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Non-Destructive *In-Situ* Condition Assessment of Plastic Pipe Using Ultrasound

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Abstract

Pipelines in potable water distribution system are a vital part of modern infrastructure, providing one of the most important services for society. This vital, complex infrastructure is endemic to our urban environments but is ageing, with current average age of around 70 years and with current replacement rates an inferred serviceable asset life of hundreds of years. Hence it is important that we develop technology that will enable pipeline condition assessment without service interruption. Due to environmental and operational stresses acting upon these pipelines, the common structural health problems include stress corrosion, thermal degradation, cracks or even leaks [1]. In particular, it has been suggested that void formation external to buried pipe wall is a crucial factor in pipe breakages due to lack of structural support [1, 2]. This paper presents the development and laboratory testing of ultrasonic non-destructive inspection technology for the condition assessment of plastic pipes, provide a measure of the structural integrity of the pipe, as well as 'looking' through the pipe wall to assess void formation and critical loss of support. Ultrasonic detection results are presented for grooves and cracks with two common plastic pipe materials, HDPE (High-density polyethylene) and PVC (Polyvinyl chloride) in order to simulate material loss in pipe wall. In addition, four voids in the ground external to plastics with varying shapes and dimensions were detected. Tested soils include two particle sized sands and two particle sized gravels. The study demonstrates the feasibility of developing a new technique for condition and health assessing for buried water plastic pipes

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Keywords: Plastic pipe; Non-destructive testing; Voids detection; Health monitoring

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1. Introduction

Pipeline systems buried underground are serving precious resource to our community, but is invisible from the ground surface. It was reported that pipe breakage was occurring under both environmental and operational stresses in the process of gradually losing structural integrity (circumferential breaks, longitudinal breaks, and split bell [4, 5]. Moreover, a figure of 35%-65% of the supplied water volume was wasted caused by pipe breaks [3]. Any type of pipeline failures can be extremely costly, including repair costs, disruption and associated damage [2]. Therefore the condition assessment of them cannot be a more important topic for both civil engineers and the society. It has also been widely recognized that proactive techniques are both technical and economically beneficial than reactive strategies [6]. It is advantage to assess and monitor the condition of the buried infrastructure routinely, so that proactive warning of impending failure can be achieved and thus the probability of the serious consequences of accidents of the utility network can be effectively reduced.

In the past 40 years, a new generation of low cost and high resistant polymeric pipelines, such as polyethylene pipe, has been extensively used in pressurized water distribution systems. Early surveys were usually carried out by an inspector walking or crawling through the pipe and providing visual and non-destructive defects information, i.e. CCTV for inner surface defects detection. However, when the pipelines are too small for manual inspection, i.e. potable water distribution pipelines, limited information can be obtained for engineers and water society. Therefore the working condition assessment can only be carried out by theoretical analysis or pipe sampling and destructive lab testing.

For *in situ* pipe inspection sensing technologies, camera, laser and ultrasound have been reported in application. Moraleda et al. [8] and Choi & Ryew [9] addressed the adoption of camera for inpipe inspection for water and gas pipelines individually. By producing the interior surface of the pipe wall, this inspection method was mainly and applied to sewers, storm water pipes or gas pipelines. Poor quality of the acquired images due to difficult lighting conditions was considered to be an inherent disadvantage. As a more accurate detecting method, laser scan has been developed for pipe inspection [10,11]. This profiling technique was only used in de-watered pipes. There is no document reporting the application of laser profiling on underwater application even though it produces more accurate internal image of pipe wall. Skjelvareid et al. presented a lab experiment using ultrasonic technique for internal surface imaging for a section of cast iron pipe [7]. The potential inspecting capability by this method for pipe surface imaging was investigated as well as the sensitivity of ultrasonic transducer position within the pipeline. Beller and Barbian addressed the use of a combined ultrasound technique for simultaneously metal loss quantification and cracks detecton while an array of sensors were traveling through a metal pipe by a carrier [12]. This technique was designed for gas and oil pipelines only rather than water pipes. Clearly, what has been done to date is only for gas/oil/water non-plastic pipelines. Recently, Liu and Kleiner [13], Dingus et al. [14], Makar and Chagnon [15] reviewed pipe condition assessment technologies applicable to different pipe materials. Again these techniques are not suitable for small sized plastic pipelines. Particularly, these pipe assessing techniques only focused on surface cracks and material loss detection, but nothing that looked beyond the pipe wall for surrounding condition, i.e. voids in the bedding soil. It has been suggested that the presence of voids could result in a lack of structural support and therefore break by stresses [16, 17]

Nowadays, a new research area has arisen which concerns the influence of ground conditions surrounding pipes, including the interaction of the pipe material, soil and fluids, and particularly the formation of voids in the bedding medium. Rajani et al. found that unsupported length and temperature differential are the most important considerations for small-diameter pipes [18-20]. In other words, small-diameter pipes are sensitive to the extent of loss of bedding support due to voids. It is therefore important to detect the existence of voids, which would facilitate targeted maintenance or replacement of pipes prior to breakages.

In this work, three experiments were conducted using the focused ultrasonic transducer with a central frequency of 10MHz for two common plastic pipe materials, Polyvinyl Chloride (PVC) and high density polyethylene (HDPE), and for varying particle sized soils. The first experiment was conducted for detecting the material loss on HDPE plate. Three linear grooves with varying depths and two through slots were machined for simulating the material loss on pipe wall. Ultrasonic scanning was performed to detect the location of those ‘defects’. The second test was carried out for detecting the crack in the material. In this experiment, a crack was produced through a PVC