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Experimental Study of the Crushing Behavior of High Density Polyethylene Pipes

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Abstract

The paper presents an experimental study on the crushing behavior of high density polyethylene pipes used to transport natural gas. In this study two materials were studied PE80 and PE100, respectively three sizes of pipes (Φ32 × 3, Φ63 × 5.8, Φ90 × 8.2). For experimental measurements it was used the universal testing machine Instron 5587 and the optical equipment Aramis 2M. In this study they were determined the deformation on the Ox, Oy and Oz direction and also Tresca and von Mises equivalent strain occurring in such structures as well as the thickness reduction of the pipes studied.

Key words: *polyethylene pipe, Instron machine, Aramis device, stess, strain, deformations*

Introduction

Polyethylene (PE) is a solid, white, thermoplastic, slightly greasy to the touch, similar to paraffin. This similarity can be understood if one takes into account that this polymer has the structure to sacks hydrocarbon (paraffin) with a high molecular weight. In general pipes for gas transport are made of high density polyethylene (HDPE) type 316. Introduction of polyethylene pipes in gas distribution networks was imposed due to these material qualities, namely: the time safety operation, no need for maintenance, costs, life [1]. Using high quality raw materials, in same time with the use of high productivity extrusion lines (modern and specific to this type of material), allows a constant production of pipes with outstanding technological qualities, having the following properties (characteristics): optimal resistance to stress cracking with high reliability in time of the pipes under pressure, excellent chemical resistance, high UV protection, guaranteed by the use of genuine raw materials additives with carbon black, complete safety and a wide range of national and international atoxicitate norms, insensitivity to electrochemical corrosion, good resistance to temperatures below -40 ° C, high flexibility, optimum hydraulic characteristics that remain constant over time, very low roughness, which makes these pipes to fall within the type of smooth pipes, exceptional strength to abrasion, which makes them ideal for transporting abrasive fluids, long life (over 50 years), low weight, safety and ease of the connection systems, high productivity to installation.

Achievement Tests and Acquisition of Experimental Results

For determining the resistance to polyethylene pipes crushing used for the transport of natural gas, experimental tests were performed using a tensile testing machine, compression and buckling Instron 5587 and the samples were cut in the form of rings of different diameter pipes (figure 1). These tests were conducted in order to determine the mode of deformation of such specimens to determine the elastic recovery and to determine the strains and tensions that arise in such structures. For these experimental measurements, in addition to Instron machine software it was also used an optical method that uses equipment of the type Aramis 2M.

For the experimental study they were used three sizes of pipes (Φ32 x 3, Φ63 × 5.8, Φ90 x 8.2) and two kinds of material (PE80 and PE100). The stiffness (rigidity) of a pipe according to ASTM D 2412 can be calculated with the following equation:

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

where: *SN* is the pipe atiffness (rigidity), *E* is the modulus of elasticity of pipe material ($E = 1.2$ GPa for PE100 pipe and $E = 0.9$ GPa for PE80 pipe), *I* is the moment of inertia of the section, calculated with the equation $I = t^3/12$, where *t* is the thickness of the pipe, *D* is the median diameter of the pipe.

Using equation (1), for the pipes studied in this work, there were obtained for the flexural rigidity the values show in Table 1.

Table 1. Flexural rigidity values for the polyethylene pipes

Material	**Type of pipe Φ x *t* [mm x mm]**	***SDR* Φ / *t***	***SN* [N/mm^2]**
PE 80	32 x 3.0	11 (10.67)	0.083
	63 x 5.8	11 (10.86)	0.078
	90 x 8.2	11 (10.98)	0.076
PE 100	32 x 3.0	11 (10.67)	0.111
	63 x 5.8	11 (10.86)	0.104
	90 x 8.2	11 (10.98)	0.101

For the three pipe diameters studied they were cut in pieces of about 250 mm long, which were requested by radial compression (figure 1).

Fig. 1. Setting the pipe in the universal test machine

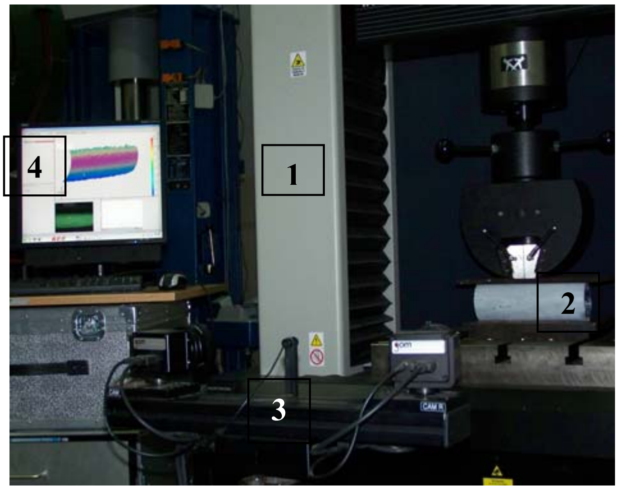

Fig. 2. The test equipment for Polyethylene pipe

For the data optical acquisition using Aramis 2M system, before being required to compression, the pipe pieces were coated with quick-drying slip matt white paint. After that, it was sprayed with graphite spray on exposed areas of the imaging system. Polyethylene pipes were requested to a maximum compression force of 7500 N, the loading speed being of 10 mm / min, achieving at the same time as the data acquisition deformation of the pipe by the Aramis 2M system and the behavior data from their compression using Instron 5587 machine software.

Figure 2 presents the full set used for the experimental measurements: universal test machine Instron 5587 (1) Polyethylene pipe (2), high-speed video cameras (3) and data acquisition computer (4).

In Figures 3, 4 and 5 there are presented the load - deformation characteristic curves for the three pipe sizes studied and for both types of materials. In Figure 6 is presented the variation of maximum strain (corresponding to the maximum load of 7500 N) depending on pipe diameter and its material (PE80 and PE100).

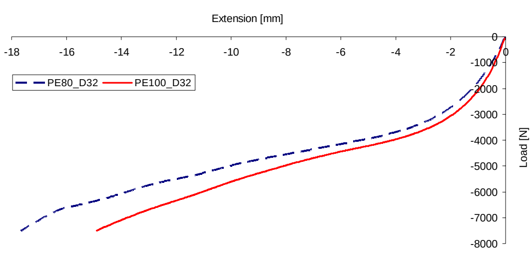

Fig. 3. Experimental load - extension curves for Φ32 x 3 pipes

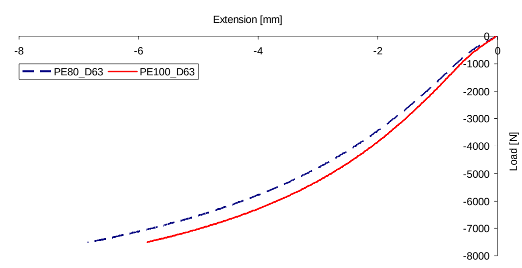

Fig. 4. Experimental load - extension curves for Φ63 x 5.8 pipes

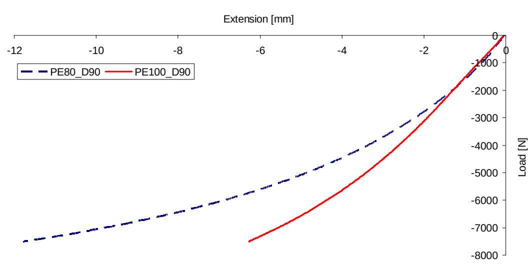

Fig. 5. Experimental load - extension curves for Φ 90 x 8.2 pipes

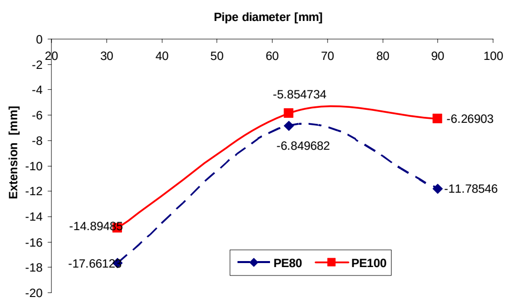

Fig. 6. Variation of maximum deformation depending on pipe diameter

Using the software equipment Aramis 2M there were determined for the three sizes of pipe and for the two materials, the following sizes: deformations (displacements of points on the pipe contour) in the three directions (Δx, Δy, Δz), total deformation (Δe), the main specific deformation (ε_1), the Tresca equivalent specific deformation (ε_T), the VonMises equivalent specific deformation (ε_{VM}), relative thinning (δ). The values of these parameters, the types of material and the pipe sizes studied are presented in Table 2.

The results obtained using the Aramis 2M system, for the pipe with 90 mm diameter and 8.2 mm thickness, made from PE80 is presented in Figures 7 … 14.

Table 2. Values determined due to the Aramis 2M

Material	Type of pipe Φ x *t* [mm x mm]	Δx [mm]	Δy [mm]	Δz [mm]	Δe [mm]	ε_1 [%]	ε_T [%]	ε_{VM} [%]	δ [%]
PE80	32 x 3.0	0.542	-9.73	5.54	10.94	26.25	26.20	31.10	21.04
	63 x 5.8	0.179	-3.47	2.52	3.81	2.84	3.40	3.86	2.86
	90 x 8.2	0.191	-6.12	4.40	7.39	3.27	3.28	3.84	3.27
PE100	32 x 3.0	0.380	-7.86	4.64	8.93	23.22	23.20	27.42	19.12
	63 x 5.8	0.149	-3.07	2.58	4.16	2.60	2.80	3.17	2.55
	90 x 8.2	0.231	-3.72	3.31	5.27	1.71	1.81	1.97	1.68

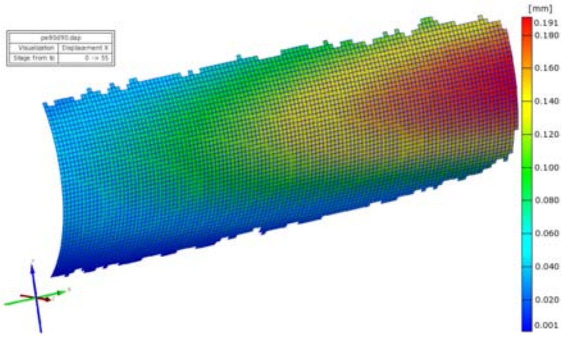

Fig. 7. Displacement on axial direction (Ox)

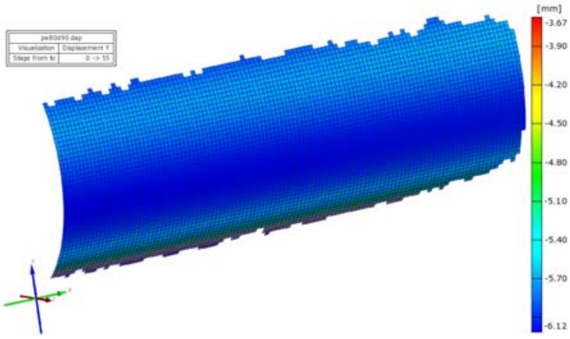

Fig. 8. Displacement on vertical direction (Oy)

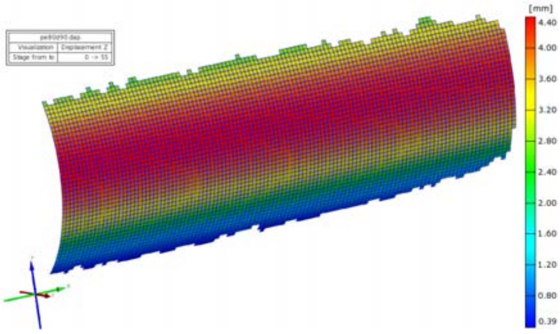

Fig. 9. Displacement on radial direction (Oz)

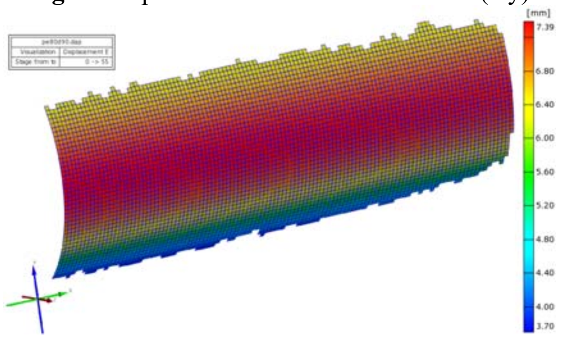

Fig. 10. Total displacement

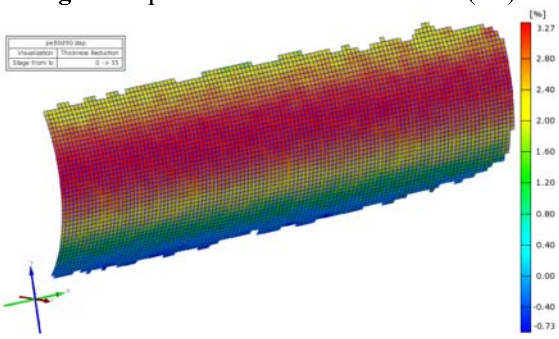

Fig. 11. Thikness reduction (δ)

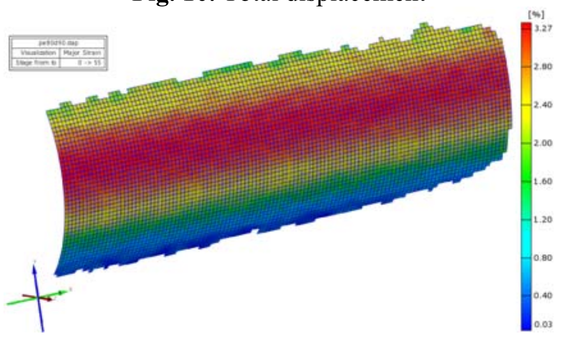

Fig. 12. Principal strain (ε_1)

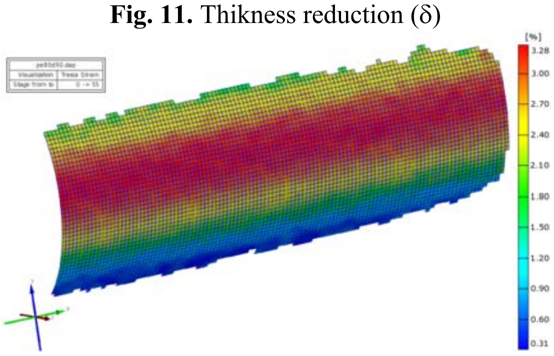

Fig. 13. Equivalent Tresca strain (ε_T)

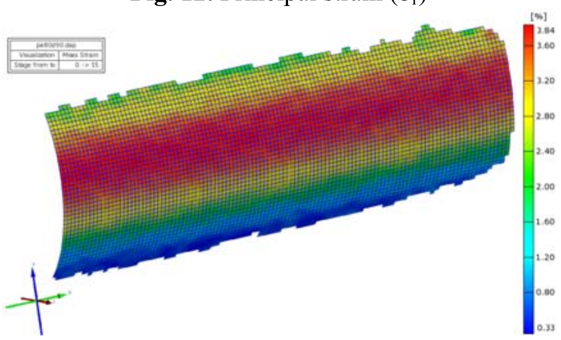

Fig. 14. Equivalent Von Mises strain (ε_{VM})

For the same pipe specimen (Φ 90 x 8.2) we select a point (figure 15) situated an exterior diameter of pipe, and for this point we plot the graphs that show the variation of displacements, stain and thickness reduction during the strain stage. All this graphs are show in Figures 16 … 23.

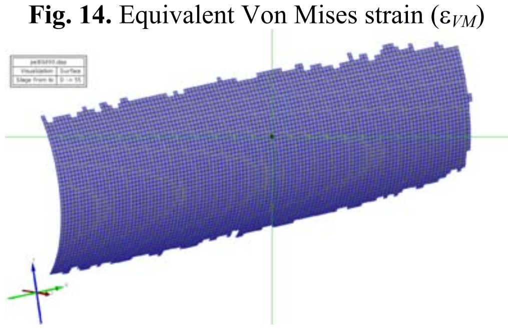

Fig. 15. Selected point

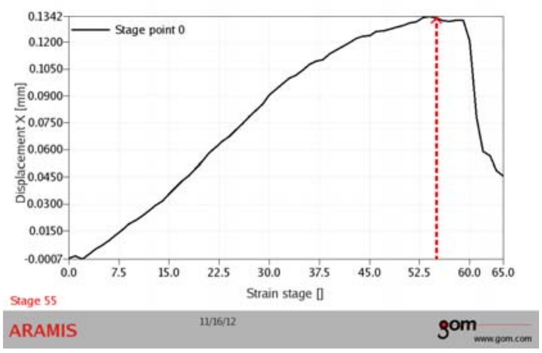

Fig. 16. Variation of axial displacement (Ox)

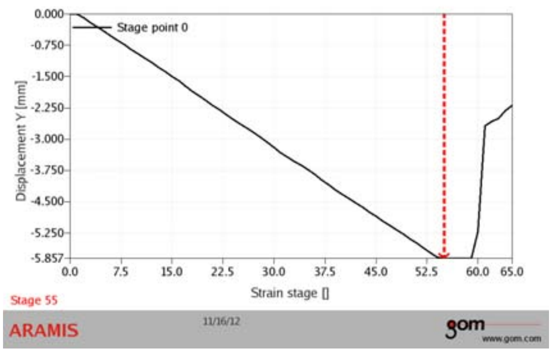

Fig. 17. Variation of vertical displacement (Oy)

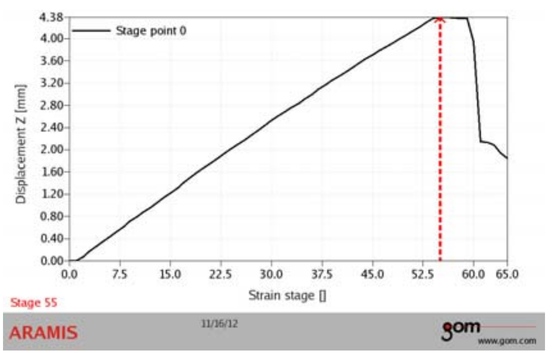

Fig. 18. Variation of radial displacement (Oz)

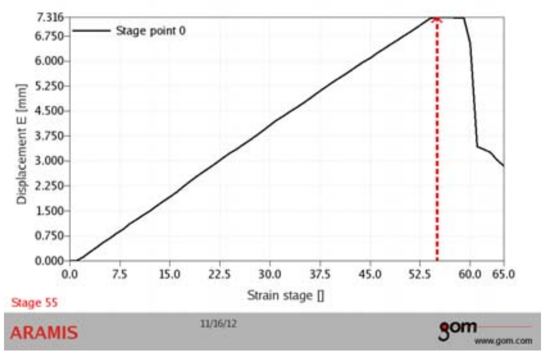

Fig. 19. Variation of total displacement

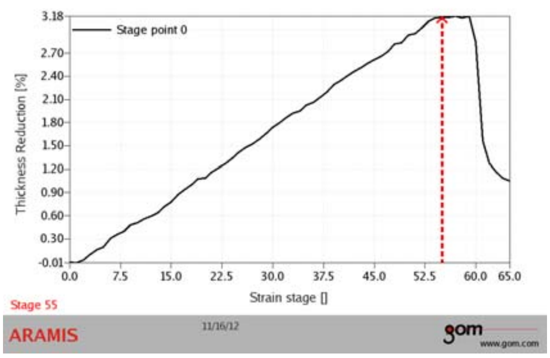

Fig. 20. Variation of thickness reduction (δ)

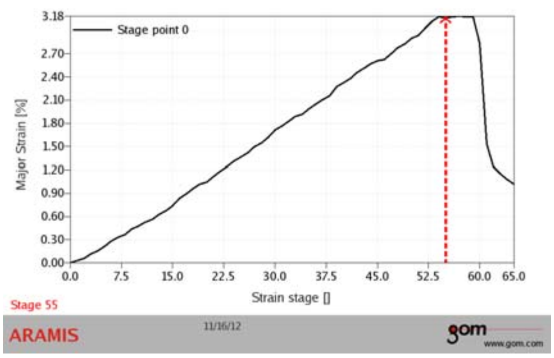

Fig. 21. Variation of principal strain (ε_1)

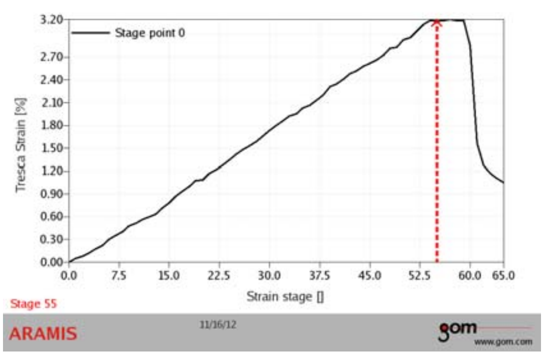

Fig. 22. Variation of equivalent Tresca strain (ε_T)

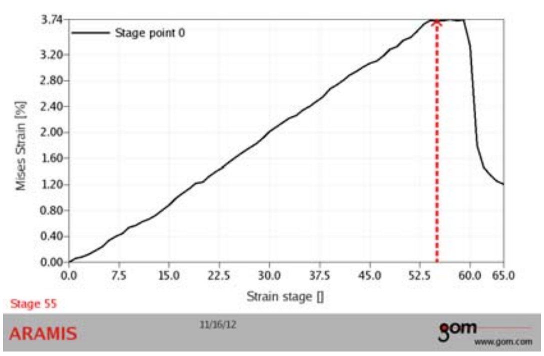

Fig. 23. Variation of equivalent von Mises strain (ε_{VM})

Conclusions

It can be seen from the experimental results from both the data provided by universal testing machine software and those from using the optical acquisition system (Aramis 2M) for the two materials (PE80 and PE100), at the same load compression (7500 N), the smallest deformation is obtained for the pipes with diameter of 63 mm and thickness of 5.8 mm. Also there may be a decrease of deformation for PE100 pipes of approximately 17...18% for the pipes with diameters of 32 mm and 63 mm, and about 88% for the pipes of 90 mm diameter. The same situation also occurs for the formations concerning the load application direction (Oy) determined by Aramis optical system; they are lower for PE100 pipe with approximately 24% for pipes with 32 mm diameter, with about 13% for pipea with 63 mm diameter and with about 65% for pipes with 90 mm diameter.

The limits of these experiments consist of performing only one test for each pipe size which can lead to an alteration of the results. However, the advantage of the method used is that the relative thinning of pipes tested can be measured, the being very important in terms of reliability of these pipes, given that they are used to transport the natural gas.

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Studiul experimental al comportării la strivire a conductelor din polietilenă de înaltă densitate

Rezumat

Lucrarea de față prezintă un studiu experimental privind comportarea la strivire a țevilor din polietilenă de înaltă densitate utilizate la transportul gazelor naturale. În cadrul acestei lucrări au fost studiate două materiale PE80 şi PE100, respectiv trei dimensiuni de țevi (Φ32 × 3, Φ63 × 5,8, Φ90 × 8,2). Pentru determinările experimentale s-a utilizat maşina universală de încercare INSTRON 5587 şi echipamentul optic Aramis 2M. În cadrul acestui studiu s-au determinat pe lângă deformațiile pe cele trei direcții (Δx, Δy, Δz) şi deformațiile specifice echivalente Tresca şi von Mises ce apar în aceste structuri, precum şi subțierea relativă a conductelor studiate.