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VIRTUAL STUDIES ON THE BEHAVIOR OF POLYURETHANE ON MECHANICAL STRESSES

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Abstract: *In this part of the paper, we will study the behavior of PUR polyurethane at different mechanical and thermal stresses, stresses for which this material behaves very well. It is known that this material behaves well as a protective material against shocks, so it is used as protection against mechanical elements. PUR behaves excellently at uneven static stresses and dynamic stresses. That is why it is used in the construction of the rollers of medium weight mobile devices or rollers that have cam functionality, strongly required for static and dynamic contact. PUR has very good thermal properties, it is used as a thermal insulator when it is in the form of high-density polyurethane foam (PUR / PIR).*

Keywords: *mechanical properties, SolidWorks; polyurethane, thermal stresses*

1. INTRODUCTION

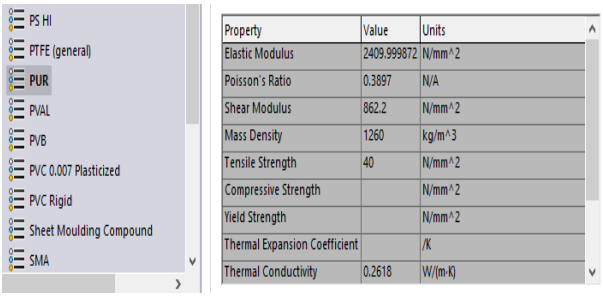
Virtual tests on the mechanical properties of PUR polyurethane. PUR is intended in the machine building industry to make various parts to protect certain products in the production process [1,2,3]. For example, the transport or support of parts whose surfaces have been machined, and it is not desired to destroy them by contact or friction, will be protected by the support or transport on surfaces constructed of PUR.



Figure 1. Landmarks constructed of PUR

So it can be said that the PUR must have a certain mechanical strength in terms of:
- stretching-compression;
- bending;
- twisting;
- contact pressure.
- low weight (1250 kg / m^3);
- low breaking strength in relation to metals, but good in relation to other polymers);
- good tensile strength (it can be seen that the tensile strength and tensile strength are dependent on the PUR density);
- the temperature resistance is not very good (max. 110^0C), but for materials with high working temperatures other materials can be used.

Figure 2 show the PUR properties for the virtual study environment.

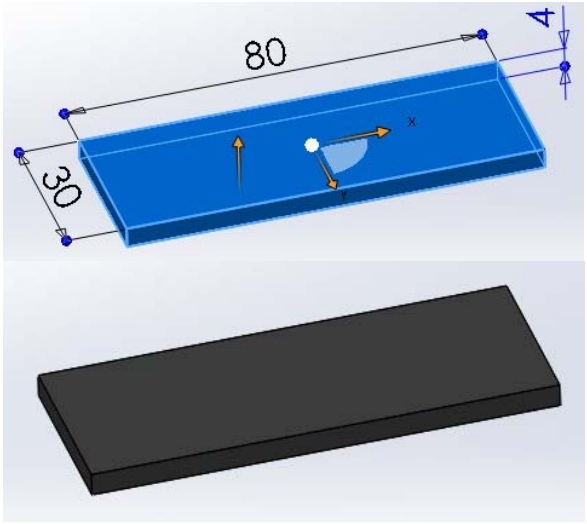


Property	Value	Units
Elastic Modulus	2409.999872	N/mm^2
Poisson's Ratio	0.3897	N/A
Shear Modulus	862.2	N/mm^2
Mass Density	1260	kg/m^3
Tensile Strength	40	N/mm^2
Compressive Strength		N/mm^2
Yield Strength		N/mm^2
Thermal Expansion Coefficient		/K
Thermal Conductivity	0.2618	W/(m·K)

Figure 2. PUR properties - virtual material

PUR stretch-compression virtual test

For this test I designed a sample of PUR virtual material, in the form of a plate (80x30x40mm) which I will submit to the stress and compression requirements.



PUR virtual sample 80x30x4 mm

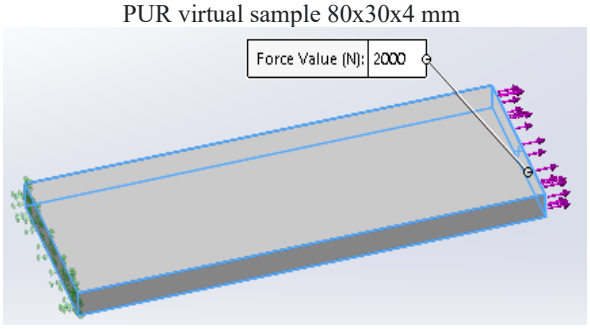


Figure 3. Stretching request F = 2000 N

Tensile strength testing was performed in SolidWorks using the Simulation module using AEF (finite element analysis).

Request parameters:

- application of a traction force F = 2000 N;
Stretch request results:
- the tensions developed in the material (fig. 4, a);
- tensions in the direction of extension (fig. 4, b);
- deformation in the direction of extension (fig. 4, c);
- FOS safety factor (fig.4, d).

The stresses developed in the material [4,5]are calculated as the result of stresses in the three directions (x, y and z).
Tensions in the direction of tension are only those on the Ox axis, in the direction of the tensile force. The deformations are also considered in the Ox direction, ie in the direction of application of the tensile force.

The FOS safety factor expresses the moment of loss of dimensional and structural stability of the sample and sample material. Values greater than 1.5 show material destruction.

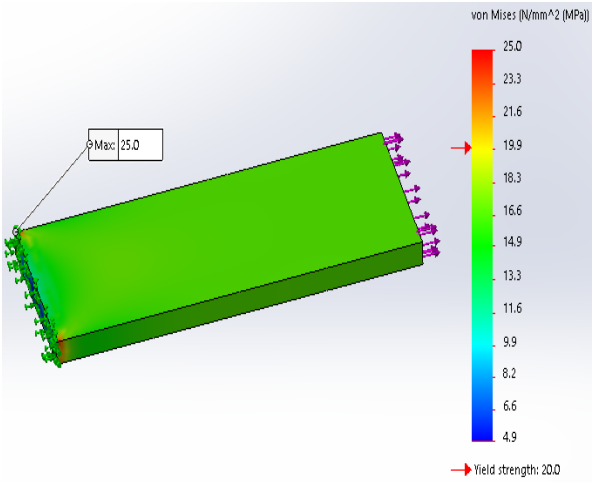


Figure 4a. Tensions developed in the material

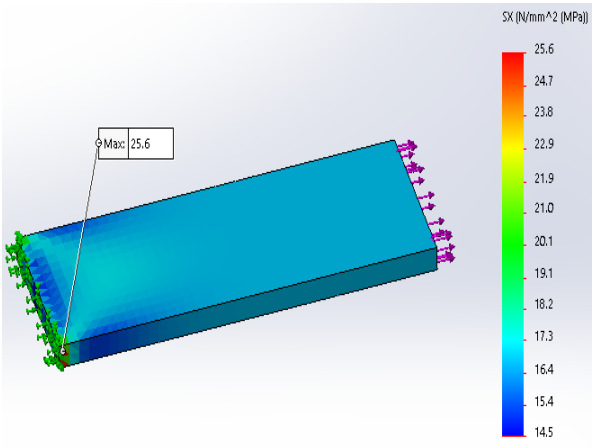


Figure 4b. Tensions in the direction of extension

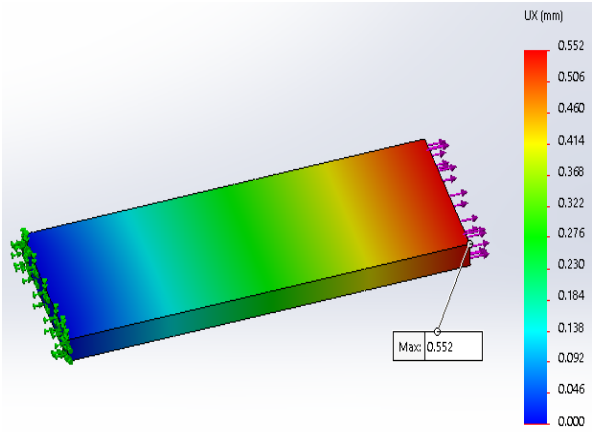


Figure 4c. Travels in the direction of extension

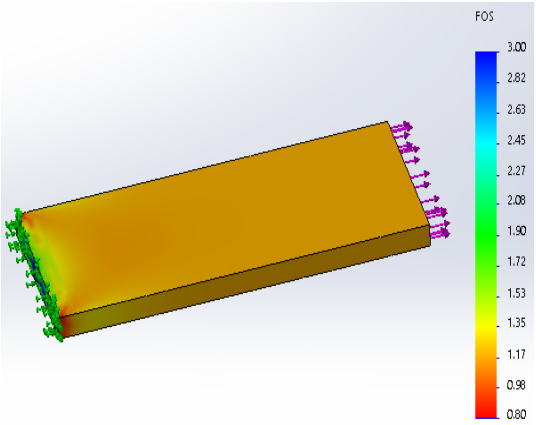
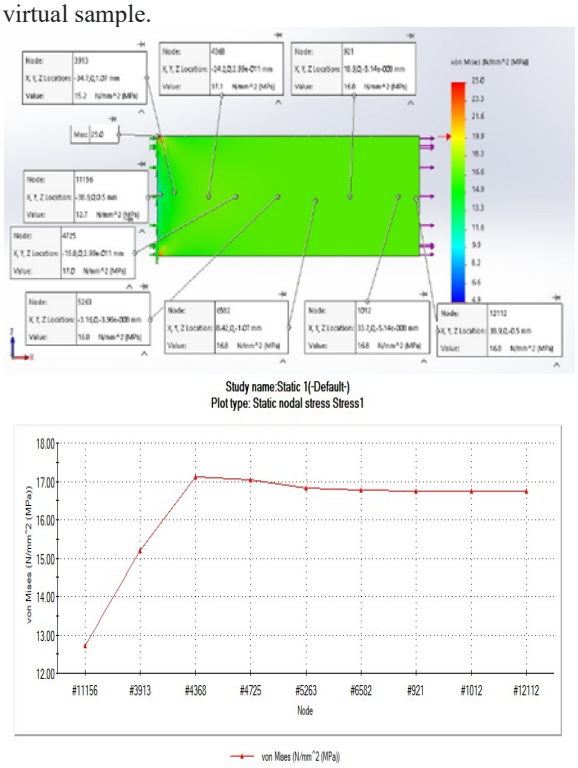


Figure 4d. FOS safety factor

Stretch test conclusions

PUR polyurethane behaves very well when stretched.
A small sample (80x30x4 mm) is well resistant to stretching, high stresses only occur on the surface of the sample[7,8]. The deformation δ = 0.552 mm is small for the sample length of 80 mm.
The FOS safety factor only signals the loss of material stability at high voltage points at the grip surface of the virtual sample.



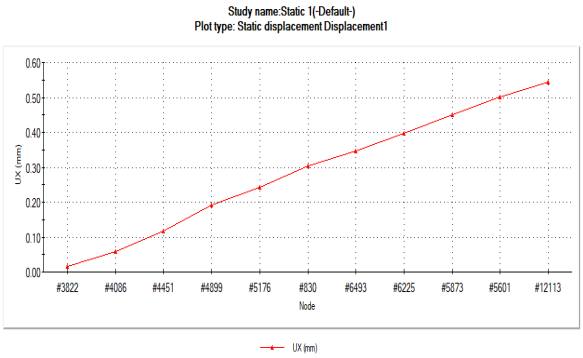


Figure 5. Distribution of stresses and displacements along the length of the sample (80 mm) – stretching

Virtual PUR compression test

Request parameters:
- application of a compression force F = 2000 N;
Compression request results:
- the tensions developed in the material (fig. 6, a);
- tensions in the direction of extension (fig. 6, b);
- deformation in the direction of extension (fig. 6, c);
- FOS safety factor (fig. 6, d).

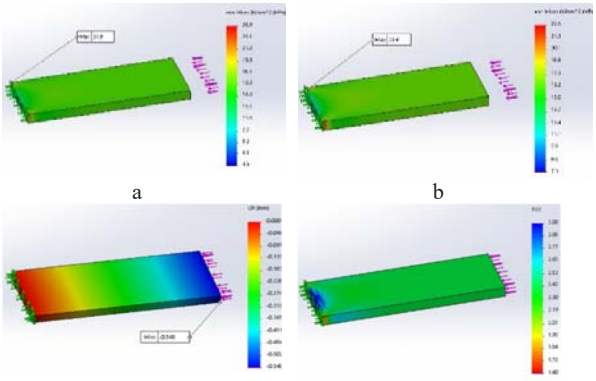


Figure 6. Compression test results F = 2000 N

The results obtained for compression are similar to those from stretching:
- You have. tensile: σ_t = 25 MPa, tens. compression: σ_c = 24.9 MPa;
- You have. stretch, dir. Ox: σ_t = 25.6 MPa, tens. compression, dir. Ox: σ_c = 22.6 MPa;
- displacements on Ox, extension: δ_t = 0.552 mm, displacements on Ox, compression: δ_c = 0.548 mm;
The evolution of the compression stresses along the sample length (80 MPa) [9,10,11] and of the deformations are represented in fig.7.

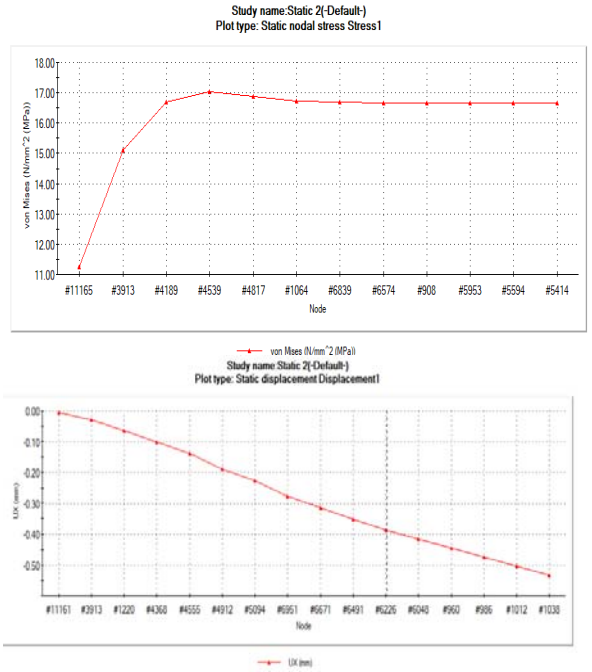


Figure 7. Distribution of stresses and displacements along the length of the sample (80 mm) - at compression

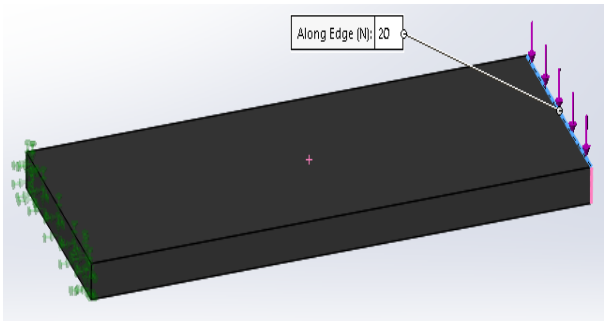


Figure 8. Application of bending stress - PUR virtual material

Virtual PUR bending test Request parameters: - application of a bending force F = 500 N; Compression request results: - the tensions developed in the material (fig.9 a); - tensions in the direction of extension (fig.9, b); - deformation in the direction of extension (fig.9, c); - FOS safety factor (fig.9, d)

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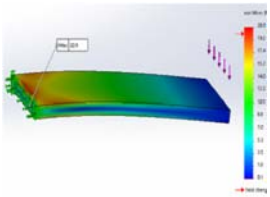


Figure 9a. Compressive stresses

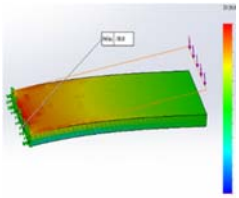


Figure 9b. Tensions in the Oy direction (transverse)

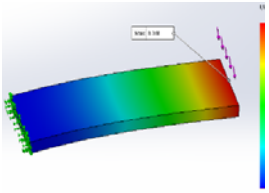


Figure 9c. Deformations in the direction of Oy stress (transverse)

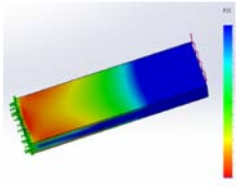


Figure 9d. FOS safety factor - bending

Bending test conclusions

PUR polyurethane does not behave very well when bending, the proof is that when applying a small force (F = 20 N) the deformation is very large (δ = 8.388 mm), but also the thickness of the sample is small g = 4 mm. The stresses in the Oy direction are in line with the tensile and compression stresses.

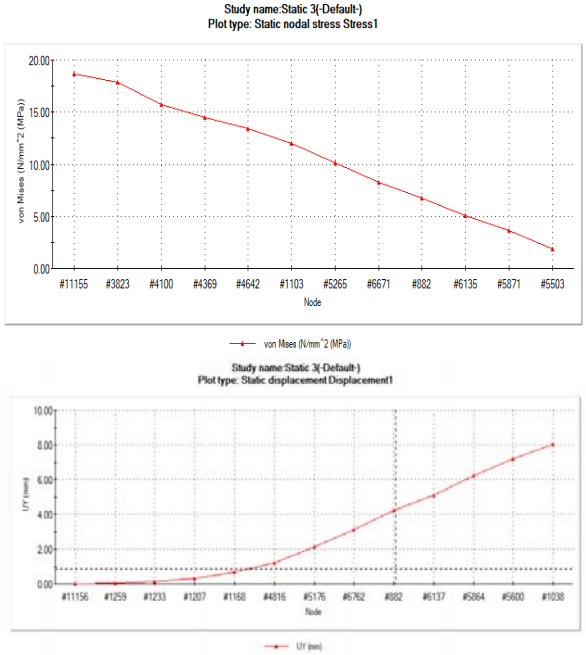


Figure 10. Distribution of stresses and displacements along the length of the sample (80 mm) - at bending

All these virtual tests applied to PUR polyurethane show that, in terms of static stress, this material is resistant. It withstands tensile forces of approximately 2000 N (200 kgf).

The stresses are not large, so the material behaves well, has some surface elasticity and low intrinsic elasticity [12,13].

The elastic behavior of PUR polyurethane can be determined from the contact pressure test.
Virtual pressure test that contact PUR
Request parameters:
- application of a pressure: p = 500 N;

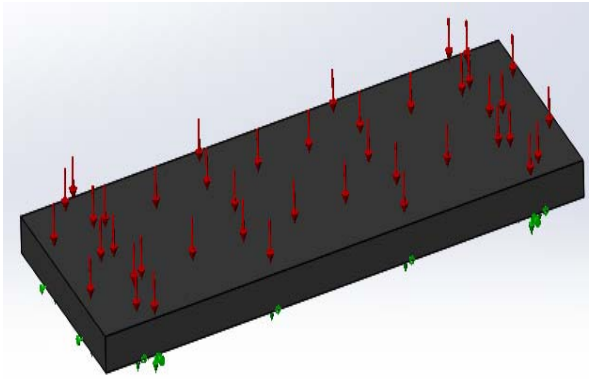


Figure 11. Contact pressure application test - PUR virtual polyurethane

Compression request results:

- the tensions developed in the material (fig. 12, a);
- tensions in the direction of extension (fig. 12, b);
- deformation in the direction of extension (fig.12, c);
- FOS safety factor (fig.12, d).

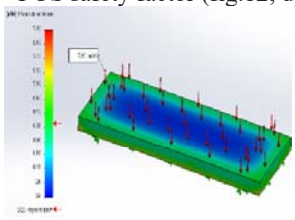


Figure 12a. Tensions equivalent to contact pressure p = 20 MPa

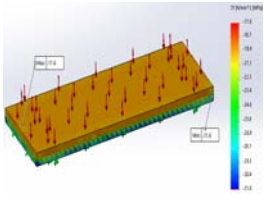


Figure 12b. Tensions in the direction of pressing, at contact pressure p = 20 MPa

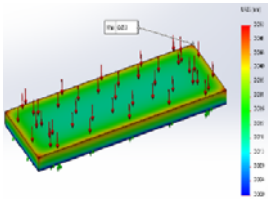


Figure 12 c. Deformations in the direction of pressing, at contact pressure p = 20 MPa

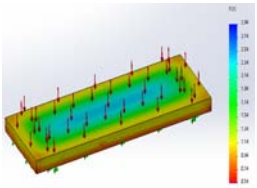


Figure 12 d. FOS in the direction of pressing, at contact pressure p = 20 MPa

From testing the PUR polyurethane sample to the contact pressure, it is observed that it behaves well on a large contact surface[14,15].

Problems occur at the edges where stresses and strains are high. But the value of the pressure applied is also a great value for such a material. The high value of the applied pressure was chosen to determine the areas with a high risk of loss of stability.

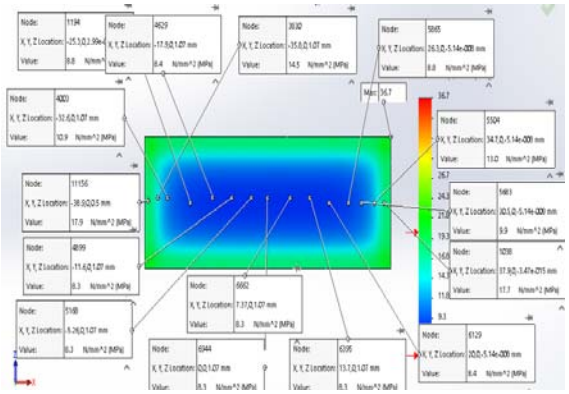


Figure 13. Tension samples along the sample length (80mm)

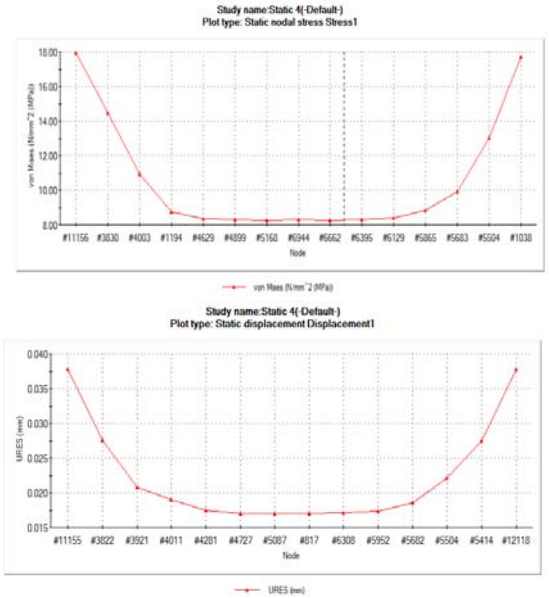


Figure 13. Variation of equivalent stresses and deformations over the length of the sample (80 mm)

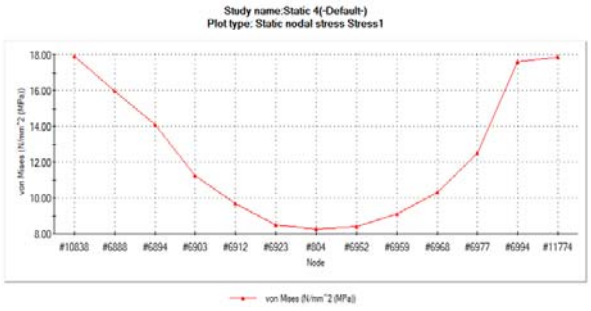


Figure 14. Equivalent voltage variation across sample width (30 mm)

Dynamic virtual tests on the behavior of virtual PUR polyurethane

The dynamic requests to which the PUR virtual material sample will be subjected mimic the reality by the fact that the virtual sample can be tested at non-linear (dynamic) requests. For this test it is necessary to build a

virtual device with which you can try how to bend the material sample by bending.

The device consists of a die and a punch. The sample is positioned on the mold and is gradually pressed by the sliding head (punch). Thus, the appearance can be seen in real time (development of stresses and deformations in the material sample).

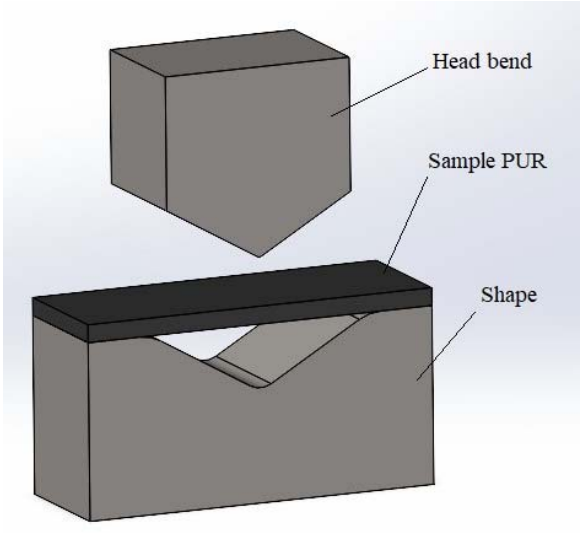


Figure 15. Non-linear testing device

Working conditions:

The only working condition in this test is the lowering stroke: 20 mm;
Thus, when it comes into contact with the sample, its deformation begins and tensions and deformations automatically appear[16,17]. The program respects the contact conditions and even shows the stresses and strains that occur between the sample and the device.

Non-linear stress test results:

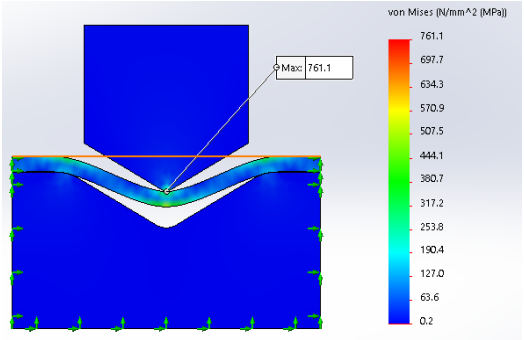


Figure 16. Tensions developed at the contact between the head and the sample and in polyurethane

It can be seen that polyurethane does not cope with such a stress, where the deformations are very high. The deformations recorded are shown in the figure below

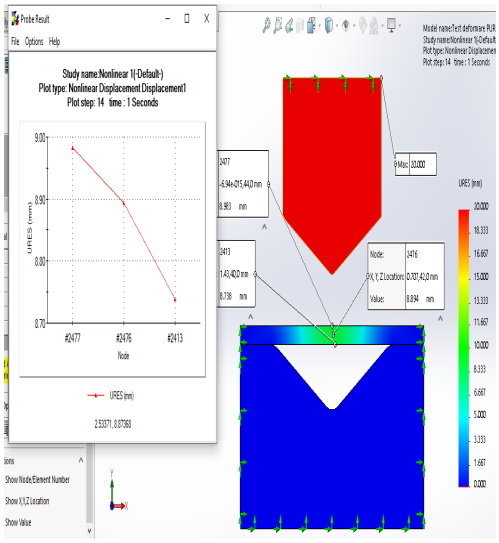


Figure 16. Deformities developed on contact between head and sample and in polyurethane

Virtual thermal stress tests on the behavior of virtual PUR polyurethane
PUR polyurethane is known as a good thermal insulator.

To demonstrate this quality we built a virtual model consisting of two boards:
- a PUR polyurethane plate;
- a steel metal plate.

The two plates are positioned in intimate contact forming a study model of heat transfer.

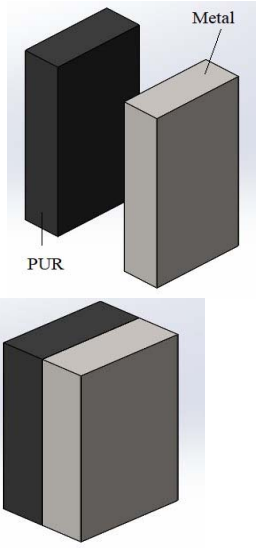


Figure 17. Virtual study model of heat transfer

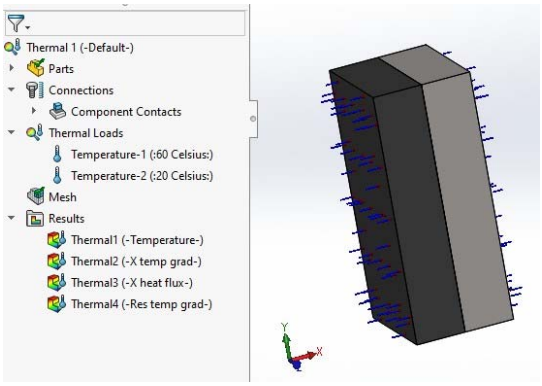


Figure 18. Temperature conditions for the study

The study is carried out by establishing a temperature of 600 on the outer face of the PUR plate and a temperature of 200 on the outer face of the metal plate.
The program determines, with the help of the finite element analysis and the thermal properties of the two materials, the mode of heat transfer and heat flow through the layer formed by the two materials[13, 5]. The figures below show the results obtained.

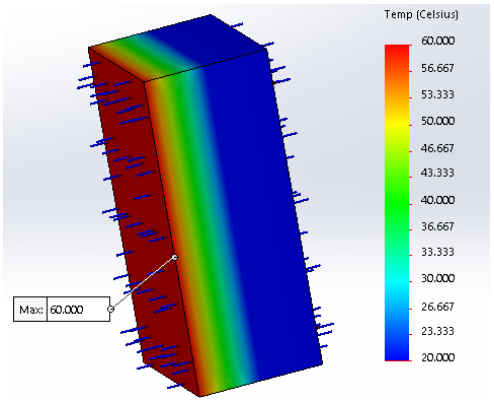


Figure 19. Heat transfer through the two plates (PUR + Steel)

Figure 19 shows that the PUR has a much lower heat transfer coefficient than the steel plate:
- PUR heat transfer coefficient: 0.2618 W / (K · m);
- steel heat transfer coefficient: 43 W / (K · m);

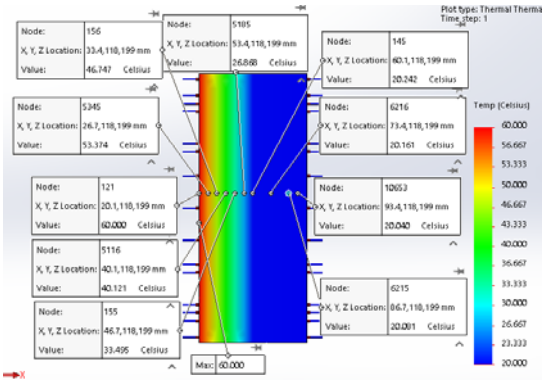


Figure 20. Selecting test points to generate the temperature graph

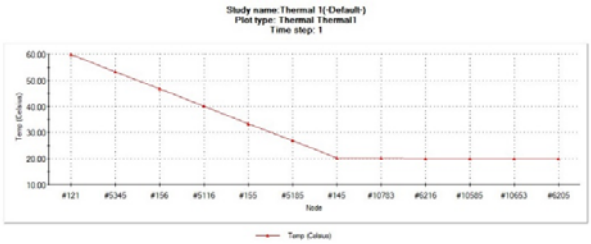
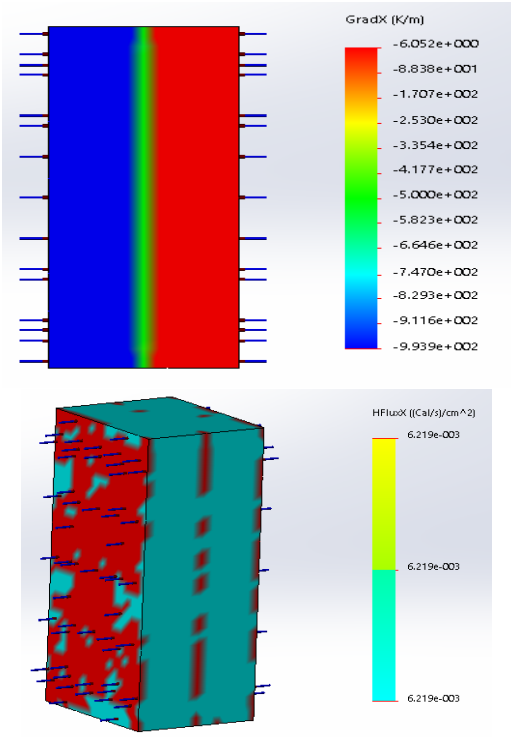


Figure 21. Temperature distribution over the entire width of the sample

In this study it is interesting to note how the temperature gradient is transmitted through the two materials.



a) b)

Figure 22. Transfer of temperature gradient and heat flow in the Ox direction he transfer of the temperature gradient (a) shows the influence of the contact between the two materials. There is a minimum transfer on that surface. PUR behaves very well as a thermal insulator. This advantage of thermal insulation also results from testing the heat flow of the two materials (b).

CONCLUSIONS

PUR polyurethane behaves very well when stretched. A small sample (80x30x4 mm) is well resistant to stretching, high stresses only occur on the surface of the sample. The deformation δ = 0.552 mm is small for the sample length of 80 mm. The FOS safety factor only signals the loss of material stability at high voltage points at the grip surface of the virtual sample.

The results obtained for compression are similar to those from stretching:

- You have. tensile: σ_t = 25 MPa, tens. compression: σ_c = 24.9 MPa;
- You have stretch, dir. Ox: σ_t = 25.6 MPa, tens. compression, dir. Ox: σ_c = 22.6 MPa;
- displacements on Ox, extension: δ_t = 0.552 mm, displacements on Ox, compression: δ_c = 0.548 mm;

PUR polyurethane does not behave very well when bending, the proof is that when applying a small force (F = 20 N) the deformation is very large (δ = 8.388 mm), but also the thickness of the sample is small g = 4 mm. The stresses in the Oy direction are in line with the tensile and compression stresses.

All these virtual tests applied to PUR polyurethane show that, in terms of static stress, this material is resistant. It withstands tensile forces of approximately 2000 N (200 kgf). The stresses are not large, so the material behaves well, has some surface elasticity and low intrinsic elasticity.

From testing the PUR polyurethane sample to the contact pressure, it is observed that it behaves well on a large contact surface. Problems occur at the edges where stresses and strains are high. But the value of the pressure applied is also a great value for such a material. The high value of the applied pressure was chosen to determine the areas with a high risk of loss of stability.
The only working condition in this test is the lowering stroke: 20 mm;

Thus, when it comes into contact with the sample, its deformation begins and tensions and deformations automatically appear. The program respects the contact conditions and even shows the stresses and strains that occur between the sample and the device.

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