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Conduct of Mechanical Tests Simulating the Accidental Action of External Mechanical Factors

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ABSTRACT: The paper aims to carry out the mechanical tests simulating the action of an excavator bucket on the polyethylene pipe and measuring the way in which the material of the pipeline displaces, by means of the rapid shooting cameras.
Keywords: insulation, polyethylene, mechanical action.

I. INTRODUCTION

We notice that 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. Crude oil is separated by distillation in several fractions. Depending on the range of boiling temperatures, different phases of distillation are obtained - gas, gasoline, kerosene, fuel oil and bitumen as residues. All these constituents consist of hydrocarbons that 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 (vapor cracking) into ethylene, propylene, butylene and other specific hydrocarbons. [1]

II. MECHANICAL TESTS

These tests were conducted on the Instron 4303 testing machine. The universal traction, compression and buckling testing machine Instron 4303 is a universal testing tool shown in Figure 16. The machine has a maximum load capacity of 25 kN, controlled through the IEEE-488 interface and the specialized Material Testing System series IX software. This universal testing tool allows you to control the moving speed of the mobile crosshead to an accuracy of 0.5% and to record the force with precision corresponding to class ASME 4-E or DIN 51221 Class 1. The mobile head's control system allows the programming of the moving crosshead's speed and assures the mobile head's position control. The resulting data are specific for the test types for which the machine was built, thus loads, displacements, stresses, specific strains, energies. During a test, the results appear as instantaneous values of the load and of the displacement or of the stress and strain, and at the end of the test, they appear as values registered in peaks or in points specified by the user.

Fig.16.a. The traction, compression and buckling testing machine Instron 4303.

The power supply to the Instron machine is controlled by a switch (1). In order to avoid accidental startup, the machine is provided with a mushroom-headed button (2) and it contains two jaws for clamping the two rams: (3) for the fixed ram and (4) for the moving ram. The moving crosshead (6) moves vertically by means of the ball screws (8) mounted on the fixed frame (16) and protected against blows, dust and possible splinters by the protective covers (9).

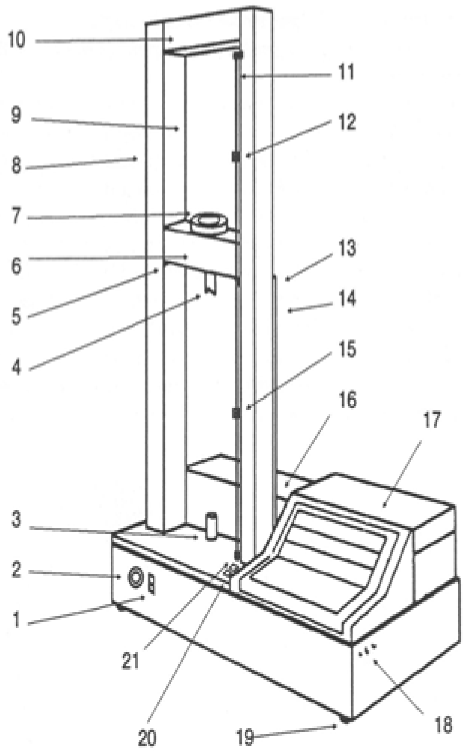

Fig.16.b. The traction, compression and buckling testing machine INSTRON 4303.

The fixed frame is stiffened by means of the fixed crosshead (10) located at the top of the machine. The transducer for measuring the force (7) and the limit ring that avoids loading the machine with a force exceeding 25kN (5) are mounted on the moving crosshead. Parallel to the two columns of the fixed frame there are two rods at the end of which there are two limit rings which are designed to avoid hitting the moving crosshead on the fixed crosshead (11) and on the lower part of the fixed frame (21). On these two rods there are also two other mobile limit rings that delimit the working area of the machine according to the size of the work stroke (12, 15). The transducers for measuring displacements (13) and the connectors used to transmit the information from the transducers to the measuring system (14) are mounted on the right-hand column of the fixed frame. On the right of the columns there is the Instron 4303 console (17) used for setting the movement, loading and moving speed of the moving crosshead. It is also used for connecting the IEEE interface to the computer. The console is provided with a locking system (18) to prevent accidental startup during transport. The machine is provided with four supporting legs (19) for adjusting the position of the machine. This must be parallel to the ground in order to avoid the occurrence of measurement errors. There are two buttons next to the work console which allow the fast ascent and descent of the moving crosshead to facilitate the positioning of the clamping jaws at the first test.
The obtained data can be plotted directly in the force-displacement coordinates. However, they are generally converted into stress-strain coordinates.

The experimental program is based on the following:
- the specimens were made;
- the most widely encountered test items have been established;
- a testing method has been developed in the INSTRON test machine's own language, namely the Material Testing System.

Figure 17 shows the specimens used for the testing and the actual testing procedure on the INSTRON 4303 testing machine.

Fig.17. The specimens used for the testing are Dn 32, 63 and 90 mm in diameter

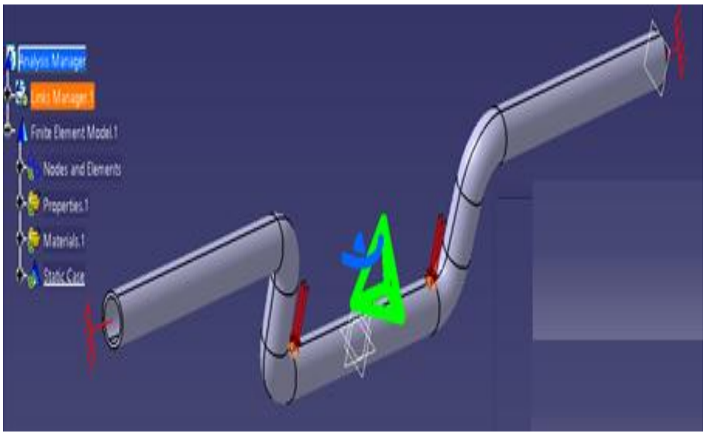

Fig.18. The schematic diagram for fastening the pipes in the upper and lower rams of the Instron testing machine

Determining the longitudinal elastic modulus

The stress- strain characteristic curves for all the tested specimens whose characteristic force - deformation curves were presented in the previous paragraph were also plotted and the longitudinal elastic modulus was determined for each case. The next figure shows the stress- strain characteristic curves for the studies polyethylene pipes.

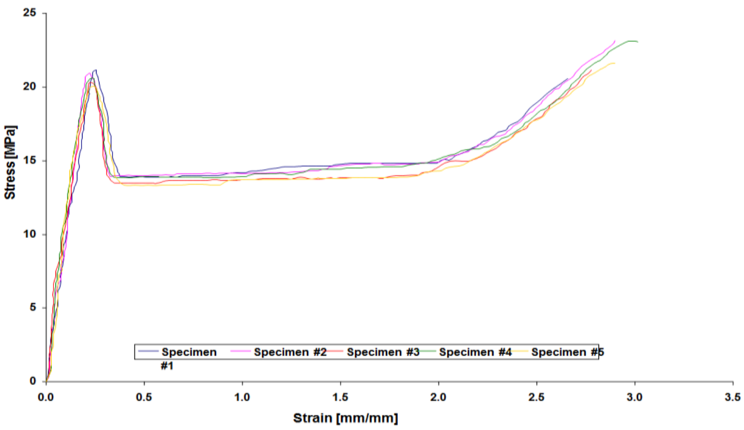

Fig.19. Stress-strain characteristic curves for pipe specimens of Φ 32 x 3.0 made of PE 100

Based on these characteristic curves, it was possible to calculate the values of the longitudinal elastic modulus, which were presented in the table, and also a statistical analysis was developed (similar to that made for the experimentally determined data for each type of pipe), establishing the arithmetic mean of the determined values, their mean square deviation, and the coefficient of variation of these values.

Table 2. Experimentally determined elastic modulus for Φ 32 x 3.0 pipes made of PE 100

Elastic modulus
modulus
Maximum stress
stress

		PE100	
		Φ 32 x 3	Φ 32 x 3
	crt.	Modul de elasticitate E [MPa]	Tensiunea maximă σ_{max} [MPa]
	0	8	3
	1.	94,58	20,9
	2.	93,01	23,2
	3.	85,55	21,8
	4.	102,51	23,4
	5.	104,43	21,9
6.	Media aritmetică (x_{med})	96.02	193.89
7.	Abaterea pătratică medie (s)	7.64	17.22
8.	Coeficientul de variaţie (CoV)	7.96	8.88

Arithmetic mean
Mean square deviation
Coefficient of variation

For the optical data acquisition using the Aramis 2M system, before subjecting the assembly to traction, the pipe pieces were coated with a matte, white, fast-drying paint. After this, the areas exposed to the image acquisition system were sprinkled with a graphite spray.

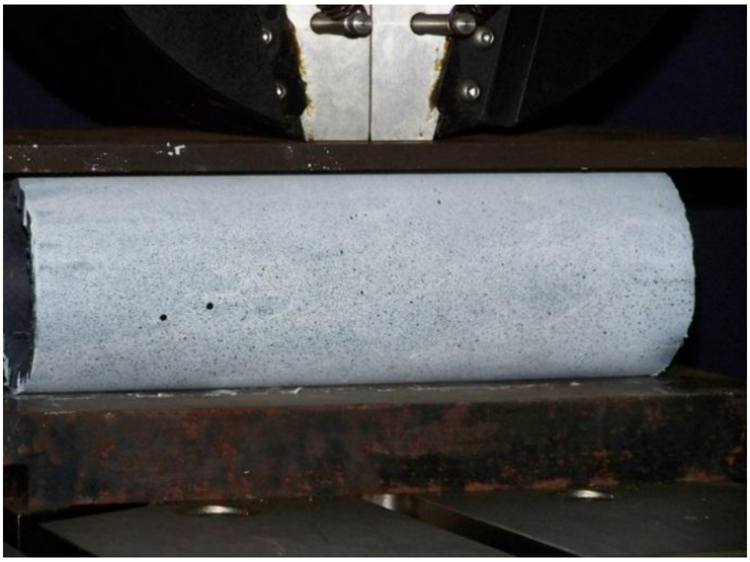

Fig.20.a. Clamping the pipe in the vices of the universal testing machine

The polyethylene pipes were subjected to bending with a maximum force of 1000 N, the loading speed being 10 mm/min, at the same time acquiring data on the deformation of the pipe through the Aramis 2M system as well as on their tension behavior using the Instron 5587 machine software.
Figure 20 shows the whole assembly used for the experimental determinations: Instron 5587 universal testing machine (1), polyethylene pipe (2), high speed cameras (3), data acquisition computer (4).

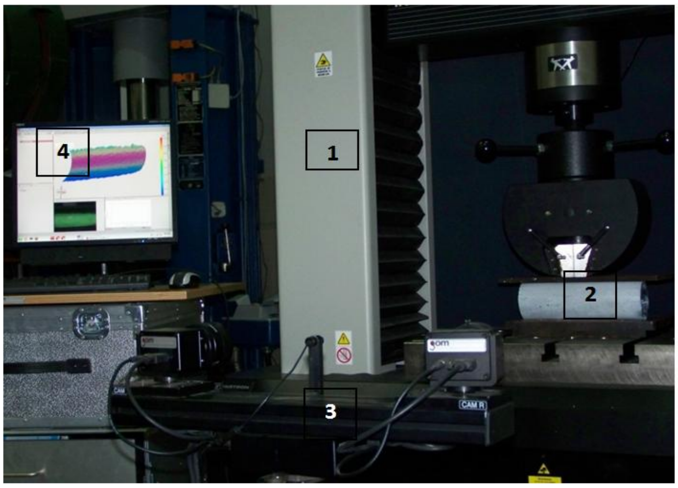

Fig.20.b. Equipment for testing the polyethylene pipes

The following figures show the force-deformation curves for pipes 63 mm in diameter, made of PE 100. The following figure shows the variation of the maximum deformation (corresponding to the maximum load of 1000 N) depending on the diameter of the pipe and on its material (PE100).

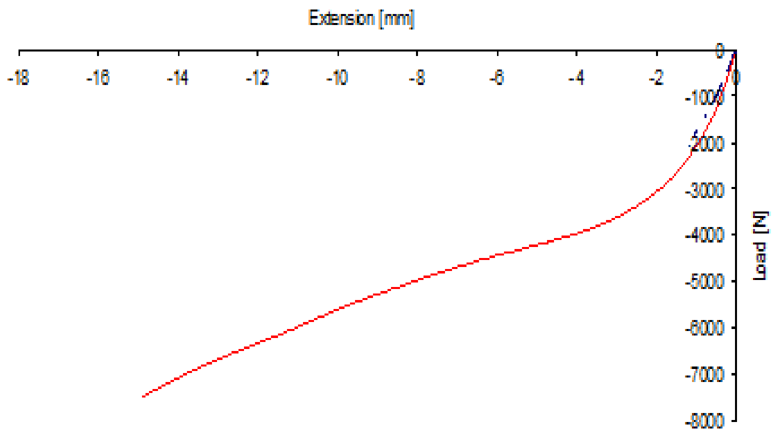

Fig.21. Experimental force-deformation characteristic curves for Φ 63 x 5.8 pipe

Using the software of the Aramis 2M equipment, the following measurements were determined: the deformations (the displacements of the points on the pipe profile) in the three directions (Δx, Δy, Δz), the total deformation (Δe), the major strain (ε_1), the Tresca strain (ε_T), the Von Mises stress (ε_{VM}), the thickness reduction (δ). The values of these measurements are listed in the table below.

Table 3. Values of the measurements determined by means of the Aramis 2M equipment.

Material	Pipe type Φ x t [mm x mm]	Δx [mm]	Δy [mm]	Δz [mm]	Δe [mm]	ε_l [%]	ε_T [%]	ε_{VM} [%]	δ [%]
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	0.460	-8.91	5.13	10.14	37.03	37.03	31.02	21.01
	90 x 6.9	0.590	-10.01	7.06	11.46	44.06	44.06	33.21	21.44

The results obtained using the Aramis 2M optical system for PE100 polyethylene pipe 63 mm in diameter and 5.8 mm thick are shown below. The measurements for the other diameters of 32 mm and 90 mm were determined similarly.

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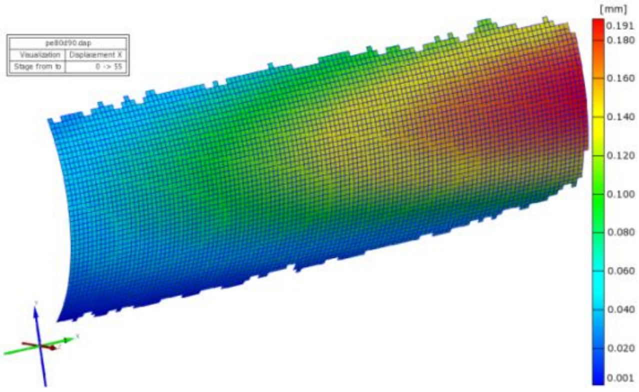

Fig.22. Displacement of the pipe in axial direction (Ox) [mm]

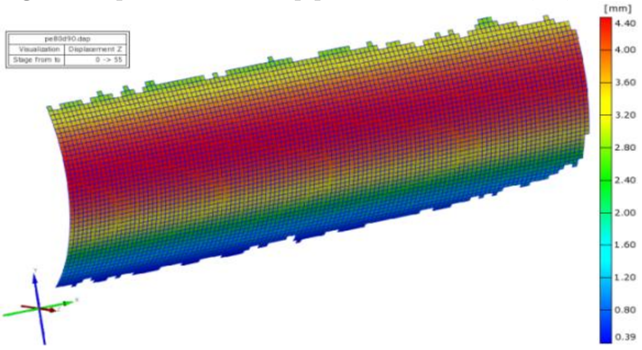

Fig.24. Displacement of the pipe in radial direction (Oz) [mm]

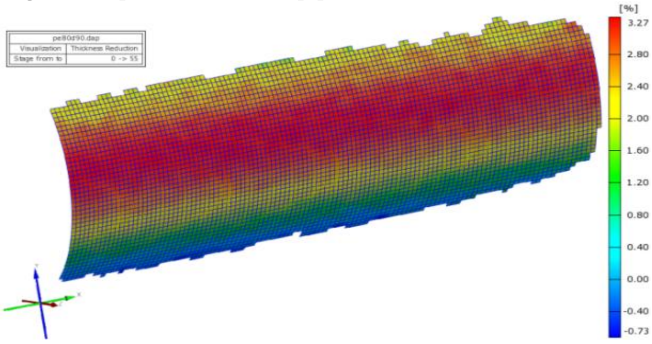

Fig.26. Thickness reduction (δ) [%]

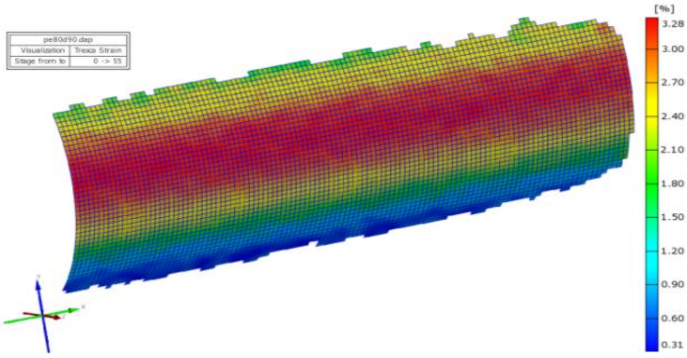

Fig.28. Tresca strain (ε_T) [%]

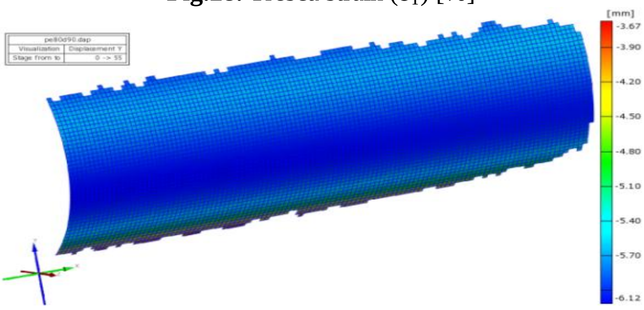

Fig.23. Displacement of the pipe in vertical direction (Oy) [mm]

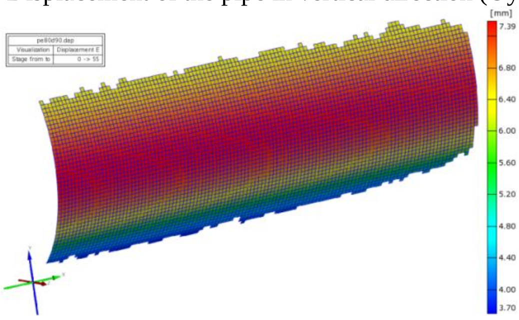

Fig.25. Total displacement of the pipe [mm]

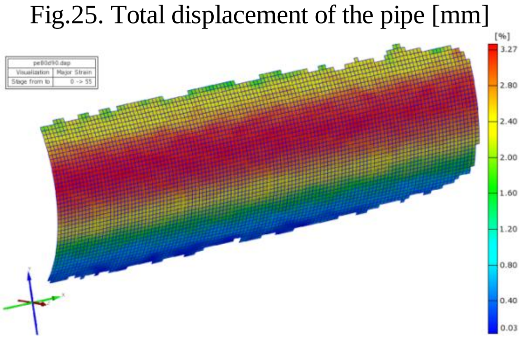

Fig.27. Major strain (ε_1) [%]

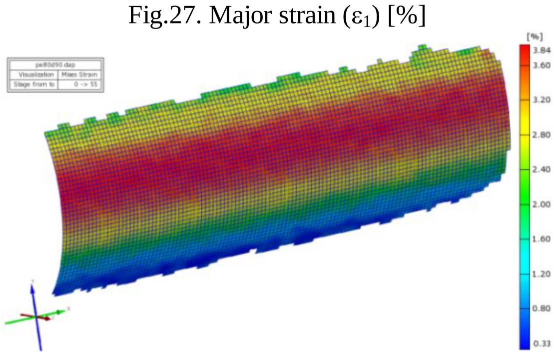

Fig.29. Von Mises Stress (ε_{VM}) [%]

It can be seen from the experimental results, both from the data provided by the universal testing machine's software and from those obtained by means of the Aramis 2M optical acquisition system that for PE100, at the same maximum traction load (1000 N), the smallest deformation is obtained in pipes 90 mm in diameter. At the same time, one can notice a decrease of the deformations in PE100 pipes by approximately 17 ... 18% for pipes with diameters of 32 mm and 63 mm and by approximately 88% for pipes 90 mm in diameter. The same trend is followed by the deformations in the direction of applying the load (Oy), determined by means of the Aramis optical system are maintained, which are lower for PE100 pipes by approximately 24% in the case of 32 mm diameter pipes, by approximately 13% in 63 mm diameter pipes and by about 65% for a 90 mm diameter pipe. The boundaries of these experiments consist of performing only one test for each pipe size, which can lead to a change in the results. However, the advantage of the method used is that the relative thinning of the tested pipes can be measured, which is very important in terms of the safe operation of these pipes, given that they are used for natural gas transport.

The experimentally obtained results are similar to those obtained by means of the finite elements, although some have a deviation slightly above the allowable one and it is necessary to reanalyze them with the finite elements because the set constraints can be reconfigured.

III. CONCLUSIONS AND RECOMMENDATIONS

The present study led to the following conclusions:

- The approached topic is a necessary topic that results from a real study on the behavior of polyethylene pipes when subjected to accidental mechanical factors;
- The questionnaire study show us the areas where problems arise when operating the polyethylene pipes;
- Analytical models were made for the three diameters suggested for the analysis, namely the diameters of Dn32, 63 and 90 mm;
- These studied models have the actual characteristics of the polyethylene subjected to traction according to the model for the four widths of the excavator bucket;
- Mechanical tests have been carried out for a 300mm bucket width for the three pipe diameters;
- The measurements were conducted by means of the optical acquisition system Aramis, the results being close to the analytical ones.

The recommendations related to the suggested topic refer to extending the study on other diameters as well as and also analyzing the situation when the PE 100 polyethylene pipe is mechanically affected by various regular or irregular bodies.

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