VOLUME-6, ISSUE-9, SEPTEMBER-2017 • ISSN No 2277 - 8160

Original Research Paper

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ESTABLISHING STRESSES AND STRAINS OCCURRING AS A RESULT OF THE INFLUENCE OF ACCIDENTAL EXTERNAL FACTORS ON POLYETHYLENE PIPES

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ABSTRACT This paper aims at determining the stresses and strains that occur after accidental pressing of various bodies existent in the environment when installing polyethylene pipes used in natural gas transportation.

KEYWORDS : mechanical action, insulation, polyethylene.

1. Introduction

The problem we intend to find a solution for comes from the bibliographic study, in which due to the inappropriate use of the polyethylene pipe protection factor (sand with specific granulation) pinches of various forms appear on the surface of the pipeline unprotected by the latter and other elements (stones, metal parts, etc.) destroy the superficial protective layer and create cracks on the surface of the pipe. [2] Compared to the fracture of metals, the study of the fracture resistance of polymers is in an early stage [2]. Many of the required theoretical supports are not fully finalized and there are many situations where the concepts of fracture mechanics that apply to metals are no longer applicable to other materials. The fracture resistance of polymer materials has become a major concern recently, when they begun to be used for critical structures.

From a general point of view, these principles can also be applied to polymers, but the microscopic details of the yield and fracture of plastics are much more different than for metals.

In the case of metals, fracture and yield follow a yielding mechanism. Fragile fracture occurs in materials where deformability is low. Ductile metals, by definition, suffer extensive plastic deformations prior to fracturing.

2. Finite Element Method Determination of Stresses and Strains Produced by External Mechanical Factors

These problems seek to determine, in a considered area, the values of one or more unknown functions such as: displacements, velocities, temperatures, stresses, strains, etc., depending on the nature of the tackled problem in the chapter on numerical simulations using the finite element method of polyethylene behavior. These analyzes try to determine certain measurements (nodal displacements, stresses, strains) under the conditions of applying different types of loads. The loads that can be applied are forces, pressures or moments. [3]

The natural phenomena of this kind are described by differential equations, and, by integrating them under given boundary conditions, we obtain the exact solution. In this way we can calculate the value of the unknown function or functions in any point in the studied area. This is the analytical, classical solving method, which is applicable only to the simple problems. However, the problems that arise in the practical engineering activity are not simple but rather complex, both in terms of physical geometrical construction of the part, and in terms of the loading and boundary 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 one and solving the differential equations on the former, 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 of those are determined by 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]

According to this classification, this chapter will cover the static analyses conducted for the high density polyethylene pipe PE 100 SDR 11 with a Dn 32 diameter used in the natural gas distribution systems.

In order for this study conducted by means of the finite elements to be comparatively precise, we considered that the displaced volume of the bodies is identical and the crush depth of the material is 1 mm.

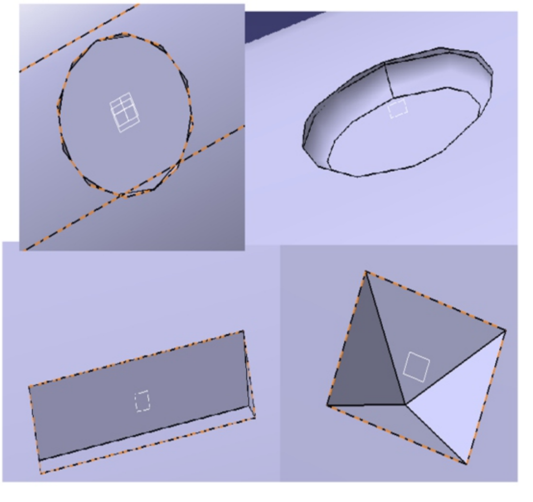

Fig. 1. The shape defined for prints left on the polyethylene pipe (sphere, ellipsoid, triangular prism, right pyramid)

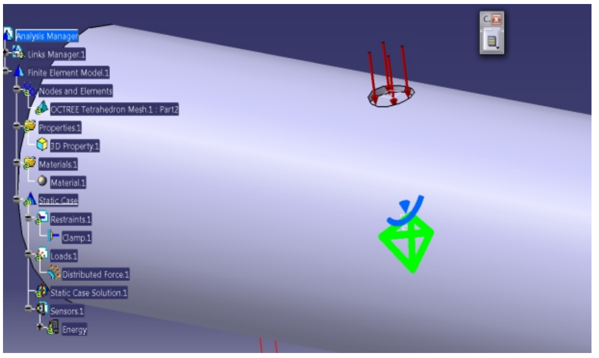

Fig 2. Determining restraints and loads for the "circle" print left on the Dn 32 diameter PE100 pipe

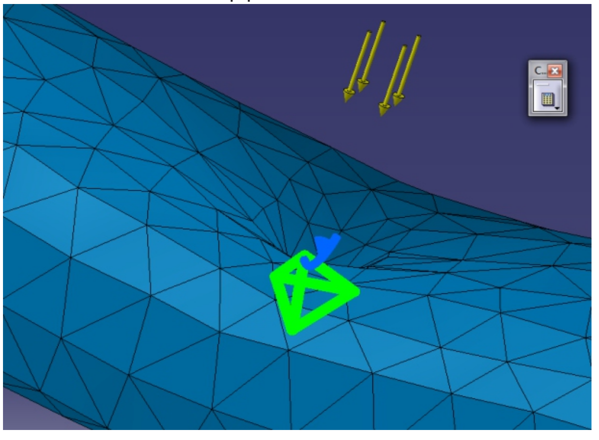

Fig 3. Meshing the body in finite elements

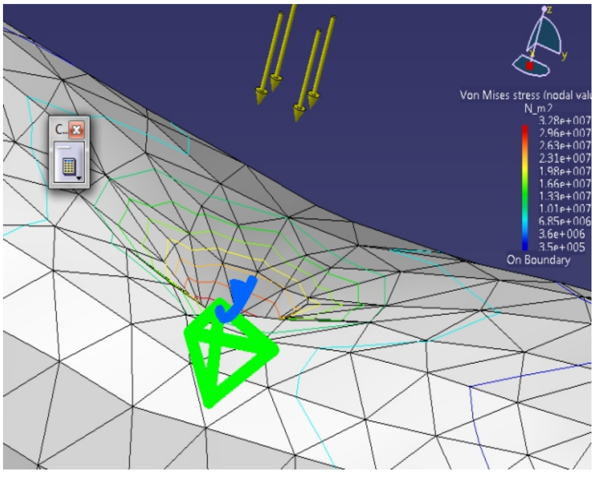

Fig 4. Von Mises stress for the load actually applied on the "circle" print

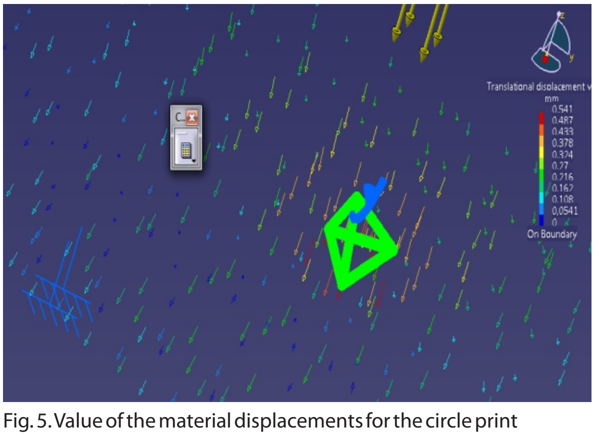

Fig. 5. Value of the material displacements for the circle print

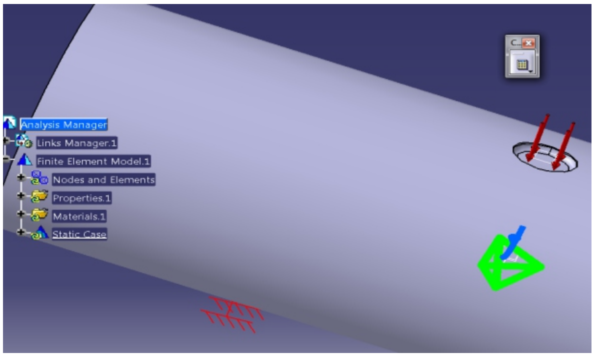

Fig. 6. Determining restraints and loads for the "ellipsis" print left on the Dn 32 diameter PE100 pipe

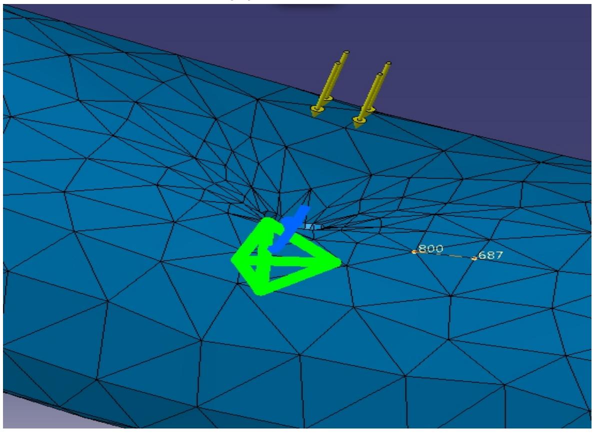

Fig. 7. Meshing the body in finite elements

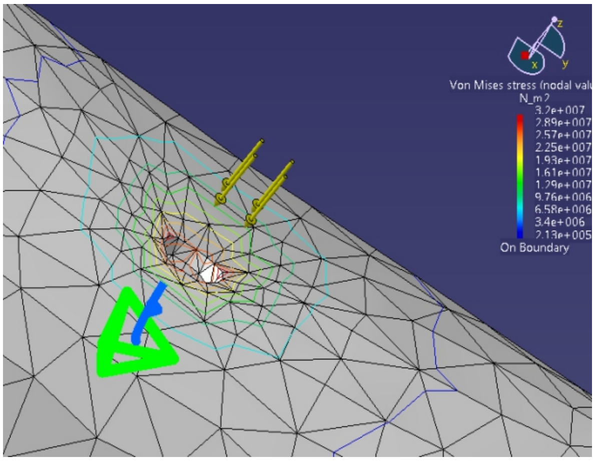

Fig. 8. Von Mises stress for the load actually applied on the "ellipsis" print

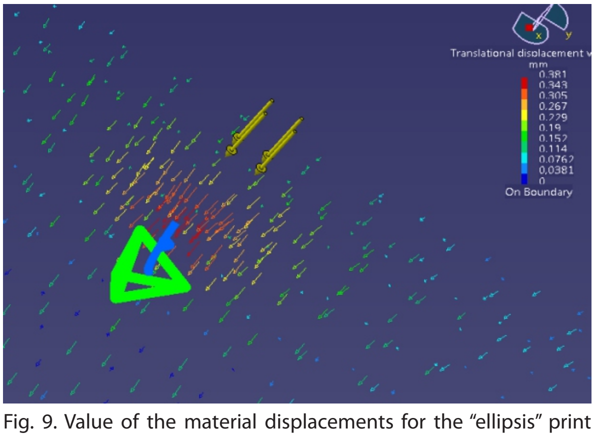

Fig. 9. Value of the material displacements for the "ellipsis" print

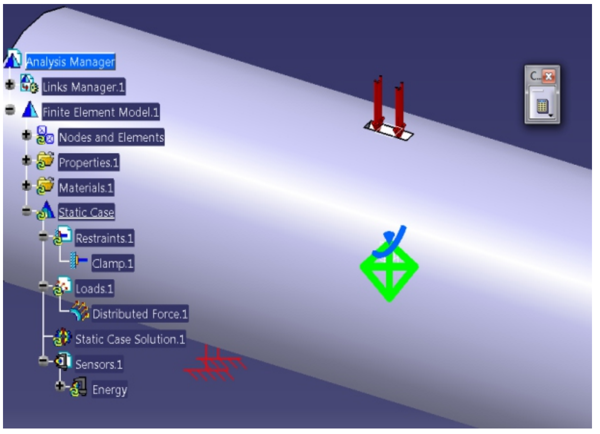

Fig. 10. Determining restraints and loads for the "prism" print left on the Dn 32 diameter PE100 pipe

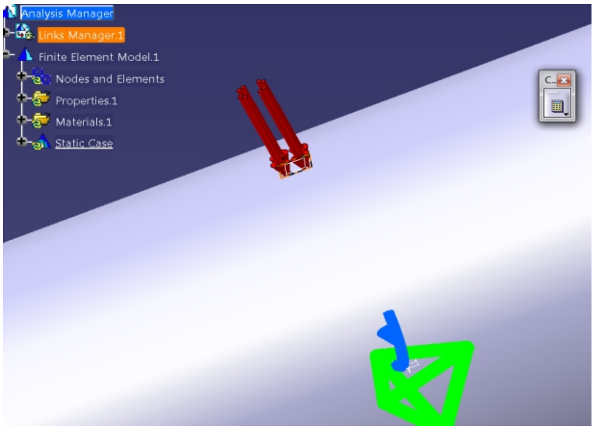

Fig. 14. Determining restraints and loads for the "pyramid" print left on the Dn 32 diameter PE100 pipet

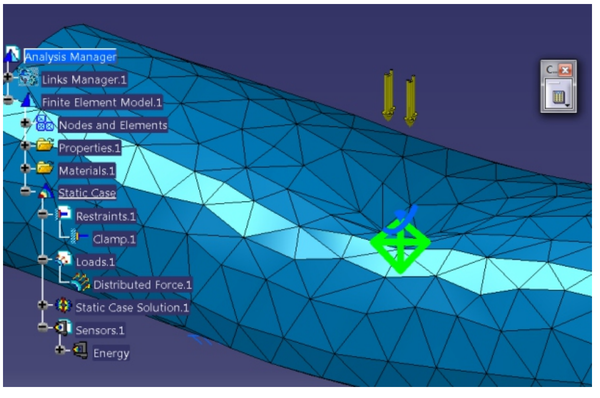

Fig. 3. Meshing the body in finite elements

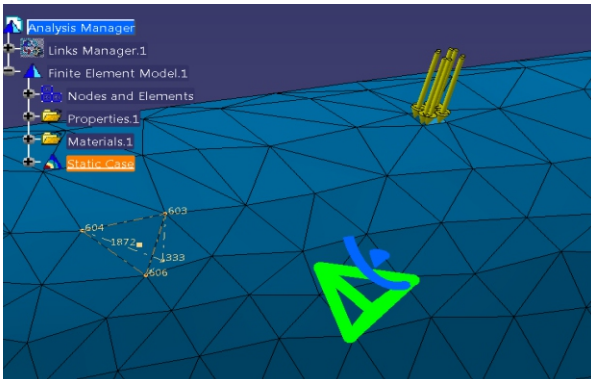

Fig. 15. Meshing the body in finite elements

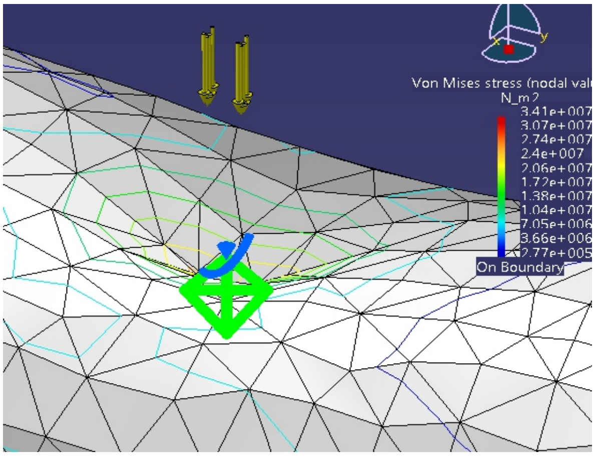

Fig. 12. Von Mises stress for the load actually applied on the "prism" print

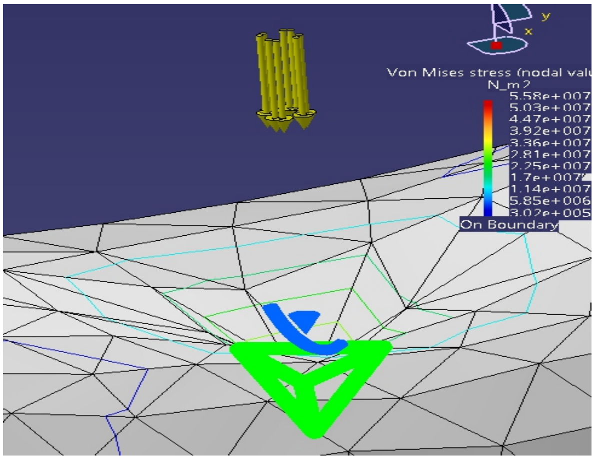

Fig. 16. Von Mises stress for the load actually applied on the "pyramid" print

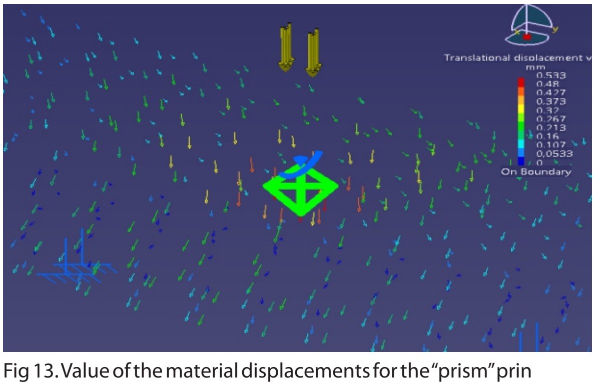

Fig 13. Value of the material displacements for the "prism" prin

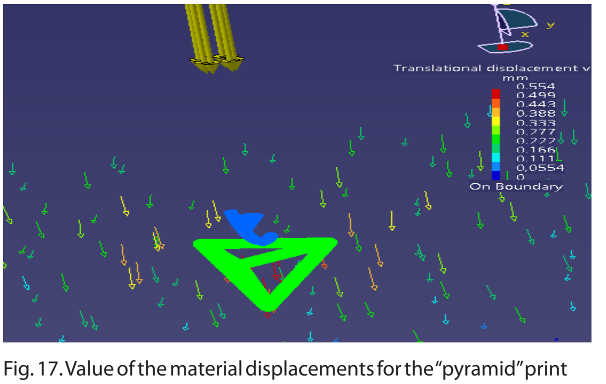

Fig. 17. Value of the material displacements for the "pyramid" print

The results obtained from the finite element analysis are listed in the table below:

Shape of print	Value of Von Misses Stress [MPa]	Value of displacement [mm]
Circle	32.8	0.541
Ellipsis	32	0.381
Prism	34.1	0.533
Pyramid	55.8	0.554

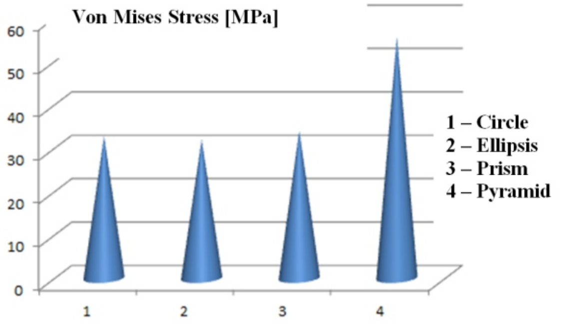

Fig. 18. Variation of the Von Mises stress for the four print shapes

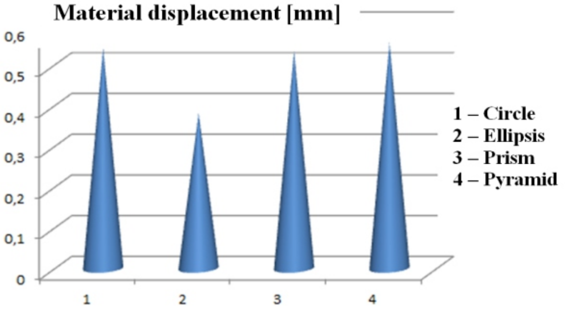

Fig. 19. Variation of the displacements for the four print shapes

3.Conclusions

The study conducted by means of finite elements highlighted the difference between Von Mises stresses and the material deformations due to the different shapes of the elements coming into contact with the polyethylene material. The volume of material dislodged by the external factors was considered to be identical, in order to observe only the influence of the shape of bodies that occurred accidentally.

Further studies will follow, which will focus on the mechanical tests performed under laboratory conditions with the shapes studied in this paper, with the purpose of validating the present results.

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