# Comparative Study on the Method of Connecting Polyethylene Pipes to the Existing Polyethylene Distribution Systems

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**Abstract:** ***The present paper aims to address a practical topic that will ensure an easier choice of the polyethylene tee type used in branching high density polyethylene pipes to other pipelines of this type with simple and safe elements. Two types of tees were analyzed through finite elements in terms of stresses, strains and mechanical constraints.***

**Keywords:** polyethylene, T tees, branch tee.

## 1. Introduction

The basic materials for the production of plastics are natural materials such as cellulose, resins, oil and natural gas. Oil and natural gas are the most important raw materials. In refineries, crude oil is separated by distillation into several fractions. Depending on the boiling temperature range, various distillation phases are obtained: gas, gasoline, kerosene, fuel and, as residues, bitumen. All these constituents consist of hydrocarbons which differ only by the size and configuration of the molecules. The most important fraction for the production of plastic materials is straight-run gasoline. This gasoline is further fractionated and transformed by a thermal cracking process (vapour cracking) into ethylene, propylene, butylene and other hydrocarbons.

One can say that plastic materials are materials obtained by chemical transformation of natural products, or synthetically based on organic compounds having carbon (C) and hydrogen (H) as their main constituents. At the base of most plastic materials are the *hydrocarbons* from which the individual combinations of plastics are derived, which are called *monomers* namely monomer molecules of the same kind.

## 2. Electro-Fusion Welding

The procedure is based on the use of a part which will be assembled through welding, called *the electro-fitting* (Figure 1). It consists of the basic body, injection molded 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 (control) and electrical connectors that can be linked to the welding machine. 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 electrofitting. By heating the pipe-fitting assembly, there is a swelling of the material, pre-calculated by taking into account the gap between the two parts and then, by heating until it reaches an optimal melting temperature of about 220 °C, we obtain a molten homogenous mass. Upon cessation of the electric current in the electric resistance, the process of solidification of the melted mass begins, thus welding the two connected parts (Figure 1).

**Figure 1:** Pipe and fitting following the polyethylene 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. First the fitting heats at the ends then towards the interior (the center), so that the melted mass solidifies without leaking outside the welded area. Only the same type of materials can be welded through electro-fusion. 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. After the welding, the technical data contained therein referring to the setting of the welding process parameters are *deleted*, therefore it can be used only once.

For the analysis, the two types of the tees used for branching polyethylene pipes to other polyethylene pipes were subjected to the present study, respectively the branch tee type T (Figure 2) and the tapping tee (Figure 3).

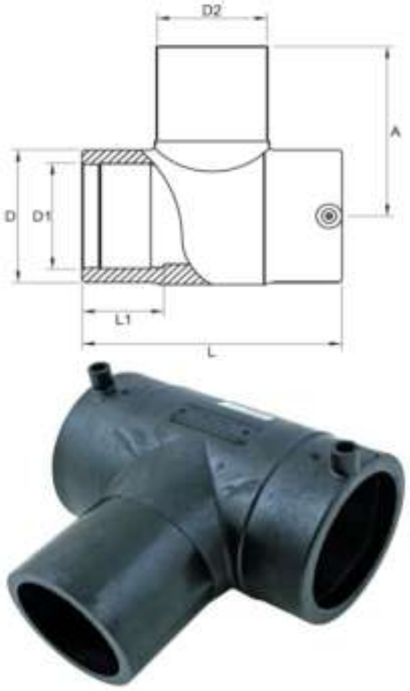



**Figure 2:** Branch tee

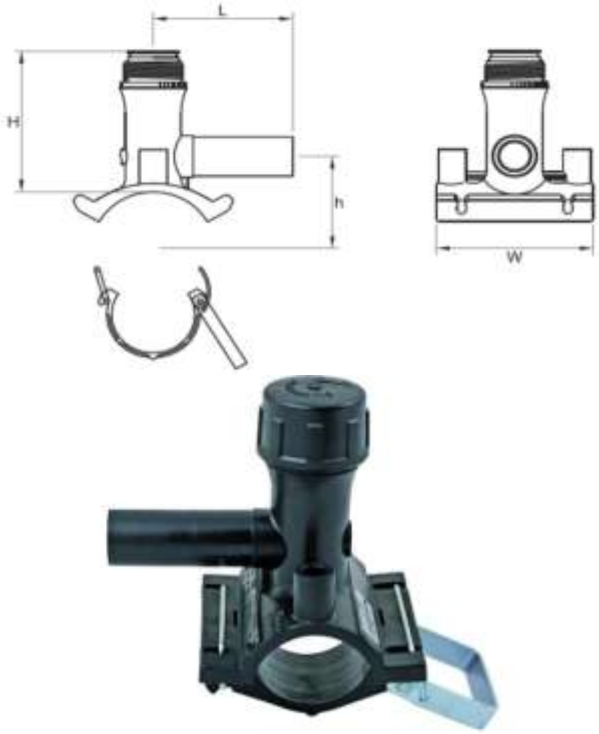



**Figure 3:** Tapping tee

## 3. Thermal Study on the Welding Process

The conducted study required the following equipment: 1 Polyethylene welding machine Sbox, manufactured by Fusion company England, which makes possible to weld polyethylene fittings up to 180 mm in diameter and allows the observation of the welding cycle, so in case this is not completed correctly, the machine will record the error and will highlight this in the welding protocol; 2. High technology camera for recording the temperatures ThermoVision A320 which ensures the measurement and recording of temperatures both on a broad area and on a specific area; 3. Software for acquiring the values measured by means of the thermal camera - allows us to create an overall or a detailed image. 4. The welding machine which consists of the high density polyethylene pipe, diameter 63SDR11, used in natural gas distribution and the analyzed polyethylene tees, 63 mm in size.

**Figure 4:** Welding machine and temperature measuring system

The welding technology is followed and the tools and machines used are certified. The mark was made on the pipe, the coating on the DN63 mm pipe was removed in the welding area by means of the metallic scraper, the welding area was etched with a special etching solution and then the DN63 electro-fusion elbows were set and the welding procedure began.

a) The equal electro-fusion tee 63 mm in diameter was welded with a welding machine appropriate for polyethylene, called S-box and manufactured by Fusion company.


**Figure 5:** Equal tee - polyethylene pipe Dn63 assembly resulting from electro-fusion welding

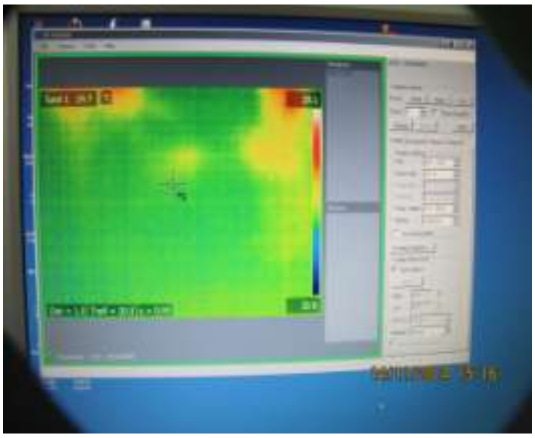
By observing the welding process it was noted that the time required for welding this fitting was 40 seconds and the minimum cooling time was 5 minutes.

b) Welding the electro-fusion branch tee 63-32 mm in diameter

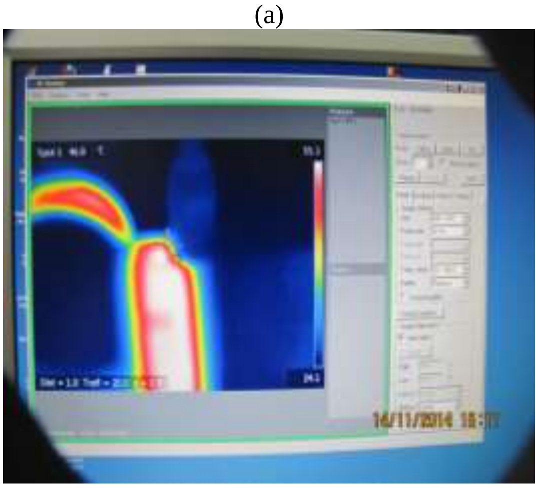

**Figure 6:** Elbow - polyethylene pipe Dn63-32 assembly resulting from electro-fusion welding

By observing the welding process it was noted that the time required for welding this fitting was 80 seconds and the minimum cooling time was 12 minutes.

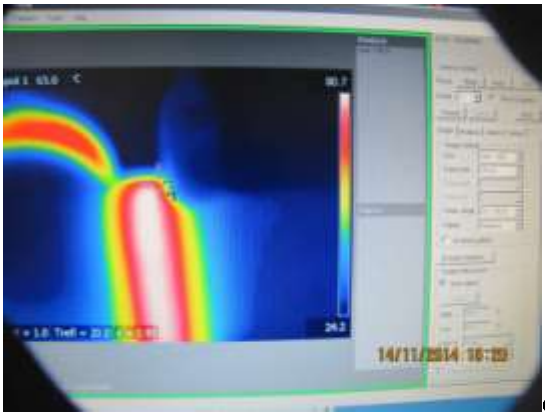
Measurements on the work assemblies (3 tests) were carried out at an ambient temperature of 22 degrees Celsius. The Sbox polyethylene welding machine allows the automatic adjustment of the operating voltage and the progressive increase of the welding temperature, which is noticeable in the following images taken during the measurements.



(a)

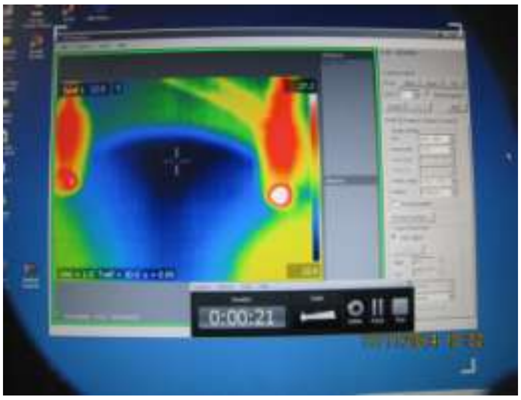


(b)

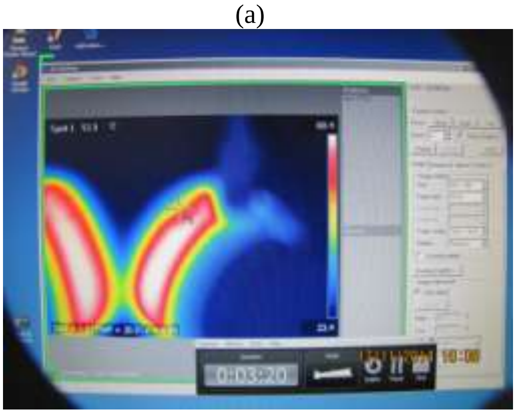


c.

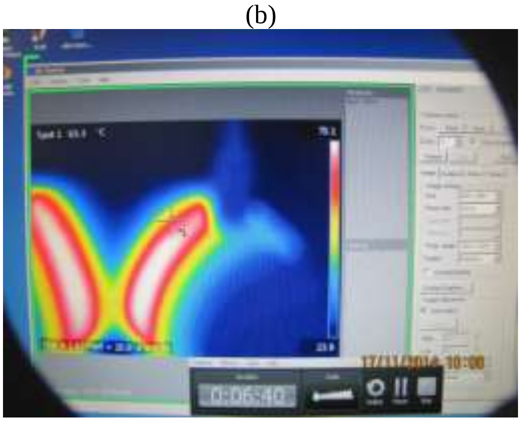
**Figure 7:** Highlighting the temperature increase in the three welding stages for the T-type DN 63 tee: a. Initial, b. Middle, c. Final, under correct working conditions




(a)




(b)




(c)

**Figure 8:** Highlighting the temperature increase in the three welding stages for the branch DN 63 tee: a. Initial, b. Middle, c. Final, under correct working conditions

## 4. Finite Elements Modeling of the Fittings to be Analyzed

The problem of geometric modeling can now be approached using assisted design software or modules incorporated into finite element analysis programs for assisted design. Such a program that allows for a finite element analysis is Catia.
One of the modules of this program is the structural one which, due to the extensive facilities it allows, was chosen for studying the static and dynamic behavior of the polyethylene parts. Among the most important facilities underlying geometrical modeling, we mention:

- Parametrizing the model of the part in order to optimize it;
- Creating the model through Boolean operations, which is possible due to the use of Solidworks model maker that allows us to conduct these operations;
- The compatibility with CAD assisted design programs that gives us the possibility to import the model of a structure made in a different program;
- The existence of a sufficient finite element data base;
- The optimization module that makes possible to define the design, state variables and the objective function within the optimization algorithm.

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, and 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 with the emergence of 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 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.

In order to make a coparative study on the stresses and strains occuring in parts like these, they were modeled and analyzed by means of Catia software.

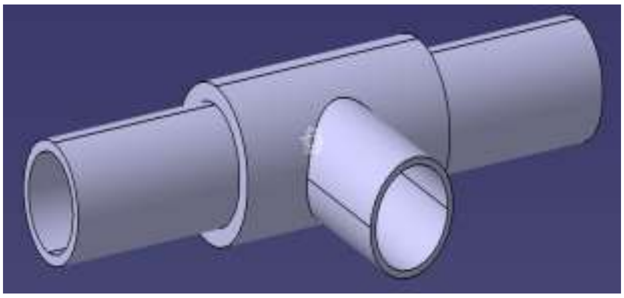


**Figure 9:** Modeling the Dn 63 mm T-type branch tee

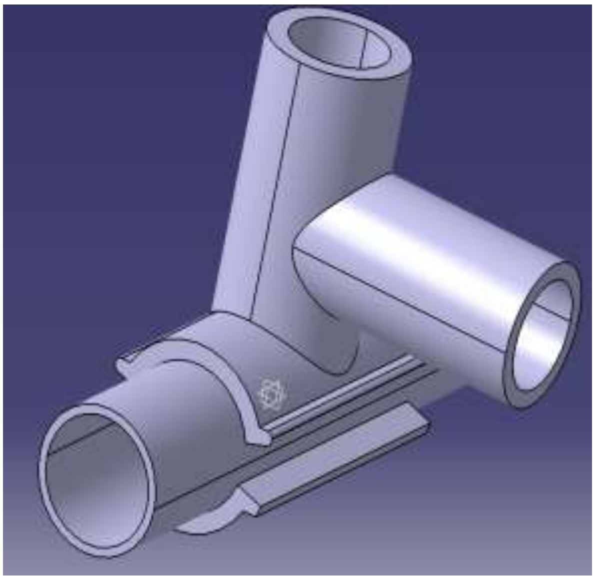


**Figure 10:** Modeling the Dn 63 mm branch tee

After obtaining the three-dimensional models they were transferred to the finite element analysis module and loaded with the mechanical characteristics and the constraints (Figures 11 and 12)

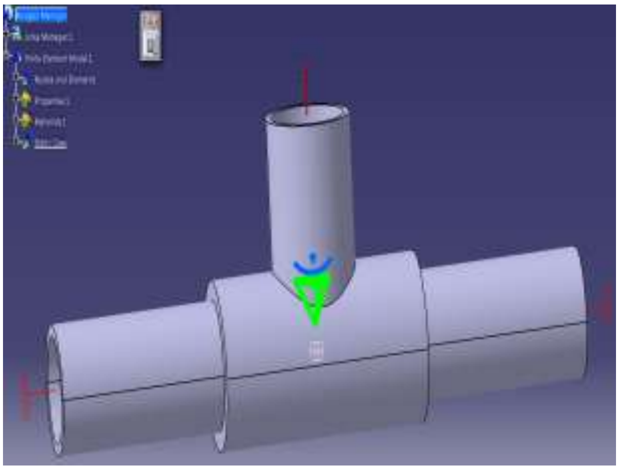


**Figure 11:** Loading the Dn 63 T-type branch tee with random constraints and forces

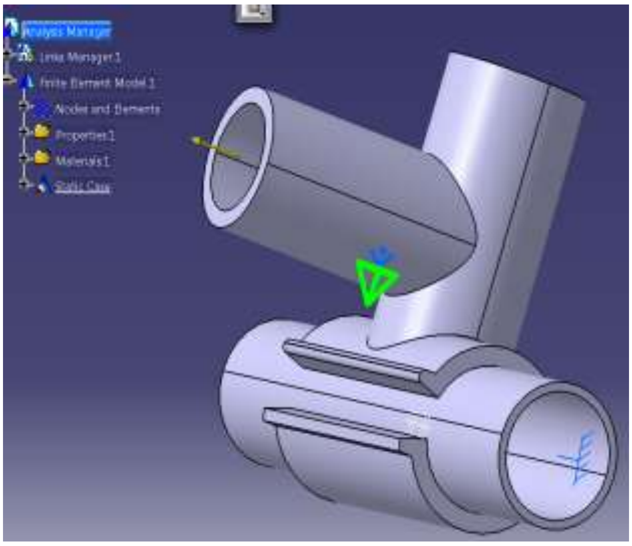


**Figure 12:** Loading the Dn 63 branch tee model with random constraints and forces

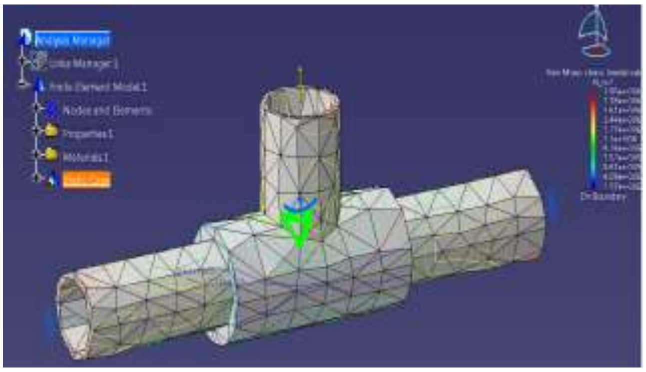


**Figure 13:** Maximum value of the Von Misses stress for a 1kN load is 1.95 Mpa for the T tee

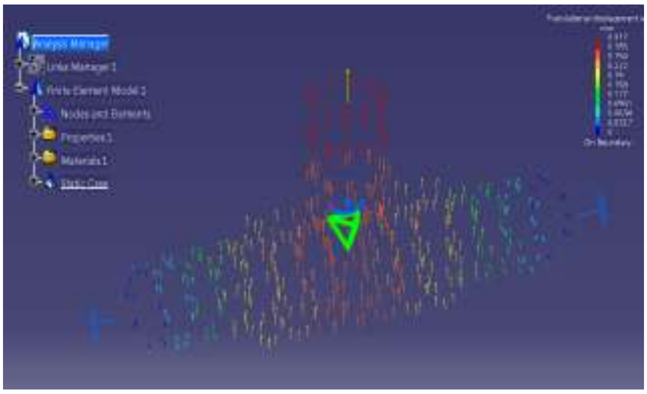


**Figure 14:** Maximum value of the displacement for a 1kN load is 0.317 mm for the T tee

Using the same methods for the branch tee, it was observed that the values of the Von Mises stress were 32.2% lower and also, those of the displacements 37.4% lower.

## 5. Conclusions

This study proved that out of the two parts chosen for the analysis the branch tee is the one recommended to be used, both in terms of the temperatures measured by means of the thermal camera, and in terms of the stresses.

The stresses and strains were higher in case of the T tee as compared to the branch tee and that is why it is recommended to use the branch tee, because it proves greater operational safety.

The temperatures measured by means of the thermal camera allow us to observe that the heat-affected area is larger in the T-tee, which requires a longer cooling time, ie a longer working time.

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