorporated between each of the bodies in the system allowing it to articulate and thus be able to navigate bends in both the vertical and horizontal planes.

Tool output

The robotic tools are equipped with multiple sensors:

- Pulse Eddy Current – PEC - NDT sensing technology to measure pipe wall thickness.
- 3D camera to map the internal geometries of the dewatered pipe.
- Standard RGB camera for visual streaming.

The robot mechanism ensures that PEC sensors are in contact with the internal cement lined walls of the pipe.

Interpretation algorithms analyse the signal acquired by on-board electronics to obtain the remaining pipe wall thickness under each of the sensors. After deployment, the information is used to produce a condition assessment report to aid the asset planner in their decision making process about asset renewal, repair or otherwise.

OUTCOMES

Preliminary analysis of the remaining pipe wall thickness data collected by the robots designed for the critical CICL water mains network **[1,3]** points towards a conservative estimate of at most 30% of localised pipe lengths needing replacement once fully inspected by the proposed robotic tools.

Assuming this trend continues in the sewer rising mains, financial savings can be estimated up to $5,000,000 over the next 4-5 years assuming 25 planned inspections take place. This takes into account the financial aspect of replacing/repairing damaged or leaking pipes, as well as potential environmental impacts caused by sewerage effluent.

FIELD DEPLOYMENT

The first field deployment of Tool 1 occurred in Febuary of 2021. The initial deployment was in a 500mm diameter sewer rising main in close proximity to a pumping station. The primary outcome of this field deployment was to verify all navigation aspects of the system held up to real world scenarios. The tool was deployed into the pipe via a removed spool in a temporary pit and traversed just over 90m along it's length. RGB and 3D camera data was assessed over the run and the performance of the mechanical drive system and sensor expansion mechanism were monitored. The safety retrieval system was also tested which entailed lack of power to the drive motors and actively retriving the robot with the automated cable winder and the communication cable which also acts as the safety tether. The tool was succesfully retrieved with no issues whilst motors were passively backdriven. This verification of the mechanical systems of both the robotic tool as well as the safety retrieval unit provides confidence for the more comprehensive full system tests and deployments scheduled during the remainder of 2021.

Figure 3 Field deployment during Feb 2021 in a Rising Main at Sydney Water

CONCLUSION

An advanced internal robotic toolkits developed by the UTS Robotics Institute for condition assessment of rising mains is being developed and tested in collaboration with SWC, providing information on the condition of critical assets, when and where to intervene. Two tools are being proposed to target diameter ranges between 250-450mm, and 450-750mm. The latter has been manufactured and seen its initial tests in the field under real conditions. The former is at the conceptual design stage. Further tests with two tools are scheduled for the remainder of 2021 prior to hand over the tool to Sydney Water tools to integrate in their daily operations. The tools will allow SWC to pro-actively target condition assessment, initiating timely interventions prior to breaks, and optimising the renewals programs based on the needs of the condition of the pipes.

By fostering strong communication and preparing a deployment strategy in partnership with internal and external stakeholders, it is expected the use of the tools will become business-as-usual in the management of SWC's rising mains.

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