Tool design and construction for leak testing of gas electrofusion polyethylene coupler by internal pressurization system

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Abstract

Nowadays, in many gas projects polyethylene pipes are great replacement for steel pipes due to the ease of implantation. However, applicable and economical nondestructive tests for control the electrofusion welding processes in polyethylene pipes is one of the essential aspect to consider. This paper introduces an efficient equipment for test of electrofusion polyethylene coupler in the implementation condition of gas network projects to detect the leakage by using internal pressurization machine. Results of laboratory experiment on artificial defect samples and site work procedure are described and computer simulation by finite element and CFD software are also shown.

Keywords: nondestructive test; natural gas polyethylene pipelines; electrofusion coupler; leak test.

1. Introduction

Polyethylene pipes have high usage in gas distribution network. They have several advantages in comparison with metal pipes including economic efficiency, easy implementation and installation as well as suitable service conditions. The history of high density polyethylene pipes (HDPE) utilization came back to 1950 in American gas industry. In Iran in 1999 the national Iranian Gas Company began to restrict the pipe lines to polyethylene pipes that nowadays it comprises more than 172000 kilometers of gas pipes. In this regards, inspection, maintenance and repair of these pipes are vital for constructors. Preparation of technical inspection processes to prevent risk and cost of environmental pollution and gas waste due to gas leakage are the first and chief aspects of such reconstruction.

For an integrated gas network, the inspection is required during pipes and fittings production, installation and even after gas injection in operation stage. These examinations have significant roles in the safety and proper function of gas distribution systems. Meantime destructive tests due to their characteristics and damaging nature are not affordable and could not be used for all couplers in gas pipe connections. Regarding to effect of instrument efficiency on the integrity of electrofusion welds, nondestructive test that could be perform on all electrofusion couplers is required. Using ultrasonic and thermography methods in the previous studies (Kafieh (2011) and Bird (2007)) which conducted to assess electrofusion welds were acceptable in preliminary results on laboratory scale. However, because of the high equipment cost, operator skill requirements and the non- applicability of these tests, using these methods have been stopped in gas projects.

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In this paper electrofusion welding has been thoroughly studied as a fundamental mechanism for connecting polyethylene pipes. Moreover, an innovative nondestructive leak test device has been proposed. The method implements differential pressure in pressurization method. A computer simulation by finite element method in ABAQUS and leak rate by CFD software has validated our proposed method. The accuracy, precision of the technique and assessment of efficiency have been evaluated in explanation of test procedure and prepared as an addendum or Appendix for EN 1555 standard. The function of the test method has been verified by comparison of artificial defect with practical samples that implies it, could be proposed as an annex in performance procedures of installation standards for polyethylene gas pipes.

According to pneumatic test procedure, pressure test in urban area needs to be done after implementation of polyethylene gas networks and before gas injection. However, in some case with full compliance of pneumatic test guidelines some leakage has been reported after injection. In such condition leak detection by Flame Ionization Detector (FID) devices with cutting and discharging pipelines are required to repair.

Because of declining in precision of pressure due to volume increase of network under the test, leak test performance of fittings separately and during the installation is required. Such inspection may reduce other costs such as leak detection and repair after gas injection.

Ability to test all fittings, efficiency aspects beside ease of use, in both commercial and operational fields without need to achieve high level of skill, quick test performance and finally omission of probable cost of gas disruption and lose gas due to forced purging especially in repairing condition and risk of gas leakage are advantages of this practical simple tool.

These tests proposed nondestructive test (NDT) for both under construction and online fitting so primary usage of this machine can improve assurance of weld health, online inspection and prevent undesirable cost of gas leakage.

The outline of the paper is as following; explains electrofusion coupler welding process. Progression strategy is described in section 3. The structure of test device is defined in section 4. Section 5 demonstrates inspection method. Finally, conclusion is provided in section 5.

2. Electrofusion coupler welding process

The equipment of the electrofusion process is shown in figure 1. The pipes are inserted in to the coupler and electric current is passed through a heating element in the coupler, causes the polyethylene of the pipe and coupler to melt and fuse.

Figure 1. Electrofusion coupler and weld production equipment

According to statistics released by the leak detection unit and laboratory corporation of Isfahan province Gas Company the cause of leakage on the faulty samples are shown in table 1.

Table 1. The chief causes of leaky electrofusion joint

Leakage cause	percentages
Lack of operator skill	52
Improper scraping and impure solvent	10
Unfavorable weather condition	10
Improper welding machine	8
Improper storage and transport of electrofusion coupler	8
Improper equipment and tools	8
Improper design and construction of electrofusion coupler	4

3. Progression strategy

After negotiating with the national Iranian Gas Company experts, it is clear that after welding process of electrofusion coupler should be assessed for leak. Due to the different shapes of electrofusion coupler in various manufacturers, lack of acceptance criteria for assessing defect and lack of applicable NDT for electrofusion couplers in site work condition as well as cost of inspection, leak test is introduced as an applicable test method.

3.1. Inspection challenges

Three methods have been used to ensure the integrity of electrofusion welds quality including crush test, pressure test and leak survey by flame ionization detector (FID) or laser test. However, each has some weaknesses. For example, crush as a destructive test performs only on 2 percent of the total electrofusion couplers in a project (According Iranian Gas Standard - IGS-C-DN-003(0)). Moreover, it imposes extra cost and delay to the project. Another test according to company procedure is pressure test with air that is done after implementation of whole project. In this method finding the leak location due to pressure declining during the test of network is impossible. The last method is leak detection after gas injection by FID or laser method which is not applicable during construction process. In this regards, the necessity of a device that allows leakage detection in the work site and immediately after welding electrofusion coupler is negligible. In order to pressurize each coupler in a leak test, we proposed a deferential pressure by pressure test and supplementary bubble test.

3.2. Defective samples

Specified defects or holes with deferent diameters needed to verify this method. Due to the maximum sensitivity of pressure change to the $10^{-4} mbar.lit/sec$. The ability of leak detection for very small holes by this method is the first desired, therefore we used laser technology to create holes with diameter of 0.01 mm, 0.1 mm and 1mm on the polyethylene pipe. Moreover, some artificial defect is created by grease pollution, no scraping and over fusion or incomplete fusion to verify proposed method. In total over 50 electrofusion coupler are evaluated with crush test results.

4. Nondestructive test device

4.1. Leak test

Leak test is one of nondestructive test methods that could be used in both pressurized or evacuated system for detection of leak and the measurement of fluid leakage. Leak testing divided in to three main categories including leak detection, leak location and leakage measurement. Each technique in all categories involves a fluid leak tracer and some means for causing fluid flow the leak or leaks.

4.2. Application of internal pressurization device

This device provides for the detection of through thickness discontinuities in fusion and pressure boundaries of electrofusion coupler in air at atmospheric pressure. It is used during construction by create deferential pressure due to internal injection system to the fusion boundary. Typical discontinuities detect by this device are holes and leak of fusion. A bubble forming solution is applied to the surface to be examined. The amount of pressure, type of fluid, test timing and other required conditions are evaluated and proper quantities are proposed. A calibrate pressure gage is used to verify the required pressure differential.

4.3. Design of test machine

As shown in figure 2 test machine is available for polyethylene pipe with 110 mm outside diameter as a prototype. It made of suitable materials for leak tightness; it is a strong and lightweight material with good impact strength.

Figure 2. Pressurization machine

4.3. Compressor

Assuming the negligible gas production in pressurized chamber, the effective speed pressurizing compressor, S_{eff}, depends on the initial pressure, P1, (usually equal to atmospheric pressure) the final pressure, P_2, the total volume internal pressure device, V, and compressing time, t, calculated in equation 1:

$$S_{eff} = \frac{v}{t} Ln \frac{p_1}{p_2} \quad (1)$$

The sealing system is reached by gasket system that used in machine, it is critical to the ease with which the coupler can be handled and sealed in to the internal faces of the polyethylene pipe to hold the internal pressure. They are made of Nitrile butadiene rubber (NBR) and Polytetrafluoroethylene (PTFE) with special design.

4.3. Gauges and cylinders

This device equipped with two pressure dial gauges in two scales and a vent valve for control and set required internal pressure according to the procedure.

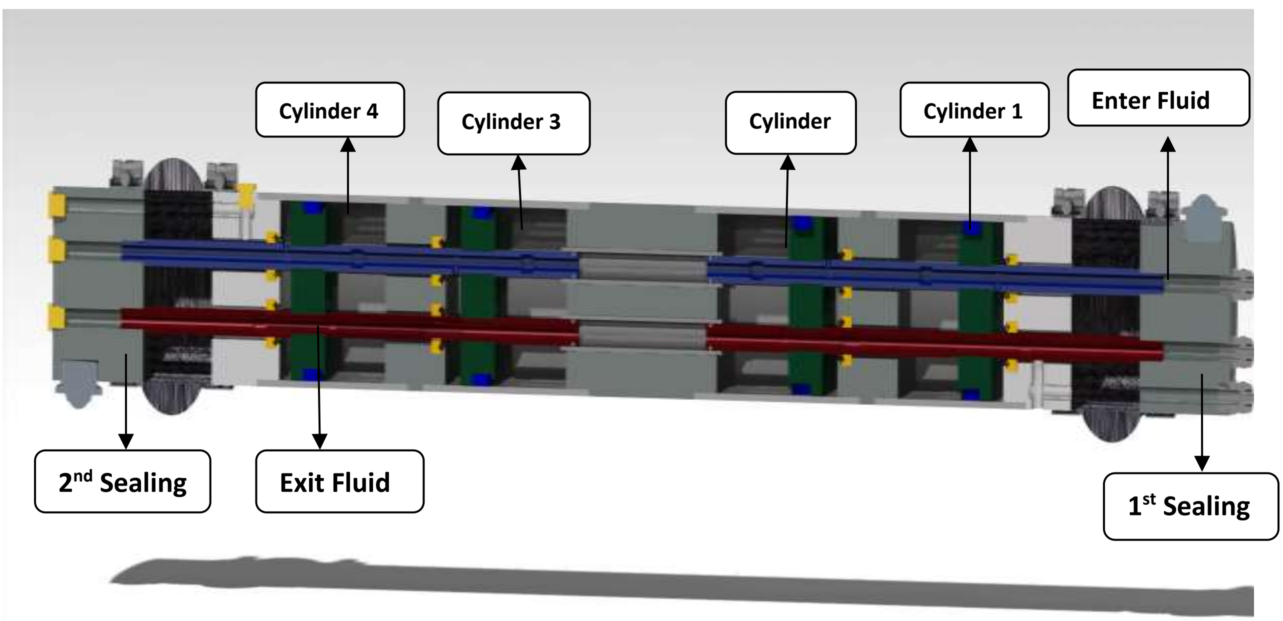

Figure 3. Side view of pressurization machine

5. Demonstration of inspection system

5.1. Verification of bubble forming and pressure rising ability with artificial leaks

The artificial leak is formed by drilling in a polyethylene pipe. Three holes with diameter of 1, 0.1 and 0.01 mm on polyethylene pipe was created. After that each hole has been under the pressure deferential until observed the bubble forming of solution. All of the holes have been detected by this method.

5.2. Verification in field condition

The prototype used in Isfahan Province Gas Company according to the proposed procedure. This method is very effective for finding defect due to lake of fusion and other defect that is cussing the leakage. In other hand, artificial defect in laboratory is demonstrated the ability of finding lack of fusion with this device.

5.3. Simulation

Stress analysis of coupler under test simulated in ABAQUS/CAE Explicit. In this model pipe and coupler have 8 and 10 mm thicknesses, respectively. The maximum deferential pressure applied with tabular amplitude of 14 psi magnitude. Mechanical properties are for PE100 were used for all parts; young's module is 1100Mpa, Poisson's ratio 0.4 and density is 0.935-0.96 gr/cm^3. Figure 4 shows the stress of mises that is 0.6 Mpa.

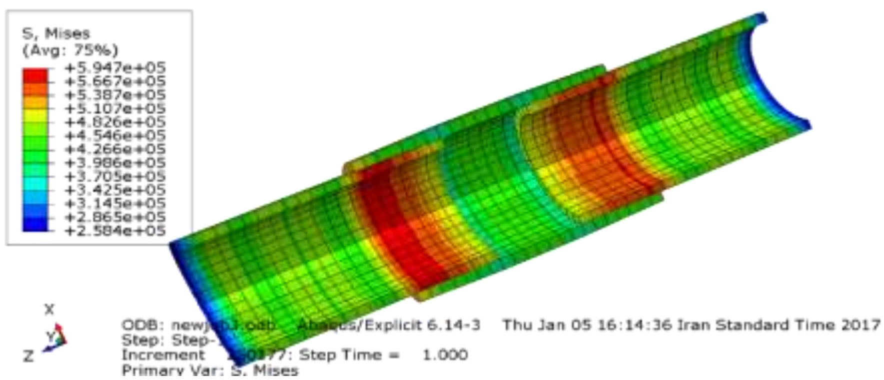

Figure 4. Stress – Mises

After calculating the rate of leakage on the holes with 1 and 0.1 mm diameter in real time, these conditions simulated by ANSYS Fluent and verified by real result.

6. Conclusion

We have developed an internal pressure method for the reliable leak detection in electrofusion couplers. The method is highly functional, economical efficient, and reliable during implementation. Moreover, this method causes the industry to reduce the cost of maintenance such as leak detection after injection of natural gas by Flame Ionization Detector (FID) or other method, discharge of gas due to repair of leaky electrofusion coupler and the environmental risks.

7. Acknowledgements

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Appendix A

PRESSURE TEST PROCEDURE

1. SCOPE

The objective of the pressurization technique for leak testing of polyethylene coupler is to detect leaks in a pressure boundary that cannot be directly pressurized. This is accomplished by applying a solution to a local area of the pressure boundary surface and creating a differential pressure across that local area of the boundary causing the formation of bubbles as leakage gas passes through the solution. Moreover, leakage ratio can measure by declining the pressure.

2. PURPOSE

The purpose of this procedure is provide a guide line to carry out the pressure test machine to check integrity of fusion welding of electrofusion polyethylene couplers.

3. REFERENCE CODE

American Society of Mechanical Engineer - ASME Sec V.

4. EQUIPMENT

The pressurization mechanism is performed by using an internal machine for internal hydrostatic test. The ends of the machine are sealed by O-Ring and sealed against the polyethylene pipe by a sponge rubber gasket. The test scheme shall have suitable connections, necessary valve and calibrated pressure gauges. The gauges shall have a range of 0 to 150 psi or equivalent pressure limits such as 0 to 250 in.Hg.

The test scheme shall be demonstrated with sample test pipe by bubble solution application at site before conduction the test on the job. The bubble forming solution shall produce a film that does not break away from the area to be tested, and the bubbles formed shall not break rapidly due to air drying or low surface tension, soaps or detergents designed specifically for cleaning shall not be used for the bubble forming solution.

Internal pressure can be drawn on the pipe by any convenient method, such as connection to a gasoline or diesel motor intake manifold or to an air compressor. The gauges shall register a partial pressure of at least 100 psi (equivalent to 200in.Hg or 700 KPa) above atmospheric pressure.

Bubble forming solution (Brand name / Type will be furnished prior to execution) to be established vide 4.2 & to be recorded.

5. PERSONNEL

The personnel shall be competent and have through knowledge in performing this method.

6. SURFACE PREPARATION

The surface to be examined and all adjacent areas shall be cleaned thoroughly and free from all dirt, grease, lint, scale, oil and other extraneous matter that could obstruct surface openings or otherwise with the examination. Prior to Pressure testing all joints shall be checked visually.

7. PROCEDURE

Although the force draft cooling for reducing cooling time is under calculation, the test shall conduct after total cooling time of the electrofusion or butt fusion. The temperature of the surface of the part to be examined shall not be below 40F (5C) nor above 125F (50C) The electrofusion or butt fusion on the test shall be applied with a bubble solution for detecting leaks prior to placing instrument. The foaming shall be minimized by means of uniform application of bubble solution. The gauges should register at least a partial pressure of 700 Kpa or 100 Lbf/in2 for inspection of the joints. The required partial pressurization shall be maintained for at least for 300 seconds examination time stop watch to be used after reaching the 700 Kpa / or 1.5 time more than designated pressure. Each pressure decrease has to record on test report.

8. EVALUATION

Bubbles or pressure decrease produced by air sucked through the electrofusion or butt fusion can detect the presence of defect. The tested areas are accepted only when no continuous bubbles formation or pressure decrease is observed. A minimum light intensity of 1000 lux is required for conducting the examination.

9. REPAIR/RETEST

Defects in fusion may be repaired by cutting electrofusion or butt fusion and replace with other fittings. After repairing retest of pressure test should be carried out on both fusions.

10. INSPECTION REPORT

The test must be carried out on each fusion in presence of the certified NDT personnel. Upon satisfactory inspection, a report should be prepared as per inspector approved format.

11. SAFETY

Safety will be followed as per Health, Safety and Environment (HSE) specification during test.