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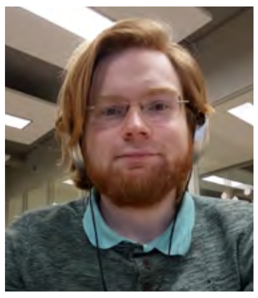
Applying nonlinear acoustics for detection and assessment of PVC water mains



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Motivation

The Dutch water grid has a vast network of pipes consisting of a variety of materials. Over half of the grid is made of unplasticised polyvinyl chloride (uPVC) [1]. This material was already used in 1950 and was determined to last at least 50 years under most operating conditions [1,2]. Many pipes have reached this age already, but it is unclear what the actual lifetime of these pipes are and when they should be replaced. Since replacement is costly, this is ideally done just before the pipe fails. Currently, the decisions on when and which pipes to replace are mostly based on the number of failures, the risk associated with failure and the pipe's age [3]. To make more adequate decisions, it is beneficial to have a way to monitor and predict the degradation of pipes. Proper predictive maintenance reduces unnecessary material use, and costs and reduces customer hindrance from downtime and contamination.

Presently, no method is yet implemented to non-destructively measure the structural health of a PVC pipe. Wave mixing has been shown to be sensitive towards microcracks and ageing of uPVC [4]. Together with only requiring one sided access as seen in figure 2, this gives it potential for a non-destructive, in-line method of degradation monitoring.

Technological challenge

Because wave mixing requires a precise alignment of the beam, it is very sensitive to the alignment of the transducers and material parameters. A robust method should either control or correct for this. Additionally, which parameters change with age and are responsible for a change of signal are still unknown.
Lastly, the measurements currently requires multiple measurements over longer timespans. If the absolute age is to be measured, a (rejuvenated) sample is required for baseline, which is in practice often problematic to obtain.

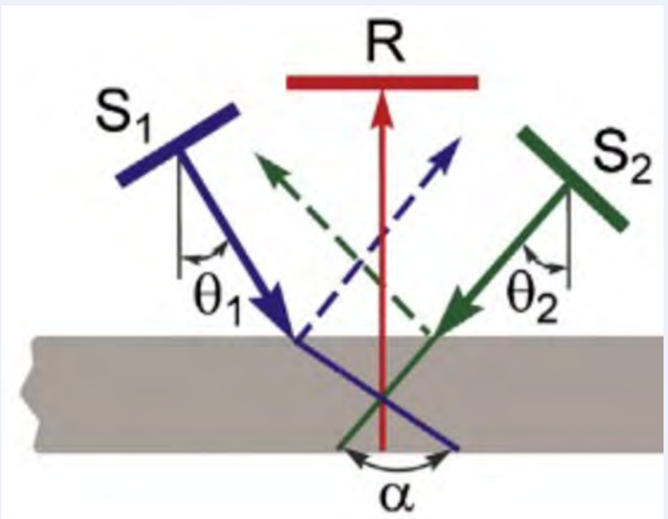

Figure 2. Schematic of noncollinear wave mixing [4]. S_1 and S_2 are sending transducers and R a receiver. The angle α of interaction governs the direction and amplitude of the generated wave.

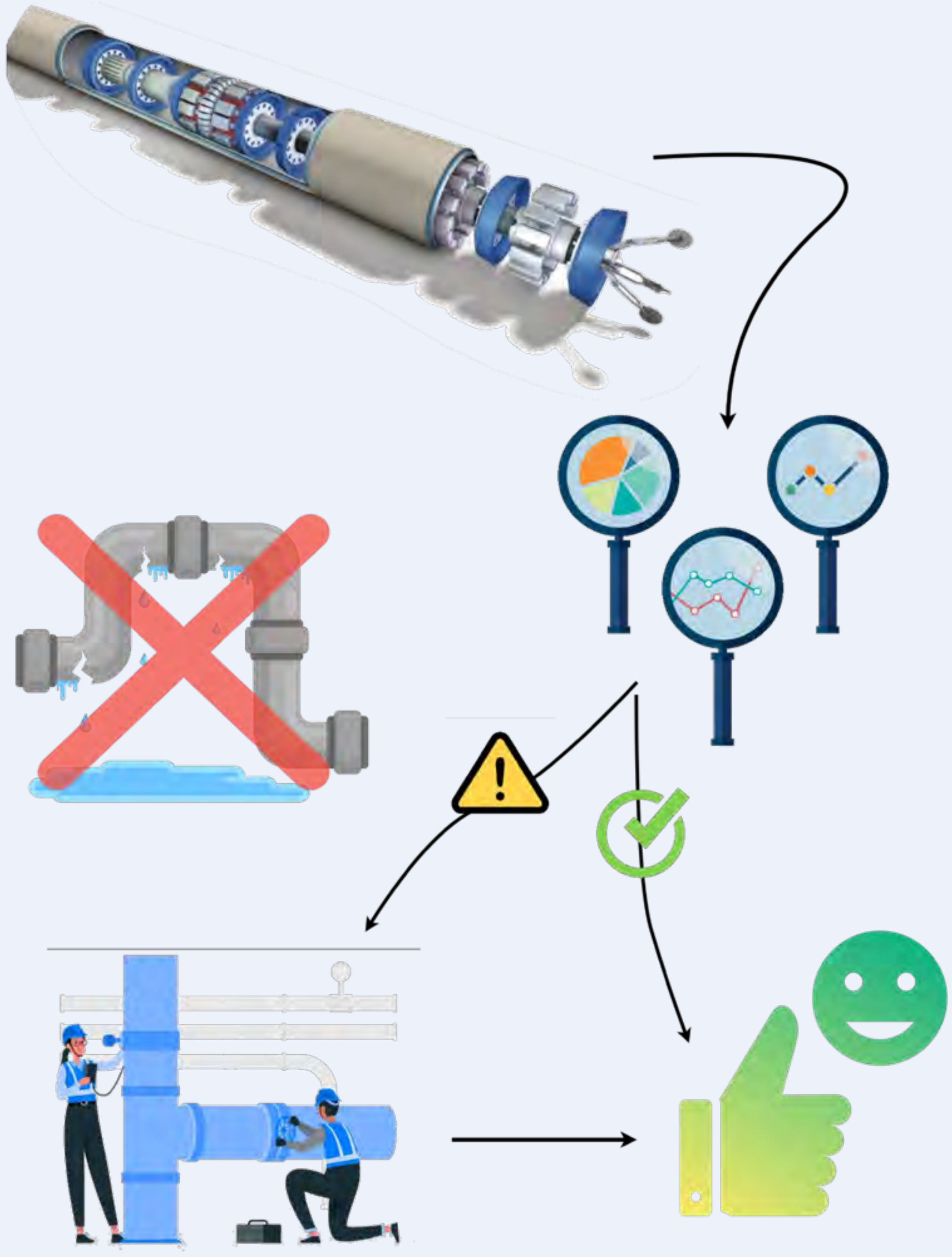

Figure 1. Project vision: using a PIG to gather data on pipes allows for predictive maintenance and leads to happy companies and customers.

Research goals

Understand the physics of wave mixing & expand the existing model.
Understand the sensitivity of noncollinear wave mixing to alignment, stress and other parameters.
Investigate if wave mixing can be made an absolute measurement technique instead of relative.
Investigate the possibility of the use of measurements relative in space instead of time for detecting material degradation.

[1] K. van Laarhoven, "Een model voor scheurgroei in PVCU buizen, geïmplementeerd in Comsima," Tech. Rep., Jan. 2020.
[2] J. Breen, "Expected lifetime of existing water distribution systems; Management summary," Tech. Rep., May 2006.
[3] A. Moerman, R. H. S. Beuken, and B. A. Wols, "Review on the development of uniform failure registration (USTORE) in the Netherlands," 2017.A. Demcenko, "Development and analysis of noncollinear wave mixing techniques for material properties evaluation using immersion ultrasonics," PhD, University of Twente, Enschede, The Netherlands, 2014.
[4] M. Sun, Y. Xiang, M. Deng, J. Xu, and F.-Z. Xuan, "Scanning non-collinear wave mixing for nonlinear ultrasonic detection and localization of plasticity," NDT & E International, vol. 93, pp. 1–6, Jan. 2018.

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