Available online at www.sciencedirect.com
ScienceDirect
Procedia Engineering 89 (2014) 817 – 822
Procedia Engineering
www.elsevier.com/locate/procedia

16th Conference on Water Distribution System Analysis, WDSA 2014

Development of Renovation Techniques for Medium and Large Diameter Water Transmission Pipes

C. Bae[a], J. Kim[a], D. Choi [a], D. Koo[b], J. Kim[a]*

[a] *K-water Research Institute/Korea Water Resources Corporation, Deajeon/South Korea*
[b] *Indiana University Purdue University Indianapolis (IUPUI), Indianapolis, Indiana, United States*

Abstract

Smart lining System was developed to restore and improve water quality, hydraulic, and structural function of water large transmission pipes through the construction of the high quality lining in the study. Smart lining System consists of smart cleaning, smart spray-on lining, and smart CIPP^{2+}. Smart cleaning is the pre-process of lining process, and could ensure SSPC SP-10 and surface roughness 50 ㎛(Rz) as the quality of surface preparation for the lining by removing effectively deposited slime, residual lining, tuberculation, graphitization of pipe wall with the high pressure water jet, mechanical scraper, and air spin-head blasting equipment step by step.

Peer-review under responsibility of the Organizing Committee of WDSA 2014
Keywords: Rehabilitation, water pipes, renovation techniques, lining

1. Introduction

Korea Water Resource Corporation (K-water) is the largest public company to provide raw and treated water to most municipal governments in the Republic of Korea (South Korea). K-water currently operates 4,448 km of water pipelines which are typically larger than 600 mm in diameter and other thousands kilometres of smaller diameter water pipelines. Approximately 20% of K-water's water pipeline exceeds 20 years of service. They are relatively newer pipeline systems than similar water pipeline systems in other developed countries. However, there are significant indications of internal lining layer deterioration and corrosion that cause water quality and structural degradation. Most

* Corresponding author. Tel.: +82-42-870-7500; fax: +82-42-870-7549.
E-mail address: juhwan@kwater.or.kr

1877-7058
Peer-review under responsibility of the Organizing Committee of WDSA 2014
doi:10.1016/j.proeng.2014.11.512

water pipelines prior to 1994 used coal tar epoxy (CTE) for internal corrosion protection lining. Maximum life expectancy of CTE internal corrosion protection lining for water pipelines is approximately 30 years. Recent condition inspection for those pipelines indicates that many CTE applied water pipelines have approached at the end of designed life or already shown significant internal deterioration.

Fig. 1. Deterioration State of Medium and Large Diameter Steel Pipe of K-water.

2. Smart cleaning & spray-on lining system

A typical polymeric spray lining process employs a combination of high pressure water jet and spin sprayer mounted on a skid or wheel tractor. Few drawbacks of conventional method is 1) inefficiency and incompletion of surface preparation process, 2) non-uniform spraying control especially where deformation occurs, and 3) difficulties of surface inspection of pre-spraying preparation. Fig. 1 shows two defects from epoxy lining. Excessive pinholes are shown in the left picture and detachment in the right picture. Forensic analysis revealed that these failures are combinational results from insufficient polymer material quality, inadequate lining equipment, and improper preparation. Inadequate lining equipment is a particular matter because of inaccessibility of workers in the pipe. Conventional high pressure cleaning and scraping did not provide proper surface preparation to ensure adherence of epoxy.

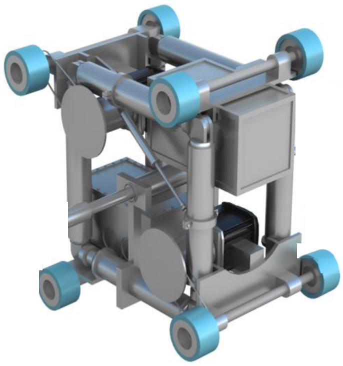

Fig. 2. Basic Frame of SCSL Units.

The new technology can perform lining for internal diameter between 500 mm and 1,650 mm. the new technology was developed by a research and development (R&D) team comprised between K-water and Jung-Ang Industries. The team introduced a pilot product in 2013 and filed a patent (intellectual property right). The new technology was titled as Smart Cleaning & Spray-on Lining Renovation Technique (SCSL). SCSL consists of four separate units for

1) high water pressure jet cleaning, 2) existing coating layer scraping, 3) blasting remaining coating layer, and 4) polymer lining spray. Multi-angled frame design enables to expand and contract depending on the internal diameter of the pipe. Individual unit is installed in the multi-angled frame as shown in Fig. 2. This compact and symmetrical design benefits especially where the machine goes through curved and deformed section. All four units are remotely controlled during entire rehabilitation process in the pipe.

Fig. 3. SCSL Units: (top) High Water Pressure Jet Unit. Existing Coating Layer Scraping Unit; (bottom left); (bottom right) Spraying-on Lining Unit.

The first unit is a device for high pressure jet water cleaning process in Fig. 3. This process eliminates most deposits from existing internal surface. The high pressure jet water nozzle is installed at the center of the SCSL frame.

The second unit is a device for existing coating layer scraping process. This process removes a CTE lining layer on internal surface. Fig. 4 shows multiple wheel cutters and a unit in the pipe during pilot testing. The multiple wheel cutters press against internal surface and CTE layer is cut into small and narrow strips

The third unit is a device for blasting remaining coating layer removal process. Most corroded steel water pipe typically has rust and graphite on surface as well. Blasting process injects abrasive grit materials using high pressure air through multiple nozzles. This process is critical process to ensure long-term quality of lining. Two quality control aspects are surface roughness (minimum 50 ㎛ Rz) and class (minimum SSPC-SP 10). Quality control issues are further detailed in following section

The fourth unit is a device for spaying polymer lining material. There are two typical spraying methods. The first method uses high pressure air. The second method uses high pressure pump and mixer directly to spray. The second method provides several benefits, such as minimum moisture and oil free, over the high pressure air. This device makes an elliptical spraying pattern and a unit in the pipe. Several spraying patterns, including circle, circumference, and ellipse, were tested and elliptical spraying pattern was proved to be the most effective pattern. Curing time depends on type of polymer materials and their properties. Poly-urea typically requires less than one hour curing time and possibly reinstate water service in several hours.

Fig. 4. Total Process of SCSL Rehabilitation Technology.

Quality assurance (QA) and Quality Control (QC) is critical to ensure quality and life extension of water pipelines rehabilitation. Most water pipe lining rehabilitation project for approximately larger than 1,000 mm can be directly inspected by human inspectors. However, smaller pipes have significant limitation of applying most post lining (curing) inspection methods except CCTV inspection.

Therefore, inspections including surface finish, roughness, pinhole, lining thickness and adhesion strength only can be done at the two end areas of the lined water pipes. This inaccessibility issue can be resolved by robotic technology development in lieu of direct human inspection in the pipe. Currently CCTV inspection is only available for entire internal surface of small – medium pipe lining. All other inspections are possible at the end of the pipe lining.

3. Smart CIPP $^{2+}$

Conventional CIPP(Cured in place pipe) technology adopt curing method with air pressure to insert the lining tube after impregnate the lining material, such as, epoxy. Construction quality of the conventional CIPP can be secured only after curing completely, since formation process of liner can be unidentified while installing the liner in the pipe. Not only energy cost is high due to working the boiler continuously to provide the steam, but also condensed water while steam curing gives a bad influence on liner. Especially, impregnated tube should be moved by refrigeration vehicle in low temperature and construction should be finished within a certain period(from 8 hours to 12 hours)

Fig. 5. Tube Inversion and Steam Curing Process of Conventional CIPP.

Smart CIPP $^{2+}$ is semi-structural lining technology. Meanwhile, liner formation process can be identified in real time, since tube inversion of Smart CIPP^{2+} technology developed in this study carried out in vacuum condition. UV curing can consume less energy and apply to longer distance of pipe than conventional boiler curing method.

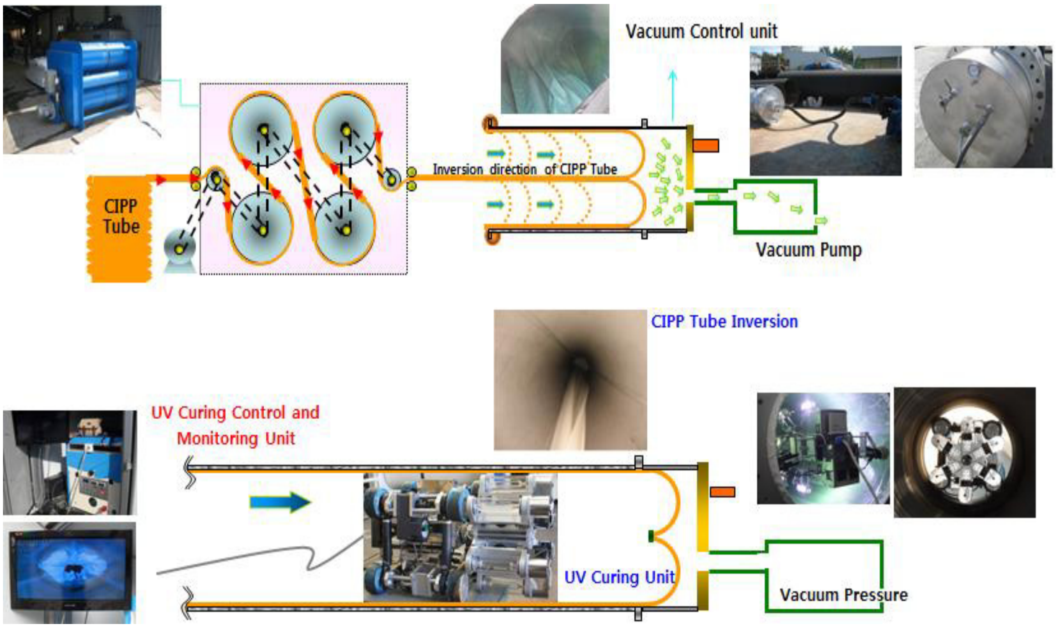

Fig. 6. Vacuum Inversion (top) and UV Curing (bottom) Process of Smart CIPP^{2+} Rehabilitation Technology.

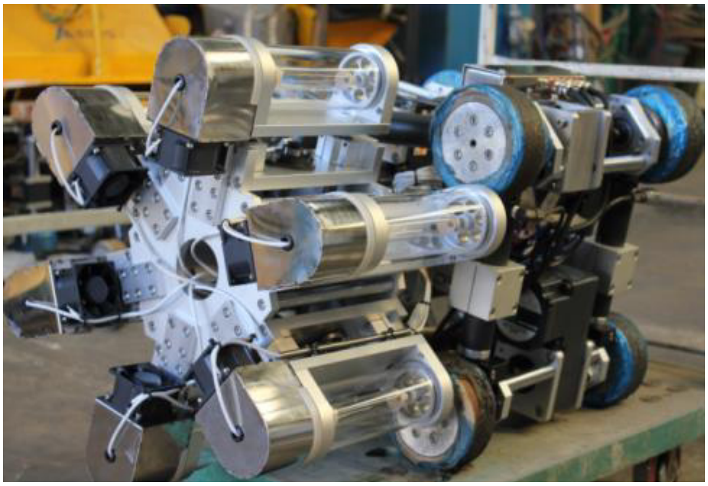

Fig. 7. UV Curing Unit.

UV Curing unit of Smart CIPP^{2+} can be seen in Fig. 7. UV lamp rotate to same direction to cure liner simultaneously while moving wheels at outer side rotate closely on liner with spiral. Nonwoven type of liner is applied in Smart CIPP^{2+} and available thickness is 3~10mm. Assessment results of mechanical properties can be seen in Table 1 based on the application of the liner.

Table 1. Mechanical Properties of Smart CIPP 2+ CIPP Liner.

Item	Unit	Results
Tensile strength	MPa	49.6
elongation	%	16.0
Flexural strength	MPa	40.7
Flexural modulus	GPa	2.37

4. Conclusion

This paper describes the new technology development and discusses benefits of trenchless water pipeline rehabilitation using polymeric lining methods and improved CIPP. Four main steps and devices applied in SCSL rehabilitation technology were demonstrated through pilot tests. Several tests prove that the new development can be effectively and efficiently utilized for water pipeline rehabilitation especially where CTE internal coating was used for corrosion protection layer.

This new technology, Smart Cleaning & Spray-on Lining Renovation Technique (SCSL), will be used to rehabilitate thousands kilometers of water pipeline constructed in 1970s and 80s using very identical design. Further technical development for SCSL is planned as field application goes. Robotic inspections shall be improved to ensure overall quality of lining for small-medium diameter size pipe rehabilitation

References

[1] D. Ellison, P.E., Investigation of Pipe Cleaning Methods, AWWA Research Foundation, 2003

[2] D. Ellison, No-Dig and Low-Dig Service Connections Following Water Main Rehabilitation, AWWA Research Foundation, 2007.

[3] E. Kampbell, Dec Downey, Wendy Condit, PE., Quality Assurance and Quality Control Practices Rehabilitation of Sewer and Water and Water Mains, EPA/600/R-11/017. U.S, 2011.

[4] S. Salem, Use of Trenchless Technologies for a Comprehensive Asset Management of Culverts and Drainage Structures, Project 07-15, Midwest Regional University Transportation Center College of Engineering, 2008.