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Original Research Paper

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THEORETICAL AND EXPERIMENTAL RESEARCH ON WELDING POLYETHYLENE FITTINGS TO PEHD PE100 PIPE

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ABSTRACT The present paper aims to carry out a study in the field of welding polyethylene pipe and fitting assemblies, a study required by the problems occurring in practice. The study aims to determine both the theoretical and the experimental problems, with the contribution of the companies operating in the field.

KEYWORDS : Electrofusion, Welding, Fittings, Pipe, Defects.

INTRODUCTION

The efficiency of a pipeline system depends on the cost of the pipes and fittings, but also on the cost of installation, on that of maintenance and on the operating life. The advantages of using polyethylene pipes (Figure 1) for the transport and distribution of natural gas in the detriment of steel pipes, may be highlighted through numerous features.

Figure 1. Polyethylene Gas Pipe Of Various Sizes

The increased mechanical strength of the polyethylene pipes and thus the increased internal pressure of operation have the following consequences:
- a reduction of the wall thickness, with important economical effects;
- an increase of the productivity of the pipe extrusion operation;
- a decrease of the residual stresses caused by the welding operation;
- the possibility of installing pipes in soft soil without a sand bed.

The usual way in which high density polyethylene pipelines subjected to pressure become damaged is the appearance and then the expansion/ propagation of cracks in the brittle material area.

The design of the polyethylene pipes cannot be based on the short-term load results, because of the influence of the long term operation factors, mainly creep and pressure fluctuations. Therefore, in order to estimate the total operating life of the polyethylene pipes used for the transport and distribution of natural gas under pressure, several different concepts have been suggested, which aim to take into account the influences mentioned above:

a. performing the standardized test of the pipes, which consists in subjecting the pipe to internal pressure, under standardized temperature and duration conditions, determining the time to yielding and the extrapolation of the test results for the considered service life;

b. extrapolating the results of short-term static mechanical tests, performed at high temperatures and/or in aggressive environments in order to accelerate the degradation processes, by applying Arrhenius' law;

c. applying the concepts of the fracture mechanics to determine the legitimacy of crack initiation and propagation, at temperatures corresponding to the operating conditions, based on tests under static and variable loads, with and without the influence of the working environments.

CURRENT STAGE OF USING POLYETHYLENE PIPES IN NATURAL GAS TRANSPORT AND DISTRIBUTION [1]

Karl Ziegler and Erhard Holzkamp invented the high density polyethylene (PEHD), and the former received the Nobel Prize for chemistry in 1963 for inventing the technology of producing HDPE.

In Romania, high density polyethylene (HDPE) pipes /piping with diameters ranging from 32mm to 630mm have been installed, while worldwide pipes with maximum diameters of 1400mm are manufactured.

The evolution of the performance of the polyethylene pipes for natural gas distribution, the development of the class of polyethylene pipes with the minimum guaranteed tensile strength of 10 MPa (PE100) allowed the use of polyethylene pipes for the transport and distribution of natural gas with pressures up to 8 bar.

Increasing the pressure from 4 bar to 8 bar (the 8 bar solution), in the new distribution areas takes into account the limitation of costs and the number of components of the network (pressure regulators, pipes of different diameters and appropriate fittings).

JOINING POLYETHYLENE PIPES BY MEANS OF BUTT WELDING AND ELECTROFUSION TECHNOLOGIES

Larger HDPE pipes can be joined (without disassembling, with or without fittings) in two ways:

1. Electrofusion Welding [3]

Welding by means of electrofusion fittings has become widely used due to the simplicity of the operation and the high quality of the joint. The polyethylene fitting is manufactured by casting and contains a built-in electrical resistance that connects the inner surface of the fitting to the outer surface of the pipe.

The electrofusion welding technology is automated. The most modern welding equipment completely eliminates the "human factor". In order to achieve high quality welds, by using this procedure, it is essential to use auxiliary devices, such as the

scrapers for chamfering the pipe ends and the aligners. Similar to butt welding, it is very important to clean the contact surfaces on the pipe and on the fitting.

Figure 2. Electrofusion Welding Machine

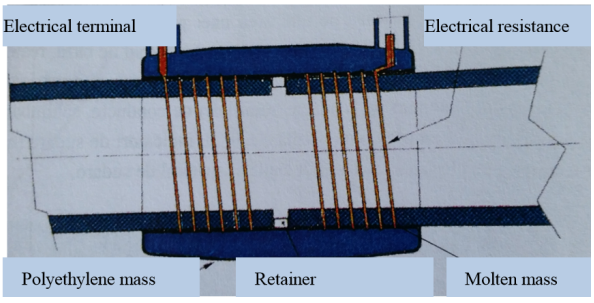


Figure 3. Mounting For Electrofusion Welding Polyethylene Pipes

2. Butt Welding

The technological order of the operations, the rules and the detailed guidelines are given in the technological instructions of each welding machine manufacturer, where the following welding parameters are precisely specified: pressure, time, temperature. The welding parameters used are also dependent on the basic material as well as on the standard SDR dimensional ratio.

Figure 4. Butt Welding Machine

Manual, semi-automatic and automatic machines are equally used when performing butt welds. These welds require well-qualified personnel. The butt welding process consists in the following phases:

- Fixing the pipe ends in the clamps of the welding machine.
- Cleaning the ends and milling them to be laid in the same plane;
- Preheating the surfaces to be joined by means of the heating plate (21 C);
- Pulling the plate away and immediately compressing the two ends;
- Cooling down in the machine until reaching a temperature of approximately 60° C;
- Disassembling the pipe ends from the clamps of the welding machine.
- The ambient temperature must be between 0 and 45°C when performing this type of welding.

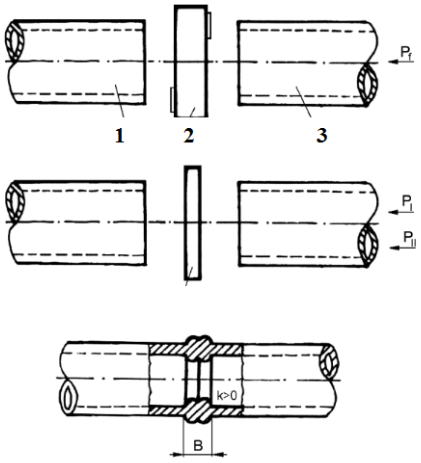


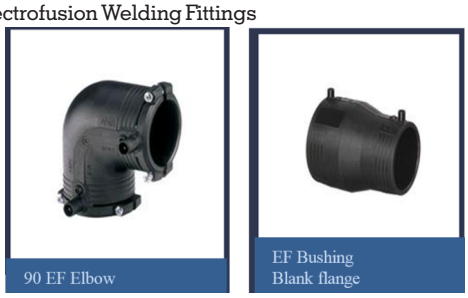
Figure 5. The Scheme Of The Butt Welding Process

TYPES OF POLYETHYLENE FITTINGS

a. Butt Welding Fittings

Figure 6. Fittings Used In Butt Welding

b. Electrofusion Welding Fittings



c.

Figure 7. Fittings Used In Electrofusion Welding

STRESSES OCCURRING WHEN USING POLYETHYLENE PIPES IN THE NATURAL GAS DISTRIBUTION SYSTEMS [3]

Stresses Caused By Pressure

If a tubular pipe is subjected to an internal pressure p_i and to an external pressure p_e (fig.8), the occurrence of a state of three-dimensional stresses is observed. There are three distinct types of stresses in the wall of the pipe.

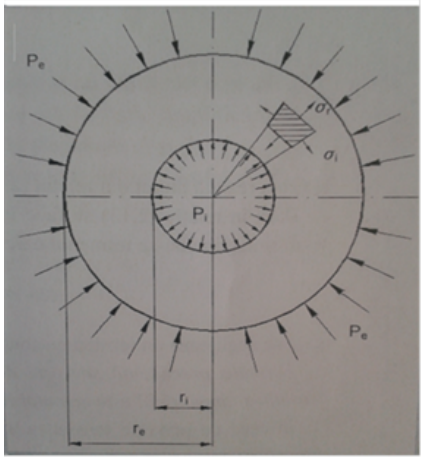


Figure 8. Distribution Of Stresses In The Wall Of A Polyethylene Pipe [3]

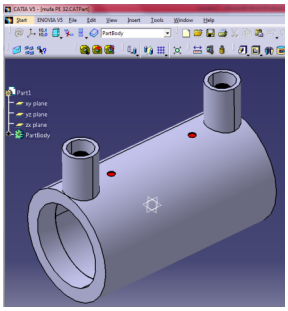
MODELING THE POLYETHYLENE FITTINGS TO DETERMINE STRESSES AND STRAINS

The CAE Module (Computer Aided Engineering) was introduced in the composition of CIM systems (Computer Integrated Manufacturing) after the development of the CAD module (Computer Aided Design); it actually appeared with the emergence of the finite element method. The method was originally used in the mechanical calculation of the aircraft structures but later it expanded widely to all the material continuum problems. These problems seek to determine the values of one or more unknown functions in a considered area such as: displacements, velocities, temperatures, stresses, strains, etc., depending on the nature of the tackled problem.[2]

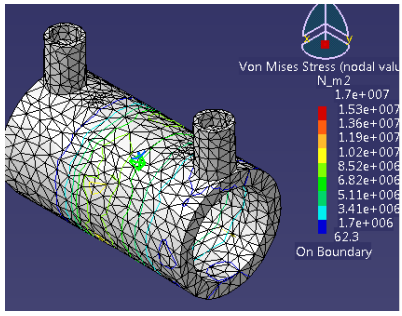
The natural phenomena of this kind are described by differential equations, and, by integrating them under given boundary conditions, we reach the exact solution. We can thus calculate the value of the unknown function or functions in any point in the studied area. This is the analytical, classical solving method, which is applicable only to the simple problems. However, the problems that arise in the practical engineering activity are not simple but rather complex, both in terms of physical geometrical construction of the part, and in terms of the loading boundary conditions. In this situation, solving the differential equations is no longer possible. At this point, there are two solving options:

- creating a simplified model of the real one and solving the differential equations on the former, thus obtaining the exact solution on a simplified model;

- obtaining an approximate solution to a real problem. [2]



a.



b.

Figure 9. Designing The Electrofusion Fitting, 32 Socket, In Catia Software

Ways Of Testing Polyethylene Fittings:

The parts were prepared for the most unfavorable conditions in practice (according to the following figures) in order to subject them to the following tests: traction (PE socket) or bending (Tapping tee).

Figure 10. Correct Electrofusion Welds For Dn32

Figure 11. Incorrect Electrofusion Welds For Dn32

REMARKS AND CONCLUSIONS

a) The current stages of using polyethylene in the country and worldwide were presented, as well as the way of using it and the appropriate operating pressures;

b) The most frequently used procedures for joining polyethylene pipes used in the field of natural gas transportation were presented, as well as the fitting models mostly used by the practitioners;

c) The calculation relations that will be used for the mathematical analysis of the process were presented;
d) The polyethylene parts were modeled in the CAD CAM Catia software, this being a future model for the numerical analysis;

e) Welds were made under normal operating conditions and under unfavorable conditions, and the mechanical tests will be performed;

f) The parts will be sectioned in order to highlight the distribution of the filler material when the fittings are welded aligned and non-aligned;

g) For the experimental research, a set of testing machines and equipment will be used, consisting of: Instron tensile and compression testing machine, an optical system for measuring the strains and the clamps for fixing the specimens to the testing machine.

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