In Pipe Repair of PE Pipe by Friction Stir Welding:
fixing without digging

Dr Richard Collins, *University of Sheffield, Sheffield Water Centre*

A significant cost of the repair of leaking pipes is in the locating and digging down to the level of the pipes. In addition there will be costs and reputation impacts due to the associated disruption, typically to road traffic. A solution that allows the repair of pipes that doesn't require digging would, therefore, be a great advantage. This proposal offers a design to allow the repair of PE pipes from inside the pipes, traversing from existing access points. By combining with existing sensing techniques it will allow the precise locating of leaks and assessment of the failure. In addition it will allow the post-installation verification and reassurance of joint viability, (both end joints and Top-Ts), a common cause of failure.

Problem

Polyethylene (PE) is the material of choice for the majority of pipe replacements due to its robustness and ability to be installed over long lengths. In general it suffers from a very low rate of failure compared to other materials. However, there exists clear evidence that there is significant leakage in MDPE mains laid by the UK water industry. In 2010 UKWIR [1] reported electro-fusion jointing as the predominant cause of joint failure on PE mains with a calculated failure rate of between 3 and 4 failures per 100 km per year. More recent data is hard to come by there is a widely held view within the industry that failure rates on PE mains have not reduced there is still a significant problem.

Proposed Solution

The proposed solution technique involves developing a smart welding head that will be able to traverse along the inside of a pipe, detect and locate the leak or joint, and then weld the leak closed, or re-weld a joint using a Friction Stir Weld (FSW) process.

Leak / Joint Locating and Assessment

Accurately navigating in the pipe environment has been demonstrated at The University of Sheffield in the Assessing the Underworld Project [2]. The project also demonstrated sensing of voids, leaks and other pipe defects using directed ultrasound.

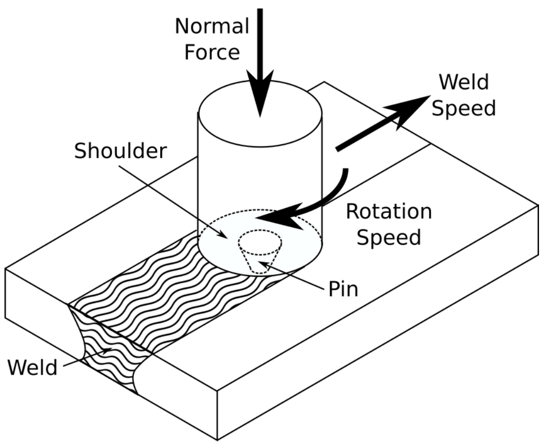

Figure 1: *General friction stir welding process, the rotating tool (shoulder and pin) moves across the joint, mixing the material and forging with the frictional heat and pressure.*

Friction Stir Welding

Friction stir welding is a solid-state joining process that uses a non-consumable tool to join two workpieces [3]. Heat is generated by friction between the rotating tool and the workpiece material, which leads to a softened region near the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of material, and forges the hot and softened material by the mechanical pressure, which is applied by the tool, much like joining clay, or dough.

As can be seen in Figure 1 the working tool rotates and is passed across weld line, the tool is comprised of two sections; the shoulder creates frictional heat, contains the softened material at the weld junction, and provides a suitable welding pressure, the pin creates additional frictional head and directly stirs the materials together to form the weld. Downward force is required to maintain the pressure on the joint and helps to create friction heat.

Friction Stir Welding of PE Pipes

Whilst the majority of research into FSW has been undertaken on Aluminum and Steel, there have been a number of publications demonstrating its ability to join PE and other plastic sheets [4, 5]. In PE the FSW process directly mixes the chains of the polymers and has been demonstrated to produce a very strong joint [6].

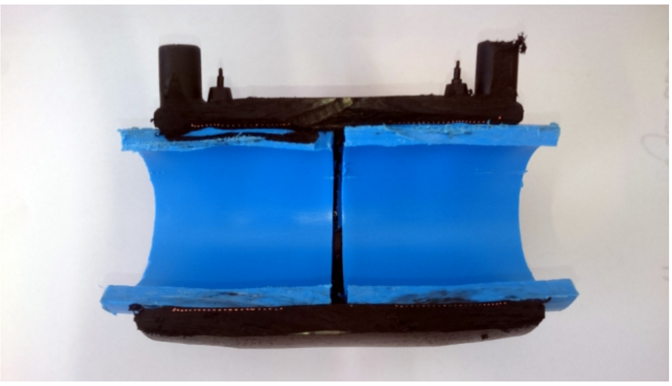

Figure 2: *Section across an badly welded electro-fusion joint, the leak location can be seen on the top left where there is incomplete weld of the blue and black PE.*

With FSW it is possible to weld both butted and lapped joints. As such it would be possible to fix leaks (butted joints), but also post installation reweld an electro-fusion end joint (lapped and butted) or a Top-T (lapped). Figure 2 shows a badly welded electrofusion joint, with the joint failure due to bad installation. The technique proposed here would allow for repair of sections such as this.

FSW is a particularly attractive solution as it should be possible to undertake a repair without de-watering the pipe [5].

Project Requirements

The project is looking for an industrial partner to help support a funding proposal through Innovate UK[1] to demonstrate the viability of the FSW in pipe repairs. FSW is a suitably mature technology that the research would not be in the fundamentals of the technique, rather in its co-option for in pipe repairs.

It is expected that the project would require to investigate:

- optimal geometry of tool (shoulder and pin)
- optimal tool rotational speed, downward pressure to maximize the weld speed and strength
- the strength and fatigue resistance of the resultant joints
- the ability to miniaturize the weld head and provide suitable power and sensing capabilities

The successful demonstration of the technique would be achieved by the construction of a prototype smart welding head that was able to enter a pipe and traverse to a leaking section and undertake a repair weld. This would be demonstrated using the new UKCRIC National Water Infrastructure Facility: Distributed Water at the University of Sheffield.

The project is ideally suited to be undertaken at the University of Sheffield due to our extensive water laboratory facilities, background in water infrastructure assessment and history of projects exploring the fatigue effects on plastic joints.

References

[1] UKWIR. *Leakage from PE Pipe Systems.* Tech. rep., 2010. 10/WM/08/43.

[2] K. Ma *et al.* In *Advanced Intelligent Mechatronics (AIM), 2017 IEEE International Conference on*, pp. 1459–1464. IEEE, 2017.

[3] R. S. Mishra *et al. Materials Science and Engineering: R: Reports*, 50(1-2):1–78, 2005.

[4] E. A. Squeo *et al. The Annals of Dunarea de Jos University of Galati, Technologies in Machine Building*, 5:241–246, 2009.

[5] J. Gao *et al. Journal of Applied Polymer Science*, 131(22), 2014.

[6] A. Zafar *et al.* In *2nd International Conference on Mechanical, Manufacturing and Process Plant Engineering*, pp. 19–36. Springer, 2017.

[1] or direct industry funding