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Simulation of the Mechanical Behavior of Polyethylene Pipes In The Static And Dynamic Field

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ABSTRACT: The purpose of this paper is to study the behavior of natural gas pipelines' material - high density polyethylene - when it is subjected to external mechanical factors. It observes the analytical displacement of the polyethylene pipes' material, the one related to the finite elements.
Keywords: insulation, polyethylene, mechanical action.

I. INTRODUCTION

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. [1]

Some of the advantages of using polyethylene in the field of natural gas distribution networks are:
- the possibility of welding at low temperatures (relative to the required temperatures for welding steel), by simple technology, and by mechanically assembled fittings, as the case may be;
- the possibility of combining polyethylene networks with the already existing steel networks or with the existing casings;
- the increased speed of installing the networks implies lower execution costs;
- the variety of dyes allows a precise marking and identification;
- the variety of pipe fittings dimensions of approximately 32,000 units;
- high resistance to corrosion, which eliminates the need for cathodic protection, a very important advantage for the gas distribution networks because the aggression of the soil in the urban environment is significantly higher than outside the localities;
- the possibility of using long pipes by delivering them in coils;
- good chemical resistance to the gas components;
- the natural environment protection due to the feature of recyclable material.

II. STUDY BY THE FINITE ELEMENT METHOD

The CAE (Computer Aided Engineering) module was developed as a component of the CIM (Computer Integrated Manufacturing) systems after the development of the CAD (Computer Aided Design) module, actually it was introduced at the same time with the finite element method. The method was initially used for the mechanical calculation of the aircraft structures but subsequently extended to all the issues of the material continuum. In these issues it is intended to determine, in a given field, the values of one or more unknown functions such as: displacements, velocities, temperatures, stresses, specific deformations etc., depending on the nature of the studies issue. Within the chapter on the numerical simulations using the finite element method of the behavior of the polyethylene, in these analyses, certain measurements are determined (nodal displacements, stresses, deformations) under the conditions of applying different types of loads. The loads that can be applied are forces, pressures or moments. [5]

The physical phenomena of this kind are described by differential equations, whose integration, under given limit conditions, gives the exact solution. In this way, the value of the unknown function or functions can be calculated in any point of the studied domain. This is the analytical habitual way of finding the solution, but only applicable to simple problems. The problems that arise in the practical engineering activity are not simple problems, but rather complex, both in terms of the physical, geometrical construction of the part and in terms of the loading conditions, the limit 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 model and solving the differential equations on this model, thus obtaining the exact solution on a simplified model;
- obtaining an approximate solution to a real problem.

The approximate solutions obtained by numerical methods more often reflect reality better than the exact solutions on simplified models. The applications of the finite element method can be grouped according to the type of the applied loads, as follows:

- problems of balance or stationary state, where the unknown function or functions are not time dependent. The study of the elastic behavior of bodies under a static state comes under this category.
- problems of eigenvalues where the unknown functions do not depend on time either and where certain critical values are determined in terms of respecting the equilibrium configuration. Included here are the modal analyses, namely the calculation of the natural frequencies of the bodies;
- problems of propagation or transient state where the unknown functions are time-dependent. This includes the dynamic study of the elastic or the non-elastic behavior. [3]

The conducted case studies proved that, following the excavation works, these polyethylene pipes have different solutions and different values of the stresses, with the risk of destroying the pipelines used in the natural gas transport and distribution. This involves ceasing the natural gas supply over a period of time needed to restore the damaged pipeline.

Fig.1. Actual situation of accidentally applying stress on the PE 100 polyethylene pipe by the excavator bucket

The study aims to approach the most widely used pipe diameters for certain widths of the excavator bucket, namely: 300 mm, 400 mm, 500 mm and 600 mm. The stress and displacement analysis was done by using the CATIA modeling and design software through successive determinations.

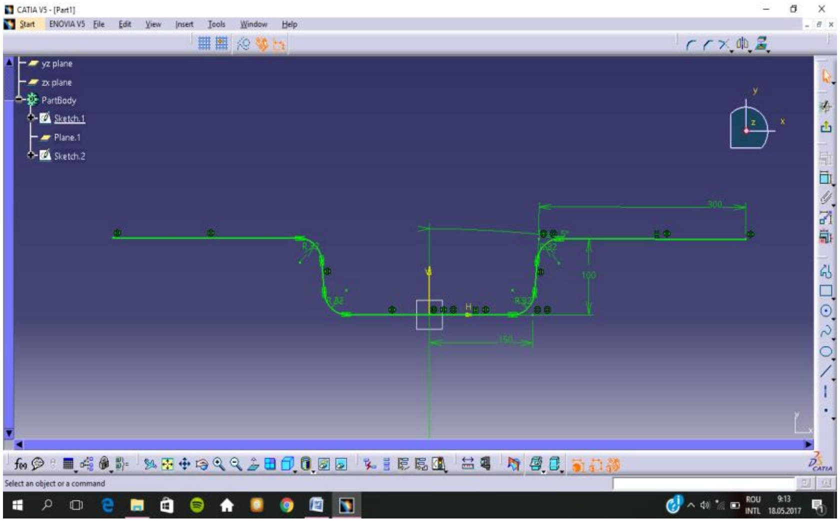

Fig.2. Developing the model needed for the analysis

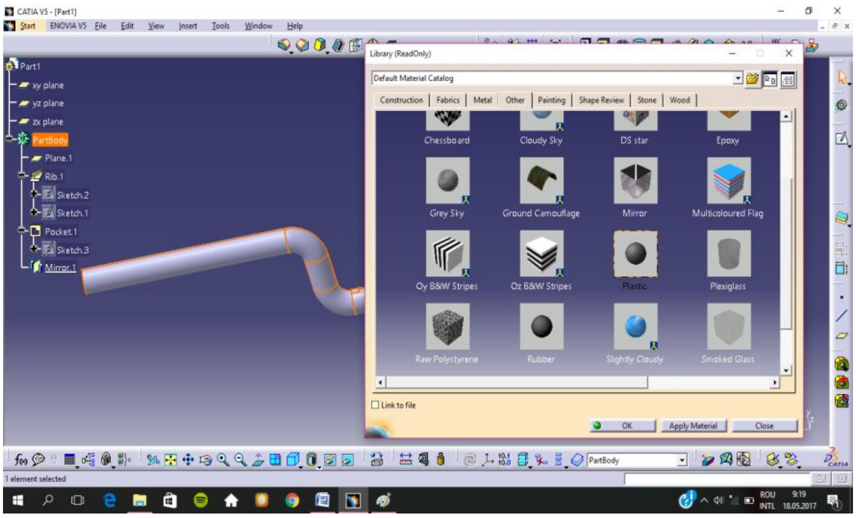

Fig.3. Selecting the material from the software library

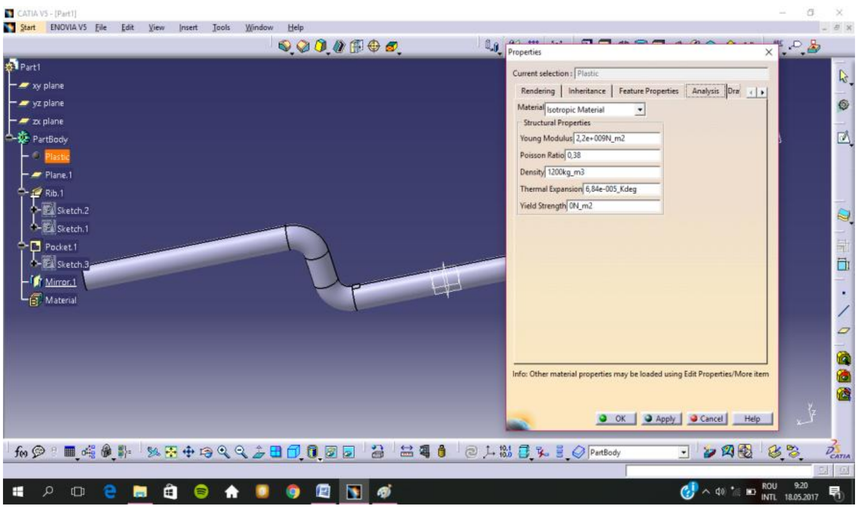

Fig.4. Changing the material characteristics for polyethylene

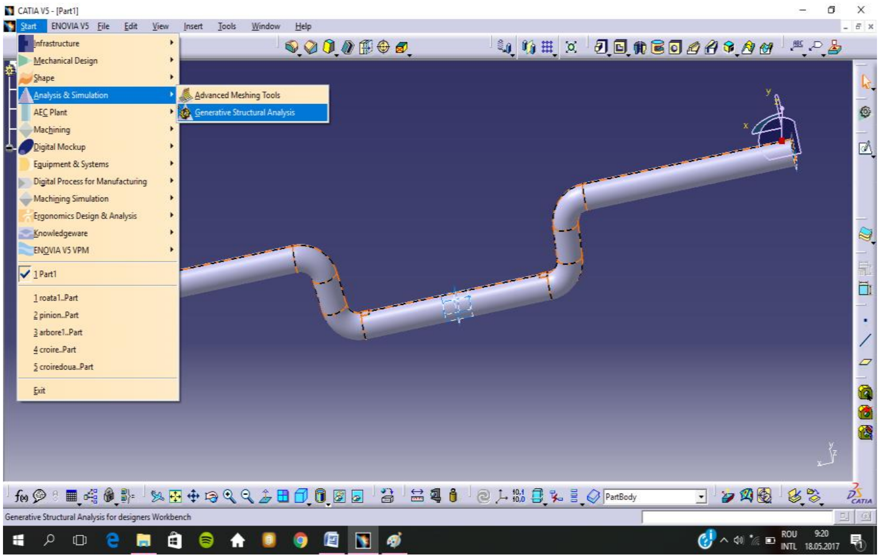

Fig.5. Delivering the part in the finite element analysis module

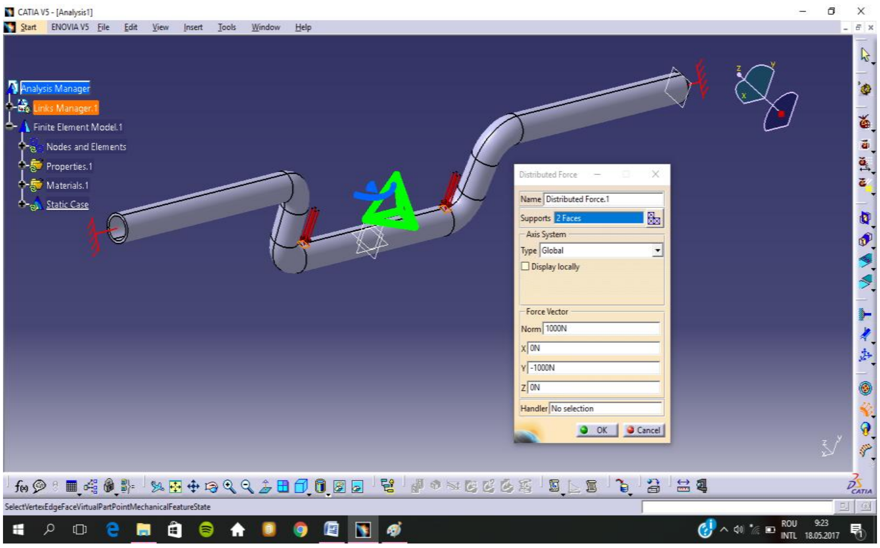

Fig.6. Applying constraints and stresses on the model

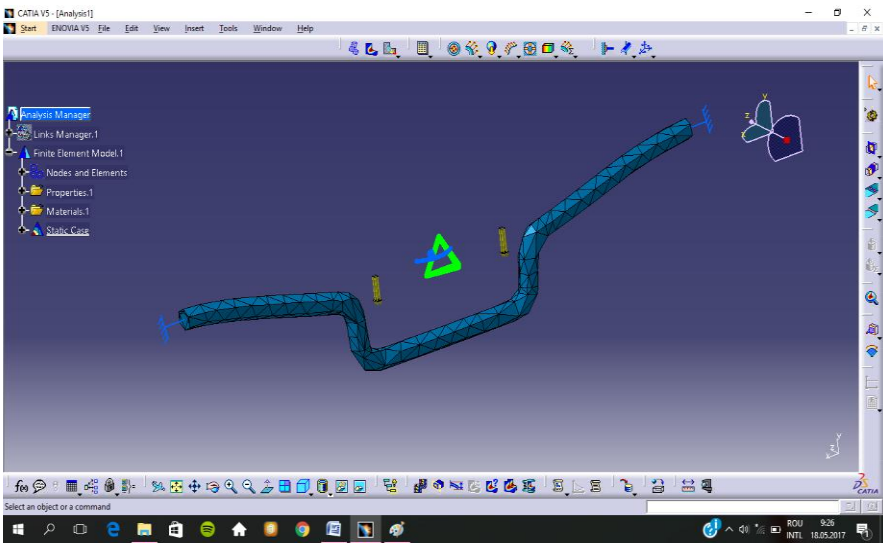

Fig.6. Meshing the model

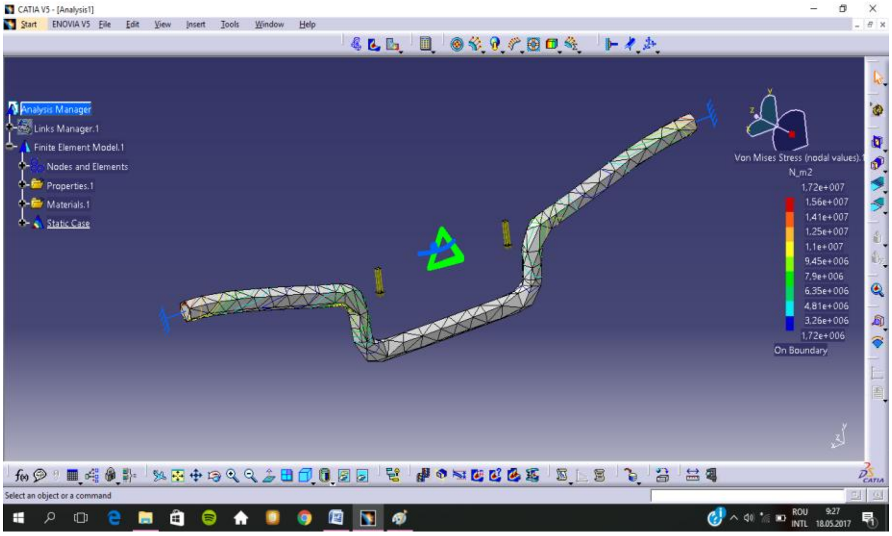

Fig.7. Determining the Von Mises stresses for the selected model

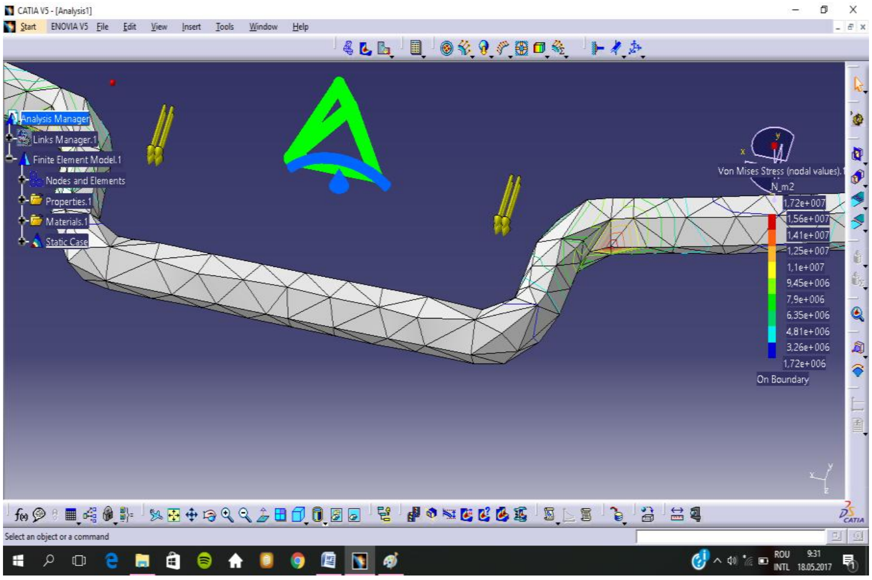

Fig. 8. Highlighting the most stressed areas of the model

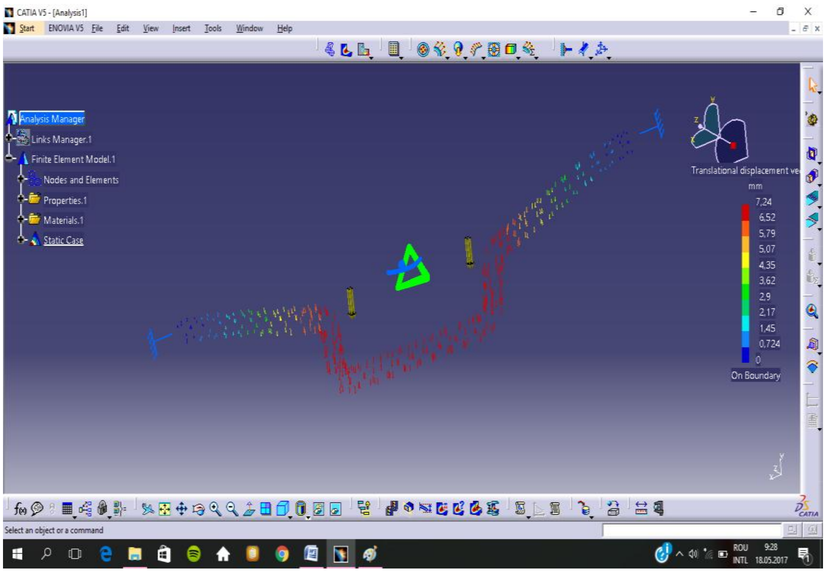

Fig. 9. Determining the maximum displacements

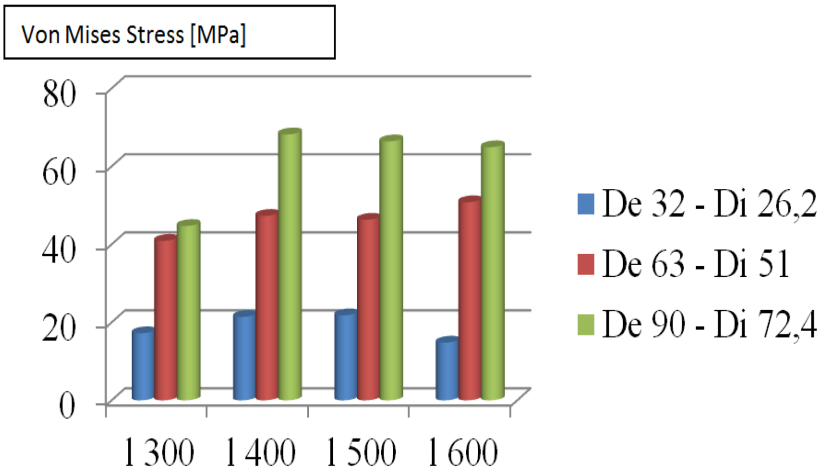

Fig.10. Highlighting the Von Misses stresses for the three types of polyethylene pipe PE 100

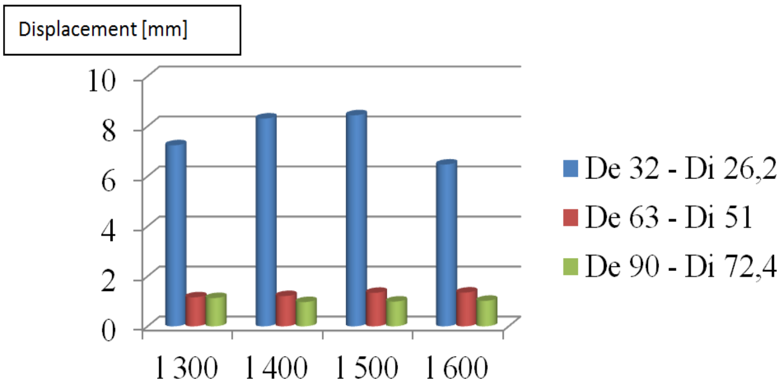

Fig.11. The displacements chart

III. CONCLUSIONS

The results of these analyzes proved that the problems that arise from accidental bumping with an excavator bucket are frequent and that the analysis made indicates that, in the case of the three types of pipes subjected to the analysis, the stressed area is larger at diameter Dn 90 mm and smaller at diameter Dn 32 and the other way around in terms of material displacement. The solutions to avoid these problems are to protect the polyethylene pipes with metallic indicating wires and to identify them precisely when performing works in the pipeline area.

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Avrigean Eugen - holder of a Ph.D. title in Mechanical Engineering, specialty Strength of Materials, faculty member in higher education (Lucian Blaga University - Engineering Faculty) and conducting research for 16 years. He has worked on numerous research books and articles, on laboratory studies, numerical analysis and computer aided design.

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