Study on the Behavior of the Cold-Applied Extruded Polyethylene Insulation under the Influence of Mechanical Actions – Part 2

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Abstract: ***The paper studies the way in which a damaged insulation yields under the influence of mechanical forces, in comparison to a compact one. This paper aims to research the mechanical phenomena leading to the advanced deterioration of insulation, considered to be the most important factor within a natural gas distribution system in terms of its protection, which is vital for supporting a good operation in exploatation.***

Keywords: insulation, polyethylene, mechanical action

3.3. The Testing Machine

The traction test was carried out on the Instron 5587 mechanical test machine at the "Lucian Blaga" University in Sibiu (Figures 6 and 7).

The machine has the following main characteristics:

- Maximum loading force in stationary state; 300kn;
- It is equipped with a force cell with a linearity of +/- 0.25% and a repeatability of +/- 0.25% for readings in the range of 0.4-100% of the capacity;
- It has a working area of 1200mm between the frame and the crosshead;
- The distance between the columns is 800mm;
- The traverse drive system is electromechanical;
- Adjustable test speed ranges between 0.001-500mm/min

Figure 6: Instron traction testing machine with the Aramis optical measuring system

- Displacement measuring system is mounted on the electric motor;
- Computer interface (data acquisition board);
- 2630-113 series extensometer, for measuring deformation in stationary state; the distance between markers is 50mm;
- Data acquisition board for the extensometer;
- Conditioning module for the data acquisition board.

Figure 7: Clamp used for fixing the specimens

The machine is equipped with Bluehill 2 software used to command and control the machine, but also to process the results. The Bluehill 2 software enables the following actions:

- Automatic calibration of sensors;
- Generating predefined reports edited by the user;
- System monitoring;
- Viewing the results in real time;

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- The possibility of determining the conventional and real characteristic curves and the plasticity characteristics.

Since the Instron 5587 Testing Machine is equipped with a single extensometer with a 50 mm calibrated length with the possibility of mounting along the longitudinal direction of the specimen; an Aramis optical deformation measuring system, manufactured by Gom, was used to determine the local specific deformations. This system gives the possibility of real-time measurement of the deformations occurring in the test specimen subjected to uniaxial traction.

In order to determine the behavior of the polyethylene materials from a macro-structural point of view (considering the necessity of entering the material data in the numerical simulation programs), we have used some types of mechanical tests such as: the uniaxial tensile test, the equi biaxial tensile test, the Bias test and the shear test.

The oldest testing method of observing the behavior of the materials is the uniaxial tensile test. The specimen is fixed at both ends and deformed at a constant speed (or not) on a traction testing machine, until it fractures. The applied force is measured with a force gauge and the deformation by means of an extensometer. To conduct the research, we used the experimental stand designed to avoid material crushing, the Instron 5587 traction, compression and buckling testing machine, and the Aramis optical system to measure deformation.

The obtained data can be plotted directly in the force-displacement coordinates. In many situations these are converted into stress-strain coordinates. In the case of the uniaxial tensile test of the polyethylene, we chose to acquire data in the form of force - elongation pairs.

By coupling the Instron 5587 traction, compression and buckling testing machine with the optical measurement system, it was no longer necessary to use an extensometer, the Aramis optical system actually being a high precision optical extensometer. [1]

Figure 8: The uniaxial tensile testing of polyethylene without stress concentrators

3.4. Results

The experimental program for determining the mechanical characteristics of the polyethylene specimens is based on the following:

- Samples of three specimens were taken for each type of application, 1, 2, respectively 3 layers, repeated also for those on which the defect was simulated. The shape of the specimens was the standard one for this type of test, as described above;
- The testing method has been developed in the instron testing machine's own language, namely bluehill 2. The following were established at this stage: the type of test (traction), the material data (specimen shape, specimen width, machine stroke distance), test speed, constraints of the machine, the machine’s acquisition rate (10 points/second), the type of the output file (ascii or dif - data interchange format, a file format that can be downloaded in any of the statistical data processing software), the type of the output data to be acquired;
- The test speed was set at 10 mm/min;
- The width of the specimen was b = 20 mm and the free measuring distance g = 115 mm;
- The uniaxial tensile tests were carried out on polyethylene material; prior to the experiments, the specimens were kept in the laboratory at a constant temperature of 25°c;
- In addition to the data specified above, the primary test data are saved (the characteristic curve in the force [n] - displacement [mm] coordinates). These data appear in the form of pairs of points in the coordinates listed above in each analysis file in ascii format;

The sequence of figures 9...14 shows the conventional loading graphs in the force-displacement coordinates for the six cases, and Table 3 lists the numerical results of the tests with the related statistical processing. [1]

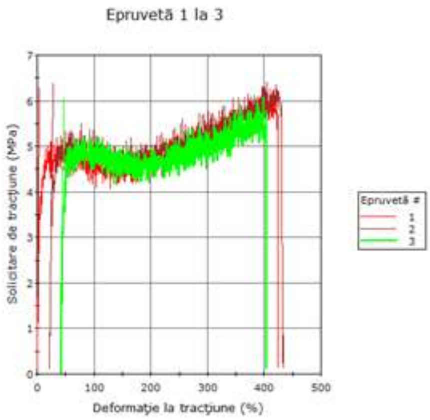

Figure 9: The characteristic force-elongation curve on one-layer specimens

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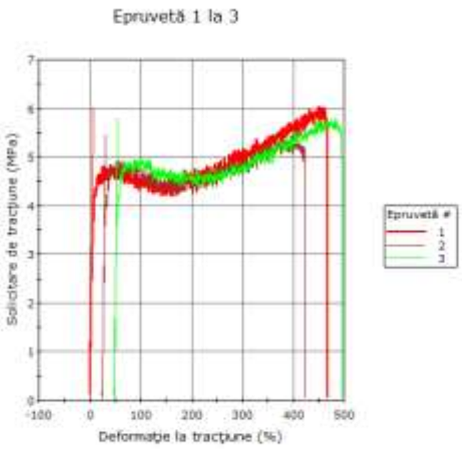

Figure 10: The characteristic force-elongation curve for two-layer defect-less specimens

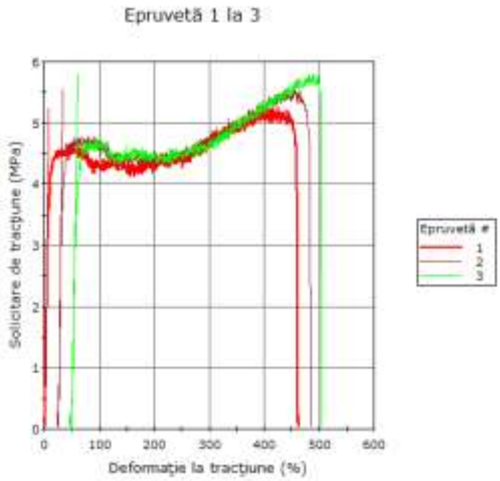

Figure 11: The characteristic force-elongation curve for three-layer defect-less specimens

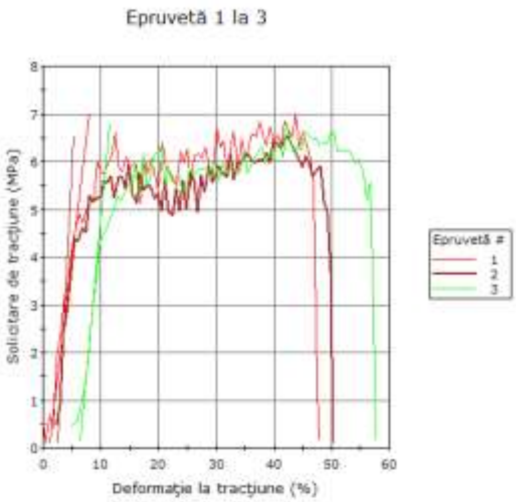

Figure 12: The characteristic force-elongation curve for one-layer defect specimens

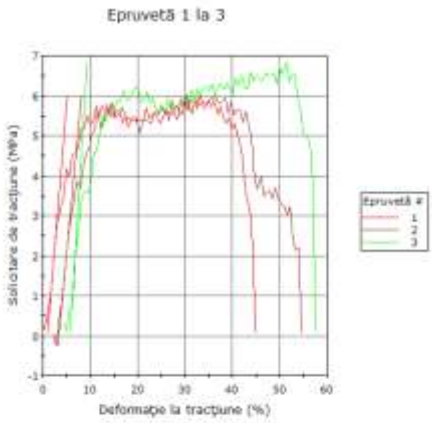

Figure 13: The characteristic force-elongation curve for two-layer defect specimens

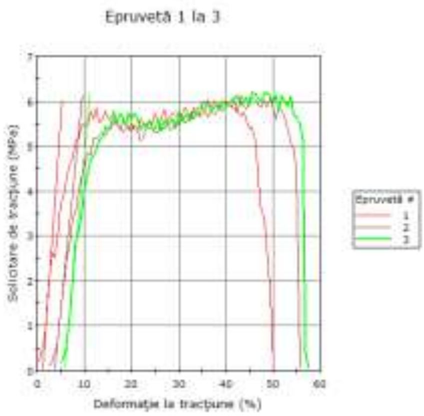

Figure 14: The characteristic force-elongation curve for three-layer defect specimens

The analysis of the graphs and the values obtained from the conducted measurements shows that in the case of the defect-less specimens, the measurements and the data obtained are almost similar, notable differences appearing between the data obtained on the single layer specimen. The two-layer specimens prove the best behavior of the tensile deformation. It is thus concluded that with a higher number of layers, under the influence of a tension generated at traction, the specimens yield almost at the same values, even smaller, due to the adhesion between the layers, which leads to the failure of one of them causing a more sudden fracture of the specimen.

In the event of an insulation defect, the yield is considerably reduced, the tensile stress generating the deformation being much smaller. In this case too, it is possible to discuss the tensile deformation in the case of the three types of specimens, the variation being different, and the highest value being shown in the single-layer insulation, demonstrating the same interpretation regarding the above mentioned adherence between layers. Thus, it can be concluded that in the case of a reduced surface due to the existence of insulation defects and the strength generated by the adherence between the applied insulation layers, the stresses generating the insulation deterioration are greatly reduced compared to the normal insulation characteristics.

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Author Profile

Stefan Mihai Filip has had an extensive and important training in the natural gas field, studying at the Petroleum-Gas University of Ploieşti and “Lucian Blaga” University in Sibiu, being awarded the title of Bachelor of Science in Engineering in the Petroleum and Gas Engineering Department. He has a rich practical experience in the natural gas distribution systems, occupying the position of project manager within the Eon Romania Distribuţie SA company, coordinating important works in the field, which allowed him to gain important knowledge and to detect certain problems the company has been dealing with, and, by performing such works, to try to find solutions for them.

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