Approval and rejection criteria for Phased Array Ultrasonic Testing on
PE electrofusion joints
Suitable for diameters from 75 mm up to 250 mm

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Abstract

Polyethylene (PE) is a commonly used material for the construction of new gas grids. The construction of new gas grids inevitably involves making many joints. For PE pipe systems, electrofusion is a common technique to create joints. Due to human and machine errors, it is possible that joints contain flaws. In order to ensure that new gas grids are of good quality, sufficient testing of joints is essential. Current practice in the Netherlands is that approximately 10% of newly installed joints are removed in order to test them destructively.

Over the last three years, Alliander studied the applicability of Phased Array Ultrasonic Testing (PAUT) on PE electrofusion joints as an alternative for destructive testing. Since then more than 200 joints have been randomly chosen and investigated using this technique leading to the following conclusions:
1. PAUT is applicable on PE joints in the trench;
2. It is possible to detect flaws in the PE joints;
3. By giving direct feedback to the welder, the quality of the joints improve.

Moreover, the experience gained during these last three years led to a set of rejection and approval criteria. The criteria are based on previous research, standards and Dutch regulations. This paper describes and explains the rejection and approval criteria for testing PE electrofusion joints by using PAUT.

Project partners: Alliander, Liander, Liandon
1. Introduction

1.1 Liander tests 10% of the PE joints to ensure quality

Polyethylene (PE) is a commonly used material for the construction of new pipelines in gas grids. It is estimated that the Dutch DSO’s (Distribution System Operators) construct several hundreds of kilometres of underground PE pipelines a year. The most common diameters are 110 mm and 160 mm. The construction of new gas grids inevitably involves making many joints. Joints are necessary for connecting pipe ends, corners and T-joints. For a safe and reliable operation for at least 40 years high quality joints are essential. Currently approximately 10% of the newly constructed joints are tested destructively.

Previous research has shown that Phased Array Ultrasonic Testing (PAUT) is the most suitable technique for testing electrofusion joints non-destructively. By transmitting ultra-sonic waves through the material, a "real-time" 2D image is generated. With PAUT, it is possible to observe flaws (such as sand, water and other contaminations) in electrofusion joints. This is an important difference to the destructive (peel decohesion) test, where the tensile strength is measured.

1.2 Approval and rejection criteria have yet to be determined

At the moment there are no industry-wide accepted approval and rejection criteria for non-destructive testing of PE electrofusion joints. It often takes a lot of time to achieve industry-wide accepted criteria. Therefore Alliander has established its own approval and rejection criteria for assessing the electrofusion joints.

1.3 In 2018 Alliander will start with the implementation of NDT

Alliander is the first DSO in the Netherlands that starts with the implementation of NDT for PE electrofusion joints. The past few years this technique has proven itself in various pilot projects. The established criteria have also been validated in different projects and are applicable for the PAUT inspection of electrofusion joints.
2. Background information on PE electrofusion

For PE pipe systems two types of joints are often used: electrofusion and butt fusion. Electrofusion is performed with couplers with pre-installed welding wires that heat up and make the pipe and coupler material melt and fuse together. The coupler is wired to a fusion machine that will provide the power required for the fusion process. Butt fusion (or mirror fusion) is done by heating both pipe ends and pressing them together. Whereas non-destructive 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 flaws. The most common sources of flaws found in practice are cold welds, pollution and humidity (2). To ensure that new gas grids are of good quality, sufficient testing of joints is essential.

The common method for testing joints is the ‘peel decohesion test’ based on ISO 13954. New joints are removed from the gas grid and then detached by peeling the coupler part from the pipe material. If at least two thirds of the fusion zone is properly attached, the joint passes the quality test (1). It is assumed that the remaining joints in the gas grid are of sufficient quality too. The decohesion test gives an indication of the quality of joints in terms of strength.

2.1 Advantages of NDT for PE joints

Non-destructive testing has four major advantages over destructive testing, namely:

1. Firstly, NDT ensures that approved joints remain in the gas grid. With destructive testing, both the good- and the bad joints are removed.
2. The second reason to apply NDT are the costs. The costs for removing large numbers of joints, reconstruct new joints, transportation of the joints to a test facility and the destructive test itself are high. Costs that you do not have with non-destructive testing.
3. The third advantage of NDT is that it saves a lot of time. The non-destructive tests can be performed in the trench during construction whereas the destructive test usually requires a few working days (in a laboratory). If the destructive 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 local residents.
4. Fourth and last (but not least) is the motivation of the professional welder. Pipe fusion should be carried out with care and craftsmanship. Welders express their frustration when their new joints are repeatedly removed from the gas grid for testing. With NDT only the disapproved joints will be removed from the gas grid. This in its self improves the quality of work due to the short and positive feedback on the welders craftsmanship.
3. How PAUT works on a PE electrofusion joint

A visual assessment of the weld is always done for the PAUT inspection. A visual assessment consists of, among others, measuring the out-of-roundness of the pipe and angular displacement. PAUT is an extension of the visual inspection that is performed on an electrofusion joint. Figure 1 shows the setup of a PAUT inspection of a PE electrofusion joint. A chain scanner is used to guide the phased array probe around the circumference. A couplant is used to prevent air inclusions between the probe and the surface of the joint.

![Figure 1. Setup of a PAUT inspection of a PE electrofusion joint](image)

Figure 2 shows a cross-section of a PAUT image of a good electrofusion joint. The top of the figure shows the outside of the joint. Below that is a line of ‘dots’ which are the welding wires of the electrofusion coupler. The bottom blue line is the inner wall of the pipe (back wall echo). The Phased Array probe is moved in circumferential direction along the coupler.

The figure shows an image of an acceptable joint. This conclusion is drawn from the fact that no flaws are seen on the PAUT image of the joint and there are no irregularities seen in the back wall echo.
Figure 2. Explanation of PAUT image

Figure 3 shows an example of a joint with a flaw located underneath the welding wires. In figure 3, compared to figure 2, also a disturbance is seen in the back wall echo. This is because the sound wave is reflected in the cavities under the welding wires. Disturbances in the back wall echo can be an indication of poor welds.

Figure 3. Example of a flaw in an electrofusion joint
4. Approval and rejection criteria

This paragraph describes the approval and rejection criteria. These selected criteria are based on ISO standards and Dutch regulations. The criteria have been validated in a pilot project.

For better understanding of the criteria it is important to know that anything that is different from the normal picture is considered as a possible flaw. Only indications wider than 1.5 mm have to be reported as a flaw. If so, the dimensions and location / position of the flaw have to be reported.

4.1 Approval criteria

The criteria below describe when a joint is approved:
- The pipe ends are cut off straight;
- The pipe ends are sufficiently inserted into the joint;
- No more than 2 flaws (wider than 1.5 mm) are found in the entire circumference of the joint;
- Less than 1/3 of the fusion zone contains flaws (including flaws narrower than 1.5 mm).

4.2 Rejection criteria

The criteria below describe when a joint is rejected:
- The pipe ends are not cut off straight;
- The pipe ends are not sufficiently inserted into the joint;
- With more than 1 flaw, wider than 1.5 mm, next to each other in the fusion zone;
- More than 2 flaws (wider than 1.5 mm) in the entire circumference of the weld;
- More than 1/3 of the fusion zone contains flaws (including flaws narrower than 1.5 mm).

4.3 Location flaws

The flaws can occur at the following locations:
- Underneath the welding wires - these are located directly in the welding zone;
- Between the welding wires - these are located between the wires, directly above the welding zone;
- Around the welding wires - these are located in the welding zone and above;
- Above the welding wires - these are located outside the welding zone.
4.4 Examples of flaws in electrofusion joints

In this paragraph some examples of flaws in electrofusion joints are shown to explain the approval and rejection criteria.

Figure 4 shows a PAUT image of a pipe end which is not cut off straight. The welding wires are clustered and there is no back wall echo.

![Figure 4. The pipe ends are not cut off straight](image1)

Figure 5 shows a PAUT image of a pipe which is not sufficiently inserted in the joint. There are some flaws beneath the welding surface and there is also no back wall echo. This is due to the molten PE material from the joint collapsing inside the joint.

![Figure 5. The pipe ends are not sufficiently inserted into the joint](image2)
Figure 6 shows a PAUT image with more than 1 flaw, wider than 1.5 mm, next to each other in the fusion zone. The flaws are located underneath the welding wires.

![Figure 6. More than 1 flaw, wider than 1.5 mm, next to each other in the fusion zone](image)

Figure 7 shows a PAUT image where more than 1/3 of the fusion zone contains flaws.

![Figure 7. More than 1/3 of the fusion zone contains flaws](image)
5. Conclusion

Over the last three years, Alliander researched the applicability of Phased Array Ultrasonic Testing (PAUT) on PE electrofusion joints. Meanwhile, more than 200 joints have been randomly chosen and investigated by using this technique.

At the moment there are no industry-wide accepted approval and rejection criteria for non-destructive testing of PE electrofusion joints. It often takes a lot of time to achieve industry-wide accepted criteria. Therefore Alliander has established its own approval and rejection criteria for assessing the electrofusion joints. The criteria are based on previous research, ISO standards and Dutch regulations.

Alliander is the first DSO in the Netherlands to start with the implementation of NDT for PE electrofusion joints. The past few years this technique has proven itself in various pilot projects. The established criteria have also been validated on different projects setting the standard for PAUT operation and selection criteria on electrofusion joints. PAUT is now an accepted alternative to destructive testing saving time, money and providing a direct and positive feedback to the welders. PAUT will now be implemented in operation within Alliander and the research will continue to study the applicability of PAUT on butt fusion.

References