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FEM for the tensile specimens printed in horizontal position A and made of ABS^+ material

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Abstract. 3D printing is finding more and more applications in the industrial field and represents a modern additive manufacturing process based on a digital model. There are a number of advantages of additive manufacturing through 3D printing compared to classic manufacturing processes such as: material economy, design optimization, the possibility of rapid prototyping, shortening the design and manufacturing cycle, eliminating errors and many others. Because 3D printed elements are more and more often found in various applications, an investigation is required by material categories and printing positions of the mechanical properties and how the respective landmarks behave in terms of displacements and internal stresses. The investigation of the mechanical characteristics, displacements and internal stresses can be done through laboratory tests on samples classically subjected to traction, bending, torsion. In order to reduce the number of mechanical tests, in order to investigate displacements and internal stresses, we must use finite element analysis methods. In the present work, the finite element analysis of some tensile specimens, 3D printed from ABS+ material, in the horizontal position A, will be presented..
Keywords: *sample test, 3D printing, material, printing position*

1. Introduction

3D printing is finding more and more applications in the industrial field and represents a modern additive manufacturing process based on a digital model [1]. There are a number of advantages of additive manufacturing through 3D printing compared to classic manufacturing processes, such as: cost reduction [2], design optimization [3], making parts with a high degree of complexity, economy of material, the possibility of rapid prototyping, shortening the cycle design and manufacturing, error elimination and many others.

Because 3D printed elements are more and more often encountered in various applications, an investigation is required by material categories and by printing positions of the mechanical properties and how the respective landmarks behave in terms of displacements and internal stresses. The investigation of the mechanical characteristics, displacements and internal stresses can be done through laboratory tests on samples classically subjected to traction, bending, torsion. In order to reduce the number of mechanical tests, in order to investigate displacements and internal stresses, we must use finite element analysis methods. In the present paper, the finite element analysis of some tensile specimens, 3D printed from ABS+ material, in the horizontal position A will be presented. The paper presents only a part of a wider research in which the finite element analysis of some specimens is performed required for traction and bending, manufactured by 3D printing from three categories of material in three printing positions.

The expected results of the static finite element analysis on the 3D printed tensile specimens are as follows. It is introduced as a load on the finite element model of the specimen, the critical force Fc of 1403 N, resulting at the critical moment tc of 48 seconds, in the tensile laboratory tests, when the yield limit was obtained as a unit effort on the laboratory specimen σ_C of 29.23 MPa. The finite element static analysis of the specimen is performed and it is checked if the maximum unit stresses of the Plate_Top_Y_Normal_Stress type in MPa have a value close to the yeld limit σ_C of 29.23 MPa, obtained in the specimen in the laboratory sample at the critical moment tc 85 seconds, when the critical force Fc of 1043 N acted on the specimen. If this happens, it means that the tensile laboratory test, on the 3D printed specimen, was correct and scientifically rigorous.

In the following, the stages of the analysis with finite elements will be presented for the tensile specimens, 3D printed from ABS+ material, in the horizontal position A.

2. Choosing the set of measurement units

The following set of measurement units are chosen for the MSC Visual Nastran program, for the finite element analysis of tensile samples, 3D printed from ABS+ material, in the horizontal position A: linear dimensions in mm, forces in N, moments in N*mm, unit stresses in MPa, deformations in mm, accelerations in mm/sec^2, density in N*sec^2/mm^4 and concentrated masses in N*sec^2/mm.

3. Choice of material properties

Figure 1 shows the window from the MSC Visual Nastran program for entering the mass properties for the 3D printed tensile specimen made of ABS+ material in horizontal position A.

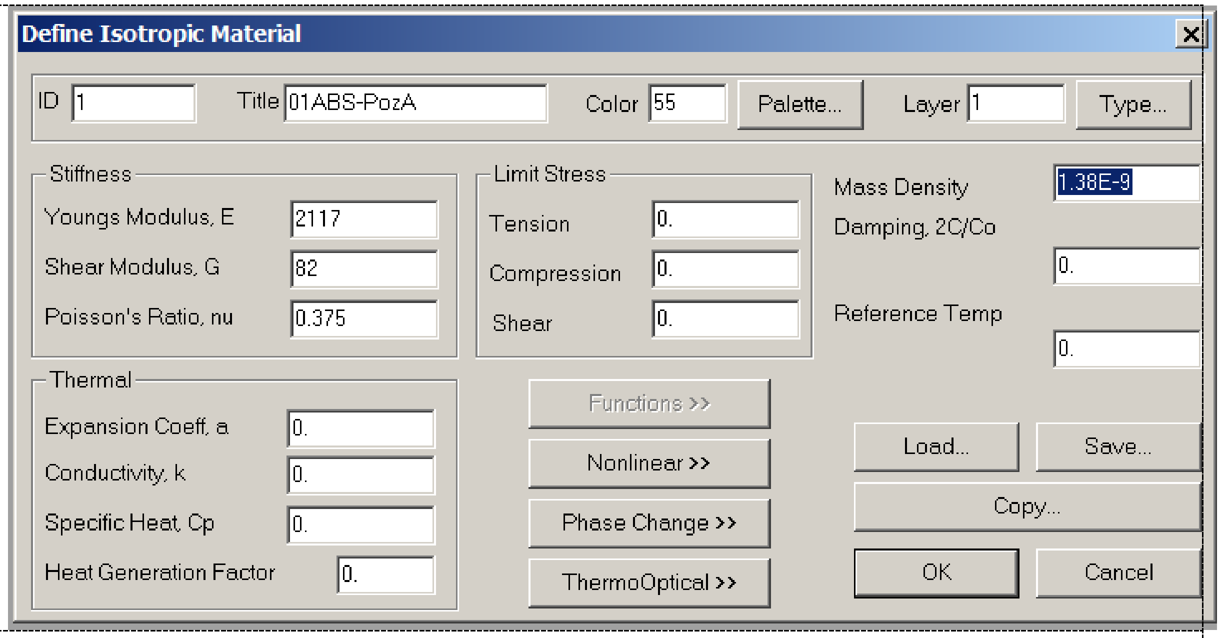

Figure 1. Introduction of the mass properties for the 3D printed tensile specimen made of ABS+ material in horizontal position A

For the ABS+ material and the horizontal printing position A, the material characteristics determined following the test of the tensile strength of the materials are chosen.

Longitudinal modulus of elasticity, Young's E=2117 MPa. Young's modulus is defined as the ratio between the variation of longitudinal unitary stress along an axis to the variation of deformation along that axis, in the linear range of elasticity of Hook's law.

Poisson's constant υ=NUXY=0.375 for ABS+ material. Poisson's constant is the negative ratio between the transverse strain and the axial strain of the material. Transverse Modulus of Elasticity G=18 MPa.

The density of ABS+=1.38x10^{-3} kg/cm^3 i.e. 1.38x10^{-9}Nxsec^2/mm^4.

Gravitational acceleration g=9.807 mxsec^{-2} i.e. 9806.65mm/sec^2.

4. Geometric modeling and discretization of the sample surface

With the property sets for defining the geometric and inertial characteristics of the element section, the finite element discretization of the tensile specimen can now be done as seen in figure 2.

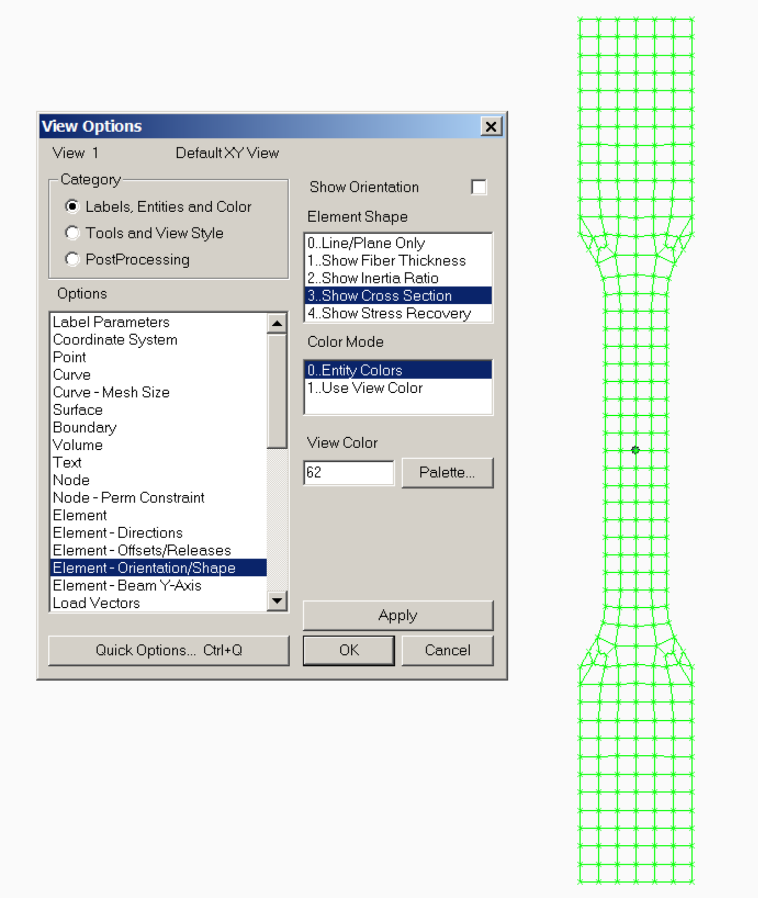

Figure 2. The drawing Tensile_Sample.dxf imported into MSC Nastran

The ACAD drawing of the tensile specimen Tensile_Sample.dwg is transformed into Tensile_Sample.dxf. This is imported as geometric elements (lines, curves, points) in the MSC Nastran program, using the menu File/Import/Geometry/DWG Specimens/Tensile_Sample.dxf. Next, the created set of curves-lines is transformed into a Boundary/Surface geometric entity that can be discretized with finite elements, through the Geometry/Boudary /Surface /From Curves command. Continue with the selection of the Boundary/Region type surface to set the Plate discretization element. Then the size of the discretization element is set, after which the discretization parameters are set with the Plate type element, finally resulting in the discretized surface in figure 2.

5. Force input on nodes

First, the representation of the Line-plane-only type elements is redone, and with the numbering of the line-curves, for the introduction of the support constraints on the nodes on the curves.

For the nodes selected on the connection curves at the bottom of the sample, the embedment is set, i.e. Fixed is selected, blocking all six degrees of freedom, i.e. three rotations and three translations.

The forces are introduced on the nodes on the upper part of the sample. The force F of 1403 N, corresponding to the critical time tc of 85 seconds, will be introduced as a load, distributed on the nodes on the connection curves at the top of the tensile test, when the yield limit of 29.23 Mpa is reached after the tensile tests, for ABS+ material, printing in horizontal position A. The variable Fnod=1403/10 is defined. Fill in the data from the window for entering the forces on nodes FY=!Fnod, after which the forces on the nodes are displayed graphically as shown in figure 3.

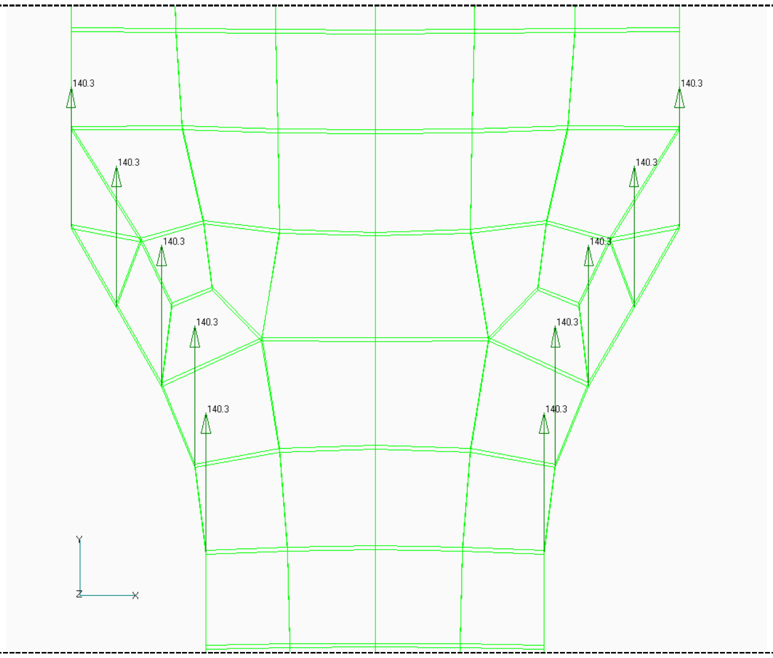

Figure 3. Graphic display of forces on nodes

6. FEM run. Displacement results

The load case was LC1-Specimen self-weight. The force was distributed on 10 nodes on the connection curves, at the upper part of the specimen, namely Force F of 1403 N, corresponding to the critical time moment tc of 85 seconds, when the yield strength of 29.23 Mpa is reached after the tensile tests, for ABS+ material, printing position A, horizontal.

The bearing case was C1 - Embedding the 10 nodes on the connection curves at the bottom of the specimen.

Following the finite element static analysis of the 3D printed tensile specimen made of ABS+ material, horizontal printing position A, (loading case LC1, bearing case C1) the maximum displacements Dis_max were obtained in the nodes on the upper part of the specimen=0.802 mm, as can be seen in figure 4.

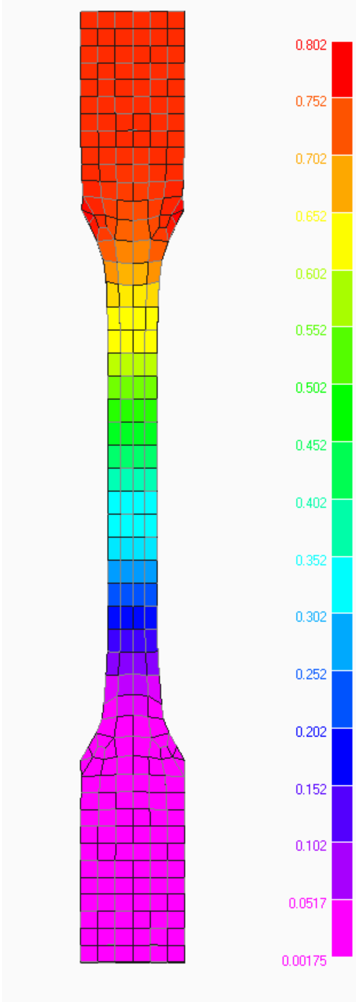

Figure 4. Displacement results for the horizontally printed tensile specimen A made of ABS+ material

7. FEM run. Result of stresses

After the finite element static analysis of the 3D printed tensile specimen from the material, ABS+, horizontal printing position A, the maximum value of the unit stresses σ_{PTNS} of the Plate_Top_Y_Normal_Stress type of 29.72 MPa was obtained in the elements from the lower part of the connection, so as can be seen in table 1 and figure 5.

Table 1 Normal stresses for tensile samples from PLA+, horizontally position A

No	Element no	σ_{PTNS} (Mpa)
1	172	29.72
2	154	28.36
3	150	28.35
4	146	28.15

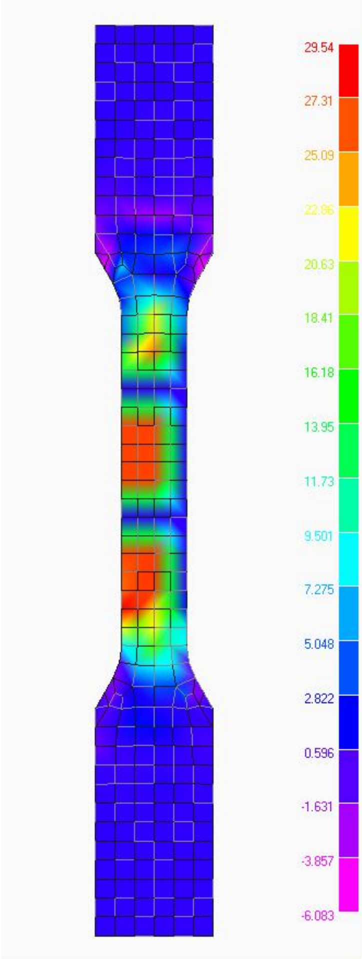

Figure 5. Results of normal unit stresses σ_{PTNS} for the horizontally printed tensile specimen A, made of ABS+ material

8. Conclusions

The finite element static analysis of the specimen was made and it was found that the maximum unit stresses obtained of the Plate_Top_Y_Normal_Stress type are 29.72 MPa and have a value approximately equal to the yield limit of 29.23 MPa, obtained in the specimen in the laboratory sample at the critical moment tc of 85 seconds, when the critical force Fc of 1403 N acted on the sample.

This shows that the laboratory test of the tensile strength of the materials, on the 3D printed specimen, was scientifically correct and rigorous.

9. References

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