# Experimentally Testing the Polyethylene Pipes upon Being Strained with the Squeeze – Off Tool

Eugen Avrigean[1], Adrian Marius Pascu[2] and Valentin Stefan Oleksik[3]
[1]Lucian Blaga University, Bulev. Victoriei nr. 10, Sibiu, 550024, Romania
[2]Lucian Blaga University, Bulev. Victoriei nr. 10, Sibiu, 550024, Romania
[3]Lucian Blaga University, Bulev. Victoriei nr. 10, Sibiu, 550024, Romania

***Abstract*—The present paper aims at monitoring the behavior of the high density polyethylene pipe when pressed by an external force in order to shut it off so that the natural gas can no longer pass through the distribution pipelines. The behavior of the polyethylene pipe will be observed by means of fast shutter cameras, and the mechanical tests will be conducted by using the squeeze-off tool.**

***Keywords-mechanical test; polyethylene pipe; rapid photography***

## I. Introduction

The high density polyethylene pipes are extensively used lately, so inferentially various problems arise due to this great usage. There are several advantages in using the polyethylene pipe compared to steel pipe, namely:

- the possibility to be joined by welding at low temperatures (compared with the high temperatures required for steel), by means of simple technology, as well as by mechanically assembled fittings, as appropriate;

- the possibility of combining the polyethylene networks with the already existing steel networks or with the existing fixtures;

- increasing the speed of installing the networks involves lower execution costs;

- the variety of dyes allows precise marking and identification;

- the array of sizes of the fittings covers approximately 32,000 units;

- the high corrosion resistance, which leads to the elimination of the need for cathodic protection, a very important advantage for the natural gas distribution networks since the aggressiveness of the soil in urban areas is considerably higher than outside the settlements;

- the possibility of using very long pipes, by delivering them in coiled form;

- good chemical resistance to the gas components;

- it protects the natural environment, due to its feature as recyclable material.

The issue undergoing analysis in this paper is related to the behavior of the PE100 polyethylene pipe at the moment when it is shut in order to achieve under pressure couplings, what happens to the polyethylene pipe after removing the squeeze-off tool and what is its tendency to recover its initial form, namely its original diameter.

FIGURE I. PE100 POLYETHYLENE PIPE(BAR OR COILED)

## II. Presentation of The Squeeze-Off Tool Used in Shutting Off Polyethylene Pipes

There are situations in every day practice when the couplings to the natural gas distribution pipes are done under pressure (on the free end of the pipe or through multiple squeeze-off tools) being required to use different size squeeze-off tools (Figure 2).

FIGURE II. SQUEEZE – OFF TOOL USED FOR SHUTTING OFF THE POLYETHYLENE PIPES OF 63 – 160 MM DIAMETER

The adjustment of this squeeze-off tool is done by means of a knob which selects the diameter and the thickness of the pipe.

The problem which occurs in such cases is related to the radial compression of the polyethylene pipes and to the behavior of the material, therefore we shall monitor the area of the pipe which was mechanically squeezed-off.

## III. Presentation of the Testing Method. Radial Compression Testing of the Polyethylene Pipes

In order to determine the crushing resistance of the polyethylene pipes used in natural gas transmission, experimental tests were conducted on a tensile, compression and buckling testing machine, Instron 5587, and the samples were cut into 250 mm sections from pipes of different diameters. These tests were performed in order to determine the deformation of such a sample, to determine the elastic recovery as well as to determine the strains and stresses occurring in such structures. For these experimental measurements, in addition to the Instron machine software, an optical method was used which employs an Aramis 2M type equipment. [3]

The experimental study was conducted on pipes of the dimension Φ63 x 5.8 and material (PE100). A pipe's flexural rigidity, according to ASTM D 2412, can be calculated with the following relation:

$$SN = \frac{E \cdot I}{D^3}, \quad (1)$$

where: SN is the flexural rigidity, E is the elastic modulus of the pipe's material (E=1.2 GPa for a PE100 pipe); I is the moment of inertia of the cross section, calculated with the relation $I = t^3/12$, where t is the pipe's thickness; D is the pipe's median diameter. [1]

By using the relation (1), for the pipes studied in this paper, the values listed in table 1 were obtained for the flexural rigidity.

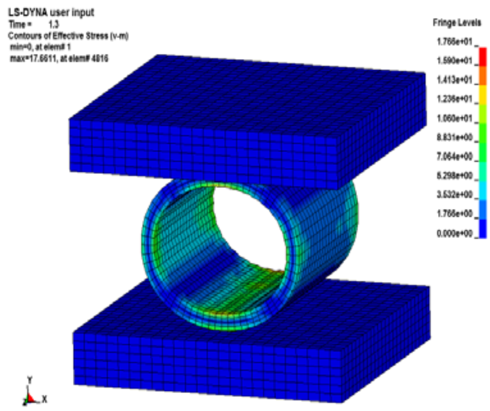
TABLE I. VALUES OF THE FLEXURAL RIGIDITY OF POLYETHYLENE PIPES

| **Material** | **Type of pipe Φ x t [mm x mm]** | **SDR Φ / t** | **SN [N/mm$^2$]** |
|---|---|---|---|
| | | | |
| PE 100 | 63 x 5.8 | 11 (10.86) | 0.104 |
| | | | |

For the studied samples, parts approximately 250 mm long were used, which were subjected to radial compression force (Figure 3).

For the optical data acquisition by means of the Aramis 2M system, before being subjected to compression, the pipe sections were covered in a fast drying adherent matte white paint.

A.[1]




B. [3]

FIGURE III. FASTENING THE PIPE IN THE UNIVERSAL TESTING MACHINE

Then, a graphite spray was used on the areas exposed to the image capturing system. Polyethylene pipes were subjected to compression with a maximum force of 7,500 N, the upload speed being 10 mm/min, achieving at the same time both the acquisition of data on the deformation of the pipe through the Aramis 2M system and of data on its behavior under compression by means of the Instron 5587 machine software.

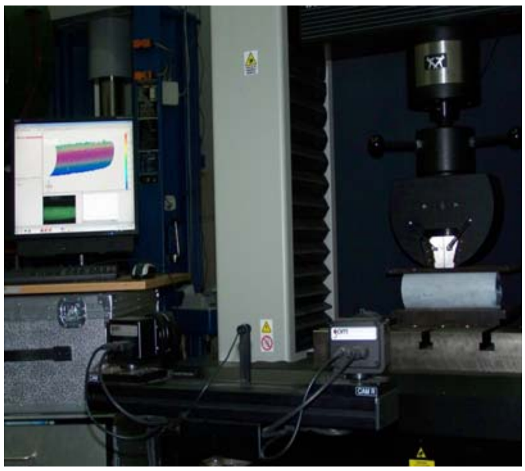


FIGURE IV. EQUIPMENT FOR TESTING POLYETHYLENE PIPES

Figure 4 shows the entire assembly used for the experimental determinations: universal testing machine Instron 5587 (1), polyethylene pipe (2), high-speed video cameras (3), computer for data acquisition (4).

The following figures contain the characteristic force – strain curves for the 63 mm diameter and PE 100 material. The sequent figure shows the variation mode of the maximal strain (corresponding to the maximum force of 7,500 N) depending on the pipe's diameter and material (PE80 and PE100)

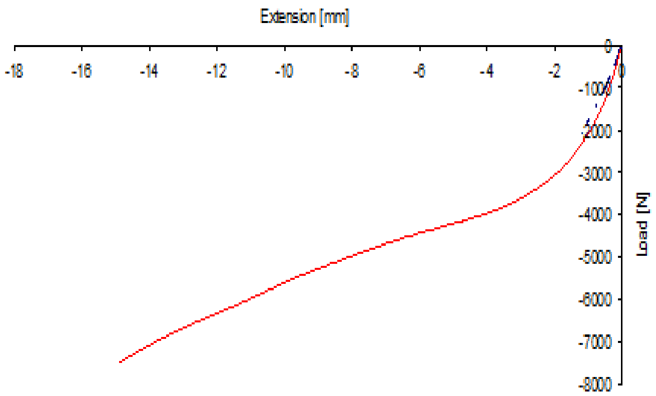



FIGURE V. EXPERIMENTAL CURVES FORCE-STRAIN FOR THE PIPE Φ 63 X 5.8

## IV. Results of the Tests

The following measurements were determined by using the software of the Aramis 2M equipment: strains (displacements of the points on the pipe's profile) on the three directions ( Δx, Δy, Δz), the total strain (Δe), the principal strain ($\varepsilon_1$), the Tresca equivalent strain ($\varepsilon_T$), the VonMises equivalent strain ($\varepsilon_{VM}$), the relative thinning (δ). The values of these measurements are listed in the table below.

TABLE II. VALUES OF THE MEASUREMENTS DETERMINED BY MEANS OF ARAMIS 2M EQUIPMENT

| Material | Type of pipe Φ x t [mm x mm] | Δx [mm] | Δy [mm] | Δz [mm] | Δe [mm] | $\varepsilon_1$ [%] | $\varepsilon_T$ [%] | $\varepsilon_{VM}$ [%] | δ [%] |
|---|---|---|---|---|---|---|---|---|---|
| PE100 | 63 x 5.8 | 0.380 | -7.86 | 4.64 | 8.93 | 23.22 | 23.20 | 27.42 | 19.12 |

The results obtained by using the Aramis 2M optic system, for the PE100 polyethylene pipe of 63 mm diameter and 5.8 mm thickness, are shown below.

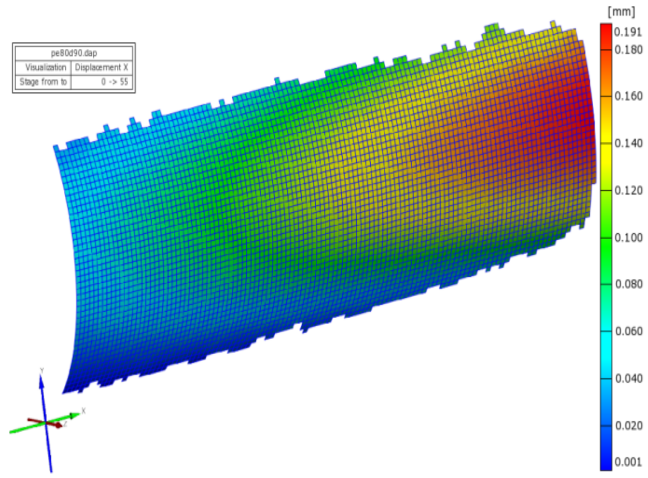



FIGURE VI. DISPLACEMENT OF THE PIPE ON AXIAL DIRECTION (OX) [MM]

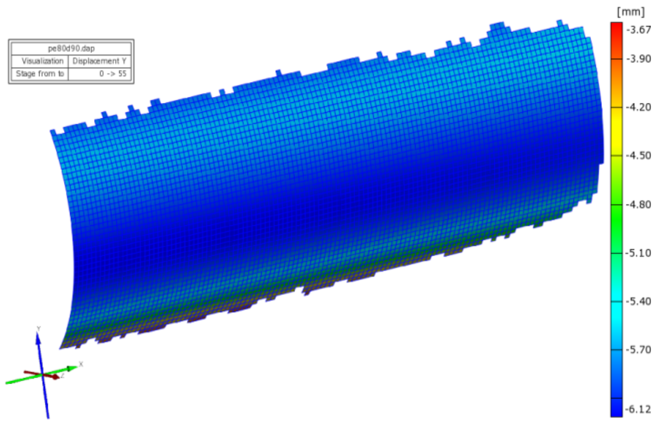



FIGURE VII. DISPLACEMENT OF THE PIPE ON VERTICAL DIRECTION (OY) [MM]

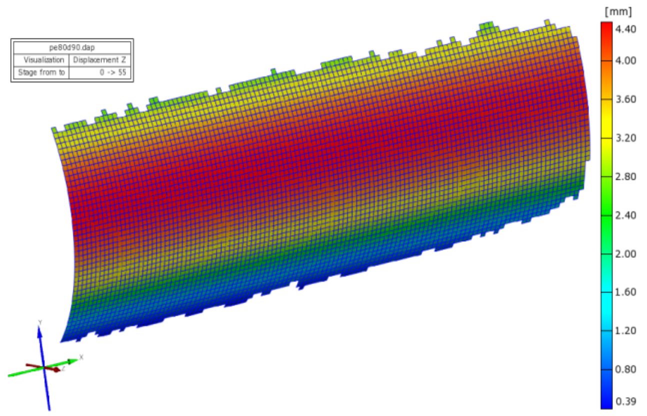



FIGURE VIII. DISPLACEMENT OF THE PIPE ON RADIAL DIRECTION (OZ) [MM]

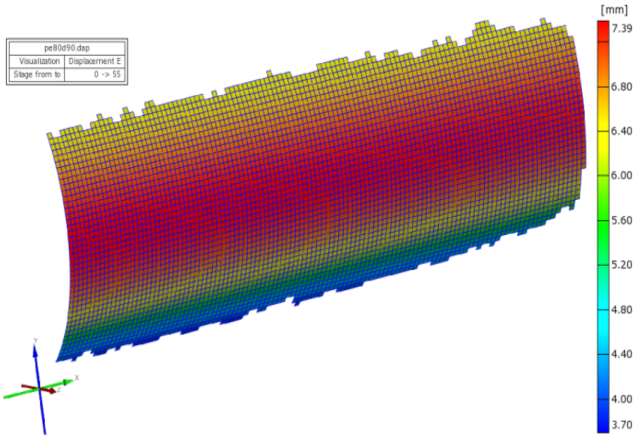



FIGURE IX. TOTAL DISPLACEMENT OF THE PIPE [MM]

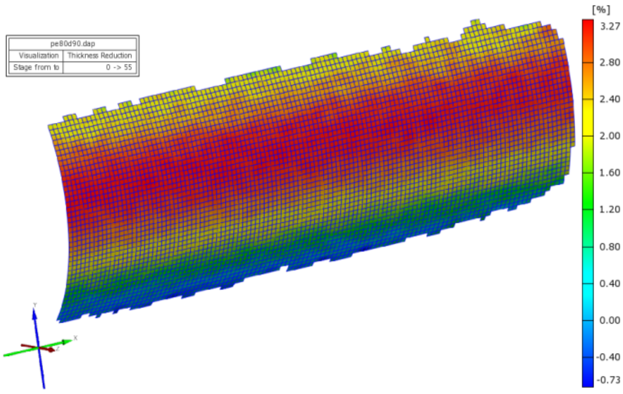



FIGURE X. RELATIVE THINNING (δ) [%]

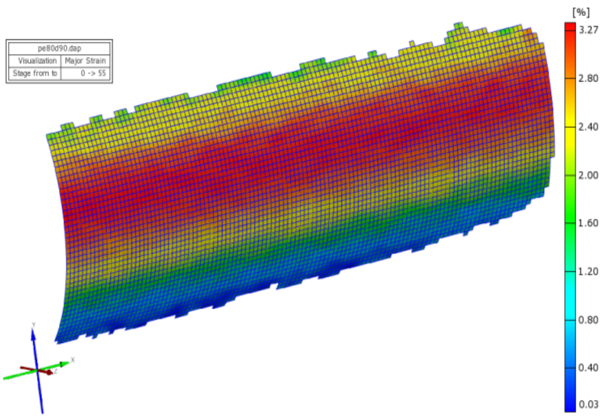



FIGURE XI. PRINCIPAL STRAIN (ε1) [%]

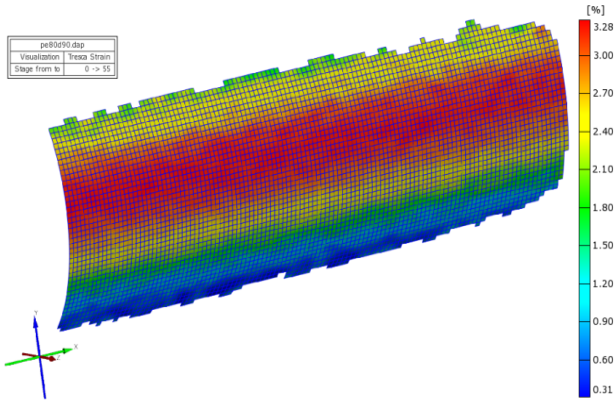



FIGURE XII. TRESCA EQUIVALENT STRAIN (εT) [%]

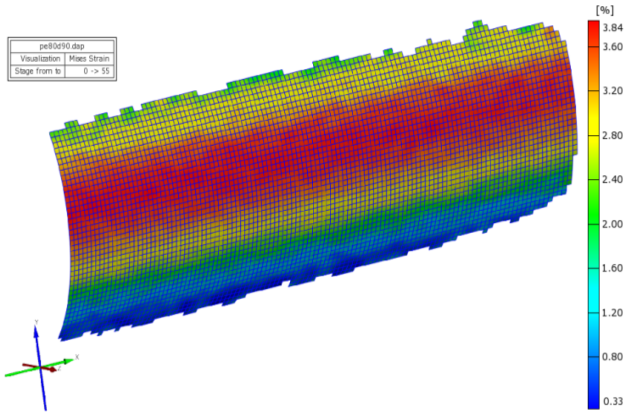



FIGURE XIII. VON MISES EQUIVALENT STRAIN (εVM) [%]

It can be seen from the experimental results, both from the data provided by the software of the universal testing machine and from those obtained by using the optical acquisition system of (Aramis 2M) that for both materials (PE80 and PE100) at the same maximum compression force (7,500 N) the smallest strain is obtained in pipes with a 63 mm diameter and 5.8 mm thickness. We also notice that the strains decrease in the PE100 pipes by approximately 17 ... 18% in the case of pipes with 32 mm and 63 mm diameters and by approximately 88% for the 90 mm diameter pipe. The same trend is observed for the strains in the direction of force application (Oy) determined by means of the optical system Aramis, being lower for PE100 pipes by approximately 24% for pipes with a 32 mm diameter, approximately 13% for 63 mm diameter pipes, and approximately 65% in the case of the 90 mm diameter pipe.

## V. CONCLUSIONS

The limitations of these experiments are related to the fact that only one testing was conducted for each pipe dimension, which can lead to an alteration of the results. However, the advantage of the method used is that we can also measure the relative thinning of the tested pipes, which is very important in terms of safety in the operation of these pipes, considering the fact that they are used in the natural gas transmission.

The values of the strains are relatively high, but the elastic characteristics of the material allow the occurrence of these values.

We must mention that the squeeze-off tools should be compulsory fitted with appropriate system for adjusting the pipe thickness that varies for each pipe diameter.

The pipe chosen for analysis, 63 mm in diameter, is often used in practice and the method to shut it off is frequently used in under pressure couplings in the natural gas distribution systems.


## ACKNOWLEDGMENTS

This work was supported by the strategic grant POSDRU/159/1.5/S/133255, Project ID 133255 (2014), co-financed by the European Social Fund within the Sectorial Operational Program Human Resources Development 2007 – 2013.


## REFERENCES


[1] Avrigean E. Study on Temperature Distribution in the Jointing Fittings for Polyethylene Natural Gas Pipes. 2015 3rd International Conference on Recent Trends in Materials and Mechanical Engineering (ICRTMME 2015) , January 15-16, 2015, Auckland, New Zealand.

[2] Balan, M. L. Contributii la utilizarea procedeului de sudare cap la cap a tevilor de polietilena destinate transportului si distributiei gazelor naturale. Doctoral thesis. Sibiu.

[3] Oleksik, V., Pascu, A.M. Proiectarea optimala a maşinilor si utilajelor, "Lucian Blaga" University Publishing House, Sibiu, 2007.