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Comparative Theoretical and Experimental Study between Electrofusion Welding and Gluing the Fittings to the Polyethylene Pipe: Part 1

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Abstract: ***The paper aims to perform a comparative experimental study between a traditional method of joining a fitting and a polyethylene pipe - welding, and the method suggested to be studied - fitting injected with adhesive.***

Keywords: insulation, polyethylene, mechanical action

1. Introduction

The basic materials for producing plastics are natural materials like cellulose, resins, oil and natural gas. Oil and gas are the most important raw materials. In refineries, crude oil is distilled into several factions. Depending on the degrees of the boiling temperatures, different stages of distillation are reached: gas, gasoline, kerosene, black oil and, as residues, bitumen. All these components are made of hydrocarbons with a difference in the size and the configuration of the molecules. [3]

Therefore, it is safe to assert that plastic materials are materials obtained by transforming the natural products chemically or synthetically based on organic compounds having carbon (C) and hydrogen **(H)** as main components. The basics of most plastic materials are the *hydrocarbons* from which the individual combinations of plastics are derived, which are called *monomers*, i.e. monomer molecules of the same kind. [1]

The advantages and the disadvantages of using polyethylene are the following:

- The ability to be joined by welding at low temperatures (compared to the high temperatures required for steel), by means of simple technology, as well as through mechanically assembled fittings, as appropriate;
- The ability to combine the polyethylene networks with the already existing steel networks or with the existing fixtures;
- The increased speed of installing the networks, implying lower execution costs;
- The large variety of dyes allowing a precise marking and identification;
- The large variety of pipe fitting dimensions of approximately 32,000 units;
- The high resistance to corrosion, which eliminates the need for cathodic protection, a very important advantage for the gas distribution networks because the aggression of the soil in the urban environment is significantly higher than outside the localities;
- The ability to use long pipes by delivering them in coils;
- A good chemical resistance to the gas components;
- The environmental protection, being a recyclable material.[2]

2. Joining the Fitting and the Pipe. Current Stage of the Process

The procedure is based on using a welding part called *the electro fitting* (Figure 1). It consists of the basic body, made through injection from high density polyethylene, having different geometric shapes depending on the purpose of the assembly (pipe joints, pipe branching, diameter change, etc.) provided internally with an electrical resistance, welding indicators (for control) and electrical connectors that can be linked to the welding machine.

Figure 1: Welded fitting - polyethylene pipe assembly

The surfaces to be welded (the exterior of the pipe and the inside of the electro elbow) are heated to the plasticizing temperature, due to the electrical resistance immersed in the inner surface of the electro fitting. By heating the pipe-fitting assembly, a swelling of the material will appear, pre-calculated by taking into account the gap between the two parts and then, by heating it until it reaches an optimal melting temperature of about 220°C, it turns into a homogeneous molten mass. Upon cessation of the electric current in the electric resistance, the process of solidification of the molten mass begins, thus welding the two connected parts (Figure 1). [5]

The welding parameters and the intensity of the current necessary to the electro elbow for the plasticization of the contact surfaces are monitored and registered automatically by the welding machine via a control processor. The intensity of the current flowing through the coil of the electro fitting is determined by the relationship I-U/R where: I- the current intensity, *[A]; U* – the voltage at the welding terminals, *[V]* and R - the electrical resistance, *[Ohm]*. The fitting heats firstly at the ends, then towards the interior (the center), so that the molten mass solidifies without leaking outside the welded area. Only the same type of materials can be welded through electrofusion. The melt flow index of the electro elbows ranges between 0.7 and 1.3 *g/10 min*, and allows the welding of pipes and fittings that have a melt flow index ranging between 0.4 - 1.3 *g/10 min*.

There is a bar code on the electro elbows which determines the parameters of the welding. Some manufacturers also provide a magnetic card with the electro elbow that is inserted into the welding machine. Upon completion of the welding, the technical data contained therein referring to setting the welding parameters are *deleted*, therefore the card can be used only once. [8]

2.1 Performing the Electrofusion Welding

The welding parameters and the intensity of the current necessary to the electro elbow for the plasticization of the contact surfaces are monitored and registered automatically by the welding machine via a control processor.

The intensity of the current flowing through the coil of the electro fitting is determined by the relationship I-U/R where: I – the intensity of the current, *[A]; U* – the voltage in the welding terminals *[V]* and R – the electrical resistance, *[Ohm]*.

At the beginning the fitting heats at the ends, then towards the interior (the center), so that the molten mass solidifies without leaking outside the welded area.

Only the same type of materials can be welded through electrofusion. The melt flow index of the electro elbow ranges between 0.7 1.3 *g/10 min*, and allows the welding of pipes and fittings that have a melt flow index ranging between 0.4 - 1.3 *g/10 min*.

There is a bar code on the electro elbows which sets the parameters of the welding. Some manufacturers also provide a magnetic card with the electro elbow that is inserted into the welding machine. When the welding is completed, the technical data contained on the card referring to the welding parameters are *deleted*, therefore the card can be used only once. According to the design and operation norms of the polyethylene distribution systems, electrofusion welding is allowed for diameters larger than 32 mm, for injection made couplings, elbows, pipes, reduction, etc. [1]. In order to perform the joint, a special welding device is used which automatically or manually secures the electrical values in the electro fitting terminals for the required welding time, depending on the dimensions and the type of pipe and electro fitting.

The Stages of Electrofusion Welding are:

- The pipes are cut to size and the ends are straightened;
- The outer surface of the pipe is scraped in the area where it will be joined with the electro fitting, at a depth of at least 0.1mm, by means of a special device (removal of the oxide layer);
- After scraping them, the surfaces of the pipes are cleaned with a cotton cloth soaked in an etching liquid (methylene chloride, isopropyl alcohol, ethyl alcohol of over 99% purity);
- The interior of the fitting is cleaned with the same etching liquid;
- The pipes are placed in the electro fitting and fastened in the fixing mechanism;
- The terminals of the welding machine are connected and the necessary data for the dimensions to be welded are introduced into its processor (manually or automatically), and the welding process is activated;
- After completing the welding cycle (assisted by the machine), we wait for the welded joint to cool down to the ambient temperature, and then remove the joined pipes from the fixture,
- The welding temperatures and times are recommended by the producers of the pipes and of the welding machines.

All the joints prepared for welding will be mounted without straining them; it is now allowed that the pipe hangs inside the fittings under their own weight or to be folded. After mounting the electro fittings, we must check whether it is possible to easily twist them (without considerable effort).

Figure 2: Polyethylene machine used for electrofusion welding

If necessary, the pipe can be supported, or appropriate supporting devices may be used. The joint will remain in a fixed position, requiring a cooling time indicated on each fitting.

An off-centered joining compared to the right position leads to a surplus of molten material, changing the inner section of the joint and the mechanical strength of the welded assembly. There are different time periods required for cooling down the areas joined with a resistive element, according to the diameter.

2.2. Performing the Electrofusion Welding and Following the Welding Process for Different Types of Joints

For performing the electrofusion welding we used the SBox polyethylene welding machine from the Fusion Romania company, operated by authorized gas installers and polyethylene welders, employees of the Proconfort company. Welding the 32 mm diameter electrofusion socket.

Figure 3: The polyethylene pipe and the fitting before welding

Figure 4: The assembly resulted from electrofusion welding

3. The Importance of Studying the Suggested Method

We have noticed the advantages of using plastic materials in the construction of the polyethylene pipes, and the fact that the disadvantages of joining fittings with polyethylene pipes are related to the working temperature that cannot be maintained at all times (the welds made below +5 cannot be guaranteed), the fact that for welding costly welding equipment and current generators are required; and that it is necessary to use specialized personnel to operate the equipment.

The suggested topic is to develop an assembly glued with a specific adhesive that must join those elements and withstand a pressure of 6 bar and different forces that put pressure on the assembly along the axis.

4. Intended Objectives

The objectives proposed in the present study are related to the development of the theoretical and experimental models, as an alternative to the electro fitting, respectively to the electrofusion welding, by gluing the components with a specific adhesive.

5. Developing the Tridimensional Models with CAD

The problem of geometrically modeling can now be approached using assisted design software or modules incorporated into the finite element analysis programs intended for assisted design. Such a program that allows a finite element analysis is Catia, by means of the finite element analysis module.

The assembly polyethylene elbow - polyethylene pipe was chosen for the present research, the conducted investigation being easily adapted to other sizes of the same category. As mentioned before, the geometric modeling was performed using the Catia software, which includes the finite element module, thus eliminating the risk of the possible inconsistencies between the Catia files and other finite element software.

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 at the same time as the finite element method. The method was originally used in the mechanical calculation of the airplane structures but later it expanded widely to all the material continuum problems. These problems seek to determine, in a considered area, the values of one or more unknown functions such as: displacements, velocities, temperatures, stresses, strains, etc., depending on the nature of the tackled problem.

The natural phenomena of this kind are described by differential equations, and, by integrating them under given limiting-conditions, we obtain the exact solution. In this way we can 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 the 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.

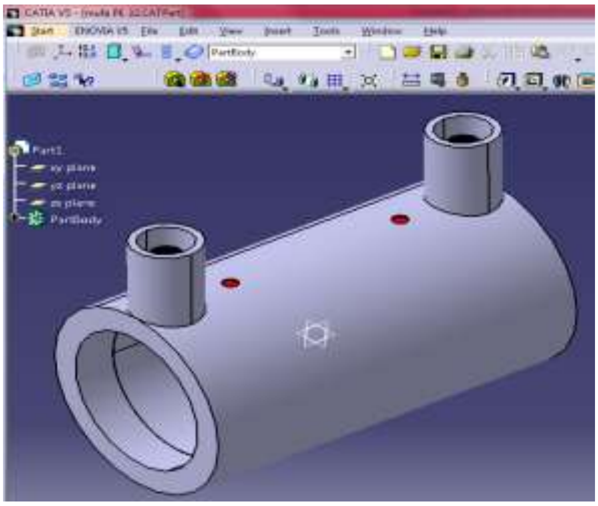

Fig. 5. Designing the 3D model of the 32 mm electrofusion fitting, by means of Catia software

After modeling in Catia the high density polyethylene fitting used for joining the polyethylene pipes, the following aspects were noticed:

- The most demanding area in the polyethylene socket is the central area, actually the area between the fitting's inner catches;
- In the future it is possible to provide such parts with a few outer groves which do not affect the functionality of the part in the region between the two pipe ends which are inserted therein;
- To preserve the linearity of the two pipe ends, it is recommended to weld the fittings and the pipes by means of a specially designed aligning tool;
- This study used several force values that strain the assembly which are not necessarily the maximum forces, but they were selected in order to observe the area of the fitting that shows a tendency towards yielding.

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Avrigean Eugen - holder of a Ph.D. title in Mechanical Engineering, specialty Strength of Materials, higher education faculty member (Lucian Blaga University - Engineering Faculty) and conducting research for 16 years. He has written numerous research books and articles, and worked on laboratory studies, numerical analysis and computer aided design.

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