WP3-12 438 Non-destructive testing of PE joints

B. Roelofs, J. Kuiphof, T. van Onna
Liandon B.V. (part of Alliander N.V.) , Liander N.V. (part of Alliander N.V.), Alliander N.V.
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Introduction

Polyethylene (PE) is a commonly used material for the construction of new pipelines. It is estimated that the Dutch DSO's (Distribution System Operators) construct a few hundreds of kilometers of underground PE pipelines a year. The most common diameters are 110 and 160 mm. The construction of new gas grids inevitably involves making many joints. Joints are necessary for uniting pipe ends and connecting services, corners and T-joints. Considered that tensile strength characteristics of PE are much better than of PVC, PE is the preferred material for locations with moving soils. Obviously, these circumstances, and the inherent risks that are basically always present with gas, makes it even more critical that joints are of high quality and are able to resist external forces.

For PE pipe systems two types of joints are often used: electrofusion and butt fusion. Electrofusion is performed with sockets with pre-installed metal wires that heat up and make the pipe and socket material melt and fuse together. The socket is wired to a fusion machine that will provide the heat that is required for the fusion process. Butt fusion or mirror fusion does not require a socket or other appliance that stays behind, but is made by heating both pipe ends and pressing them together. Whereas nondestructive testing techniques are also introduced for butt fusion, this paper will from now on focus on electrofusion.

Due to human and machine errors, it is possible that joints contain errors. The most common sources of errors found in practice are cold welds, pollution and humidity (Postma & Hermkens, 2012). To ensure that new gas grids are of good quality, sufficient testing of joints is essential. Especially considered the fact that, in specific areas and periods of time, alarming error percentages of up to 25% have been reported. At the moment, it is common to test approximately 10% of the new joints.

The dominant method for testing joints, from a diameter of 90 mm is the 'peel decohesion test' based on ISO 13954. New joints are removed from the gas grid and then detached by peeling the socket

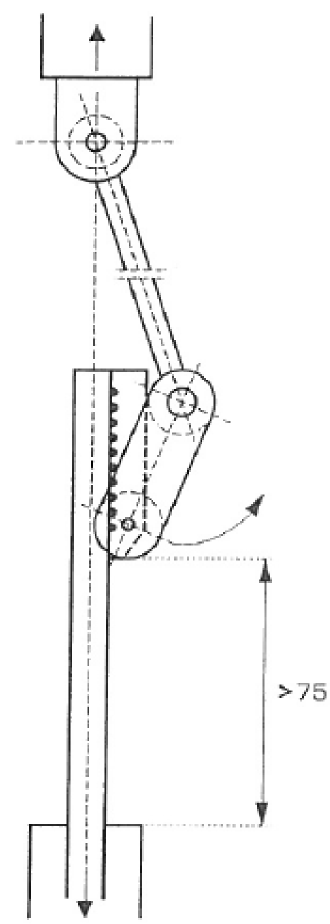

Figure 1: Test arrangement ISO 13954 peel decohesion test
(Source: Vereniging FME, 1994)

part from the pipe material. If at least two thirds of the fusion zone is properly attached, the joint passes the quality test (Vereniging FME, 1994). It is assumed that the remaining joints in the gas grid are of sufficient quality too. The decohesion test gives a great indication of the quality of joints in terms of strength and has proven itself over the years.

So, why non-destructive testing?

If the decohesion test gives such a great indication, why change to non-destructive testing?
First, question marks can be placed by how representative the 10% sample is. Is it really true, that even if one would find that 10% of the removed joints has a sufficient quality, this will guarantee that all of the remaining joints are faultless? It can be argued that this is true when all joints would be manufactured under controlled laboratory conditions, but it seems less likely if levels of related conditions as temperature, pollution, humidity and expertise are strongly varying during construction.
The second reason to apply NDT are the costs. The costs of removing large numbers of joints, and constructing new joints instead, transportation to the testing facility, and the destructive test itself, are high. Costs that you don't have with the non-destructive test.
The third advantage of NDT is the time which the test requires. When a gas grid is built or replaced it will cause inconvenience for the direct environment because of open trenches, disruption of supply, etc. It is therefore desirable that the time of work is limited to a minimum. The non-destructive tests can be performed in the trench whereas the destructive test usually requires a few working days (in a laboratory). If a test indicates an unacceptable quality of the joint, it might require that the project has to be done all over again. This leads to high costs and causes extra inconvenience for the environment. In addition to that, the relatively time intensive testing process does presumably weaken learning improvements. Briefly explained: if feedback about the quality of the joint would be provided directly, a welder would be able to relate this to the process that he or she has just followed. If, for instance, the joint was poorly installed, it would have high value to directly look for the cause and prevent that more errors will be made in the future.
Fourth and last (but not least) is demotivation of the professional welder. Pipe fusion should be carried out with care and craftsmanship. Multiple welders have expressed their frustration when their new joints are repeatedly removed from the gas grid for testing. Once NDT can be applied, only the disapproved joints will be removed from the gas grid.

Investigation to NDT of PE joints

There is clearly a desire for a non-destructive method, for testing PE joints. Therefore, Alliander initiated a research to investigate alternatives for the destructive test. During this research, various techniques were investigated, but Phased Array Ultrasonic Technique (PAUT) was found to be the most suitable technique for electrofusion joints. By transmitting ultra-sonic waves through the material, a "real-time" 2D image is generated on which deviations are visible.

In Allianders research several PE joints were tested. To do this, errors were deliberately made in the joints. There was a joint that was not peeled, and also a joint where water was applied on the surface before welding. There were also joints in which no errors were made. All joints were examined by Olympus-IMS and figure 2 gives an explanation of the image that was created. The top of the figure, shows the outside of the socket. Below that is a line of 'dots' which are the metal wires of the electrofusion socket. The bottom blue line is the inside of the pipe (backwall). The Phased Array probe is moved in circumferential direction along the socket.

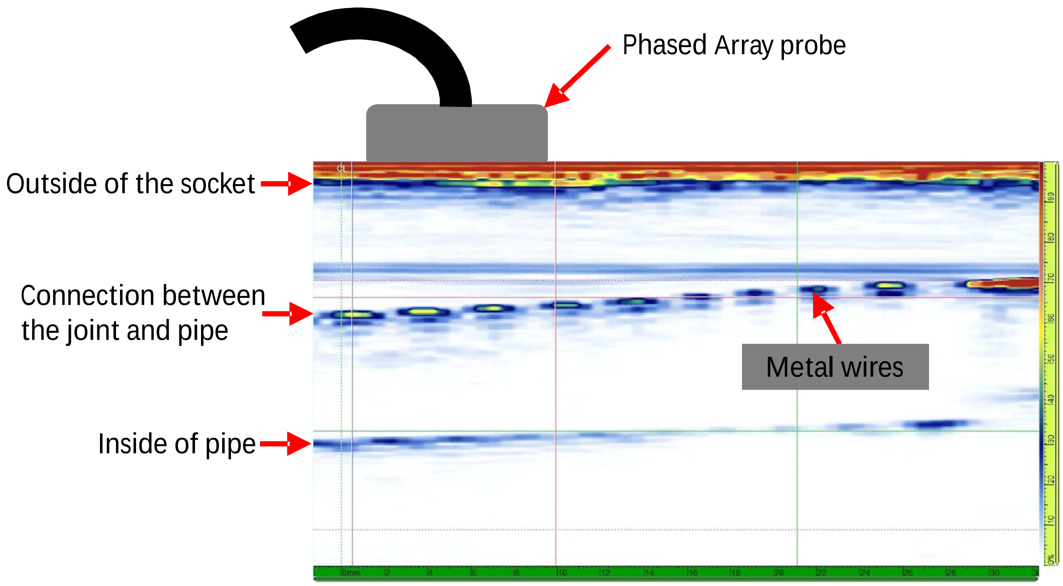

Figure 2: Explanation of PAUT image

Figure 3 shows an image of a joint with an acceptable welding surface. This conclusion is drawn from the fact that no deviations were seen on the PAUT image of the joint. The metal wires are evenly scattered in the welding surface and there are no irregularities seen in the backwall.

Figure 4 shows an example of a weld with deviations in it. There are clear distortions seen around the metal wires. These wires are no longer evenly scattered and were moved during the heating of the socket. This particular example, is the sample with the water on the welding surface. By heating the socket, the water is vaporized leading to cavities in the welding surface.

In figure 4, compared to figure 3, also major disturbances are seen in the backwall. This is because the sound wave is reflected in the cavities near the metal wires. Disturbances in the backwall can be an indication of poor welds.

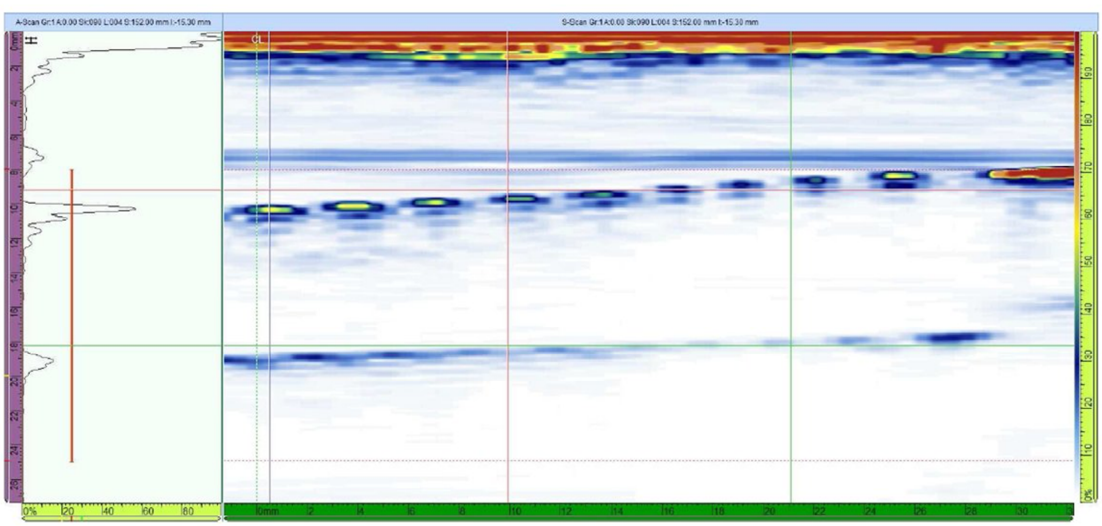

Figure 3: Example of an acceptable weld

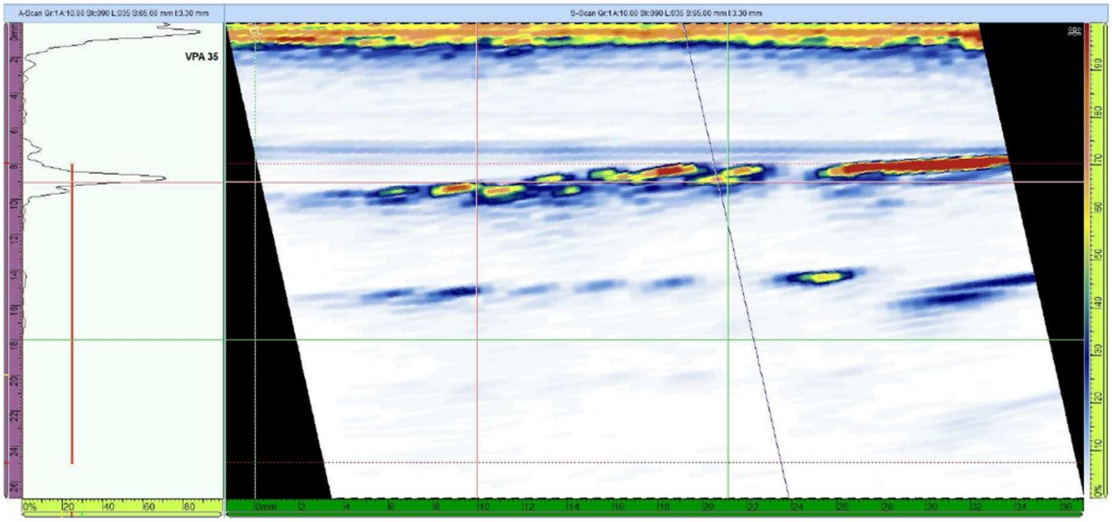

Figure 4: Example of a weld with deviations

After the joints were non-destructively examined, they were destructively tested in order to compare the new method with the existing. All joints were approved by the destructive test. The contrast in these results is caused by the fact that the destructive test examines the tensile strength of the weld, whereas the non-destructive test examines deviations. It is therefore not (yet) possible to correlate the observed deviation to the tensile strength.

Conclusion

With the Phased Array Ultrasonic Inspection Technique (PAUT), it is possible to observe deviations (such as sand and water) in electrofusion joints. This is an important difference to the peel decohesion test, where the tensile strength is measured. At this moment it is not yet possible to correlate to the observed deviation to the tensile strength.

The joint with water in it, is clearly identifiable with non-destructive testing. This proves that the measurement equipment is sensitive enough to observe deviations. The objective should be to establish tolerances, whether a weld is approved or disapproved based on the observed deviation. For this purpose, requirements must be established, on what deviations are permissible. This requires further investigation.

Next steps

Alliander starts a follow-up research in September 2014. In this research 60 electrofusion joints will be tested, first in the trench and then the same joints will be tested under laboratory circumstances. After the non-destructive testing, the joints are destructively tested. Figure 5 shows an overview of the approach of the follow-up research. The joints will be chosen randomly over the entire service area of Liander.

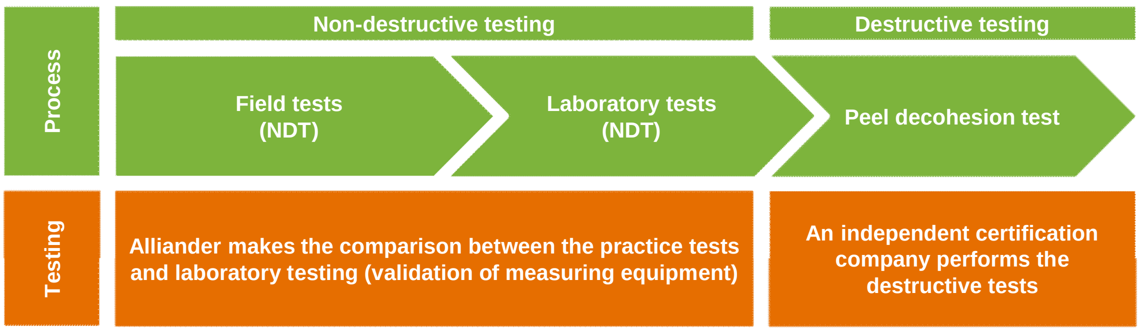

Figure 5: Approach of the follow-up research

The research has the following objectives:

- Validating the PAUT measuring equipment;
- Determining the non-destructive testing costs per joint;
- Gain experience with non-destructive testing in the trench (will problems arise, such as lack of space or disruption of the schedule for the regular activities);
- Provide insight to what extent, based on the non-destructive evaluation, can be predicted whether the weld will fail in a destructive test or not;
- Create a database with the results of the destructive testing and non-destructive testing, hoping to find the correlation between both methods;
- Identify obstacles for implementation (e.g. design of the socket).

References

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