Analysis of Stresses and Displacements in the Deformed Bent 3D Hexagonal Toroid with Regular Hexagonal Cross-Section Used in Manufacturing of LPG Storage Tanks

Assistant professor PhD. Eng. **Petre OPRIŢOIU**[1*]

[1] Technical University of Cluj-Napoca, Department of MTC, Observatorului Street, no. 72-74, Cluj-Napoca, 400363, Cluj county, Romania. * petre.opritoiu@mtc.utcluj.ro

Abstract: *In this article an integrated simulation and optimization approach is adopted in the stresses and displacements analysis of a three-dimensional (3D) hexagonal toroid with regular hexagonal cross-section used in manufacturing of LPG storage tanks from the automotive industry. A 3D parametric model was built to represent the product structure connected with input and output relations. The specific simulation algorithms and the simulation results are used to evaluate the product behavior during the optimization process for each involved design dependency. The obtained results are compared, and it can be found that in the deformed bent structure the state of stresses (σ) and displacements (u) have increased values at the end of the exploitation period (n_a = 15 years). The highest percentage values relative to the initial state are: $\Delta\sigma/\sigma_0$ = 37.56 [%] and $\Delta u/u_0$ = 39.49 [%]. The results of analyzed numerical cases demonstrate the effectiveness of the used models and methods for designing of LPG storage tanks.*

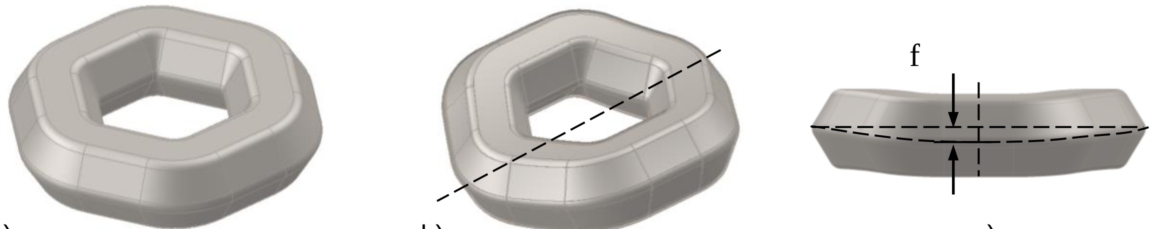
Keywords: *3-D hexagonal toroidal LPG fuel tank, deformed bent structure, finite element analysis, industrial engineering design, optimization methods*

1. Introduction

The automotive storage tank market is expected to grow due to a number of factors (such as rapid urbanization, expansion of vehicle production, innovation in storage tank technology, increase safety, and others) over the upcoming years [1-4]. In addition, the growth in electric vehicles and hybrid electric vehicles can open new growth avenues [5-8].
Automotive fuel tanks are produced by various manufacturers in many variants (for passenger cars, light commercial vehicles and heavy commercial vehicles) [9-12] and complex shapes with high mechanical and chemical resistance [13-16] and different prices.
In the current automotive fuel tank market there is segmentation based on the capacity of fuel tank, into less than 45 L, 45 L - 75 L, and greater than 75 L [17-21]. A comparative analysis indicates a growing of fuel tanks production from materials (such as plastic, steel, and aluminum materials) based on advanced safety systems and high technology [22-25].
Finite element analysis (FEA) is a computational modern tool [26-28] in engineering to design [29-31] and failure analysis which provides a lot of advantages to complement laboratory experiments and the simulation results can allow a fast, comparison of numerous results for integrated product development. In engineering design process of automotive fuel tanks, the design engineers explore, innovate, and optimize by using specific CAD tools [32-35] and a variety of design recommendations in accordance with national and international standards [36-40], the product performance according to its intended use, size, structure type, materials, and service life [41-44]. In addition, for practical applications of automotive fuel tanks a quantitative estimation of possible geometric variations are applied for different work/impact scenarios [45-49].
The objective of this study is to determine the stresses and displacements as a result of the action of a bending moment that affect the geometry of structural model, a (3D) hexagonal toroid with regular hexagonal cross-section used in manufacturing of LPG storage tanks.

2. Design methodology

A parametric model of a 3D hexagonal toroid with regular hexagonal cross-section, generated by revolving of a closed generating curve C_G (a hexagon with rounded corners) along a closed guiding curve C_D (a hexagon with rounded corners) (fig. 1), is used in the following analyses according [22].



a) b) c)

Fig. 1. a) The undeformed tank; b) and c) The deformed tank

The following geometric parameters are used in computational analyses (fig. 1): a) a closed generating curve C_G (a hexagon with a side value L = 175 mm, with rounded corners, radius R = 50 mm), and b) the guiding curve C_D (a hexagon with a side value L = 430 mm, with rounded corners, radius R = 180 mm).
The design data used were: the tank material is AISI 4340 steel; the maximum hydraulic test pressure: p_{max} = 30 bar; the working temperature between the limits: T = -30 ^{0}C up to T = 60 ^{0}C; supporting surfaces located on the inferior side; the duration of the tank exploitation: n_a = 16 years; the corrosion rate of the material: v_c = 0.07 mm/year; the thickness of the cover: s = 10 mm.
Let's consider as parameter the inclination angle α that occurs between horizontal plane and the deformed median plane that determines the vertical arrow *f*.
The geometrical model was created with AutoCAD Autodesk 2020 software [50] and the optimization analysis was performed with SolidWorks 2020 software [51] applying the: Static, Thermal and Design Study modules. The finite element method analysis was performed with the following parameters setting: mesh standard type, solid mesh with high quality, automatic transition, Jacobian in 16 points, element size 10 mm, tolerance 0.5 mm, number of nodes 436510, number of elements 219620, maximum aspect ratio 12.5.
Applying the proposed analysis procedure, the values of the state of stress and of linear deformations, as a function of temperature, flexion angle and corrosion, is shown in Table 1.

Table 1: The Von Mises stress of geometrical 3D model σ (T, α, n_a)

σ [MPa]	n_a= 0 years				n_a= 5 years			
	T [°C]				T [°C]			
α [°]	-30°	0°	30°	60°	-30°	0°	30°	60°
0	442.967	402.354	367.684	402.303	476.814	424.192	380.605	425.947
1	488.906	440.955	396.644	403.908	530.217	482.336	437.783	421.500
2	488.906	440.955	396.644	403.908	501.985	450.381	401.721	412.022
4	550.017	466.968	435.906	470.532	551.485	476.887	455.962	495.63
6	564.078	471.655	431.488	462.456	544.817	461.509	464.226	493.763
8	557.426	467.669	421.722	454.871	584.454	497.238	525.941	565.523
10	459.991	415.98	374.398	374.52	523.966	480.525	443.654	432.795

σ [MPa]	n_a= 10 years				n_a= 15 years			
	T [°C]				T [°C]			
α [°]	-30°	0°	30°	60°	-30°	0°	30°	60°
0	501.696	454.657	410.976	451.969	533.786	485.660	440.704	476.922
1	575.507	527.073	481.699	448.798	629.543	580.439	534.174	491.550
2	479.139	427.909	385.301	433.090	516.429	467.660	421.770	460.625
4	595.403	510.138	491.384	535.976	632.426	533.338	572.433	626.159
6	582.945	496.902	495.935	534.353	620.499	544.402	586.990	633.040
8	584.454	497.238	525.941	565.523	619.644	546.724	580.126	615.802
10	523.966	480.525	443.654	432.795	567.888	528.245	490.211	454.101

The graphs of the resultant Von Mises state of stress are shown in figs. 2-5.

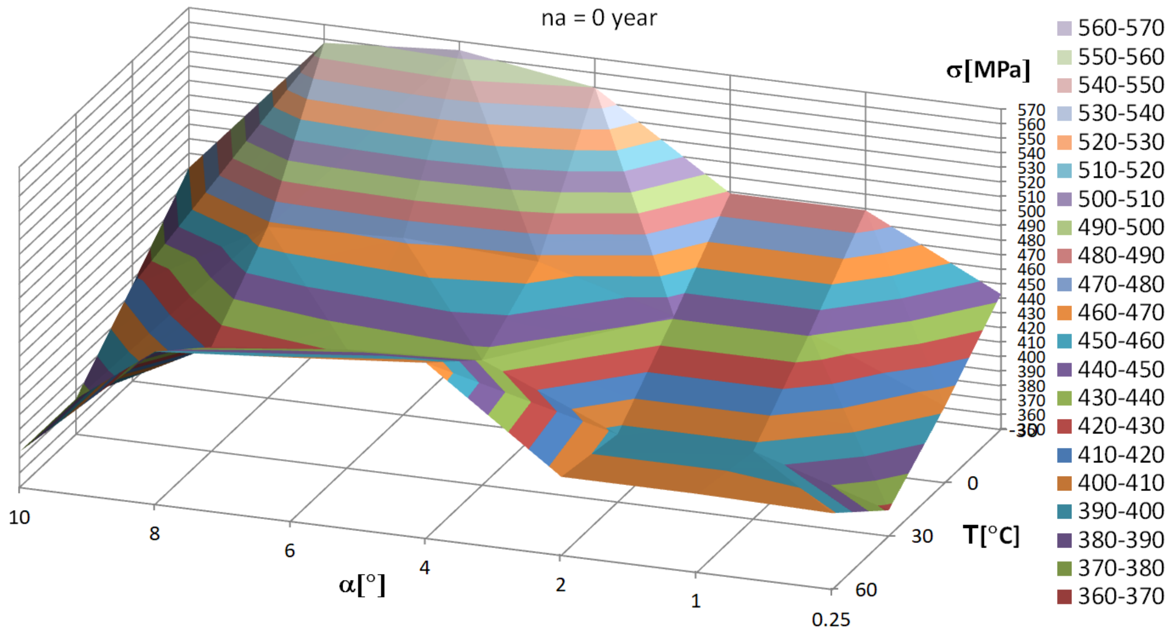


Fig. 2. σ (T, α, n_a= 0 years)

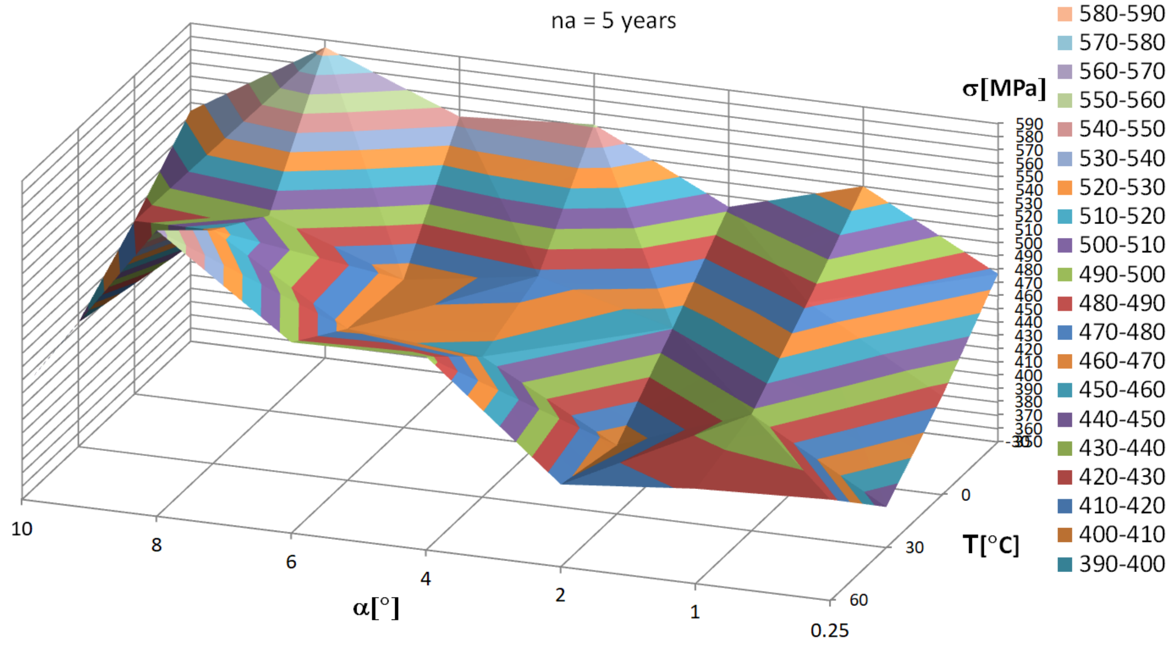


Fig. 3. σ (T, α, n_a= 5 years)

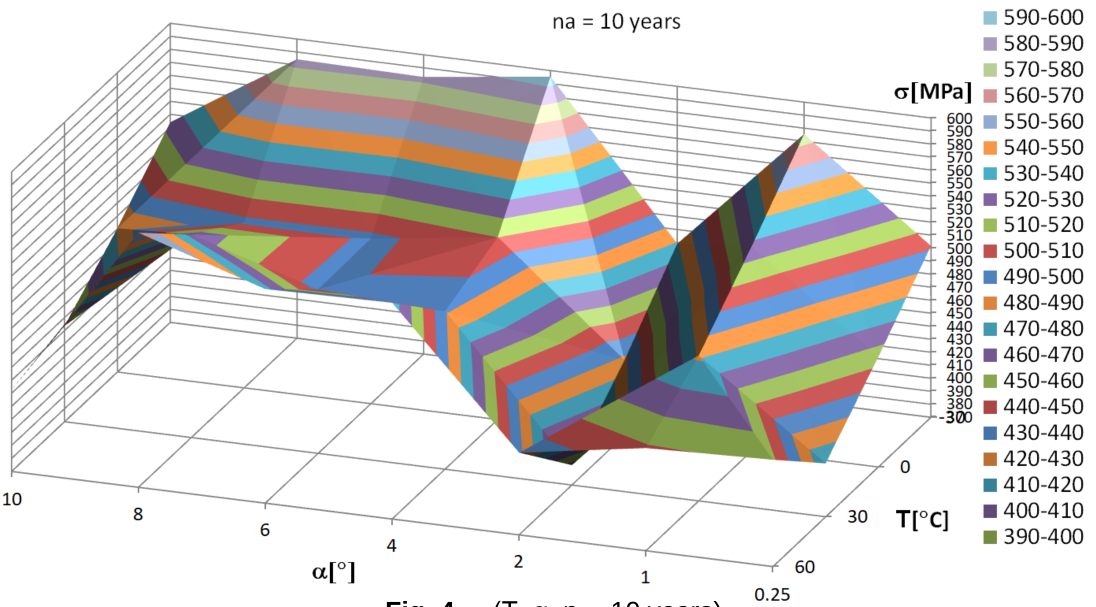


Fig. 4. σ (T, α, n_a= 10 years)

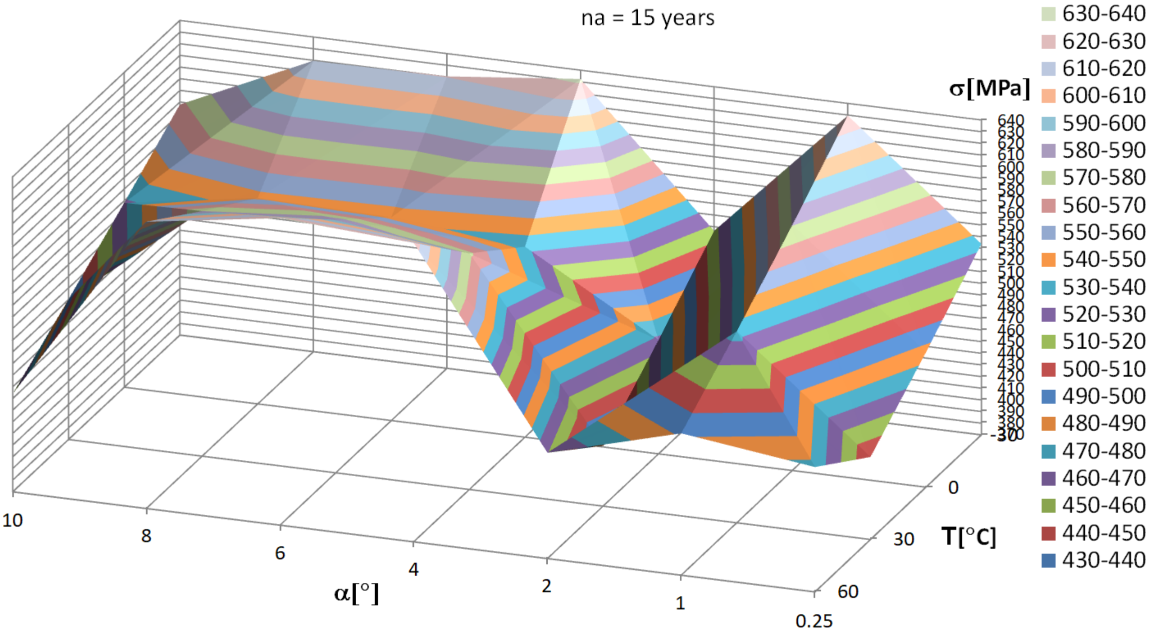


Fig. 5. σ (T, α, n_a= 15 years)

Table 2: The resultant Von Mises state of stress percentage relative to the initial state of geometrical 3D model, $\Delta\sigma/\sigma_0$ (T, α, n_a) [%]

$\Delta\sigma/\sigma_0$ [%]	n_a= 5 years				n_a= 10 years				n_a= 15 years			
	T [°C]				T [°C]				T [°C]			
α [°]	-30	0	30	60	-30	0	30	60	-30	0	30	60
0	7.64	5.42	3.51	5.87	13.25	12.99	11.77	12.34	20.50	20.70	19.85	18.54
1	8.44	9.38	10.37	4.35	17.71	19.52	21.44	11.11	28.76	31.63	34.67	21.69
2	2.67	2.13	1.27	2.00	-1.99	-2.95	-2.85	7.22	5.62	6.05	6.33	14.04
4	0.26	2.12	4.60	5.33	8.25	9.24	12.72	13.90	14.98	14.21	31.32	33.07
6	-3.41	-2.15	7.58	6.76	3.34	5.35	14.93	15.54	10.00	15.42	36.03	36.88
8	4.84	6.32	24.71	24.32	4.84	6.32	24.71	24.32	11.16	16.90	37.56	35.37
10	13.90	15.5	18.49	15.55	13.90	15.51	18.49	15.55	23.45	26.98	30.93	21.24

The graphs of the resultant Von Mises state of stress percentage relative to the initial state of geometrical 3D model, $\Delta\sigma/\sigma_0$ (T, α, n_a) [%] are shown in figs. 6-8.

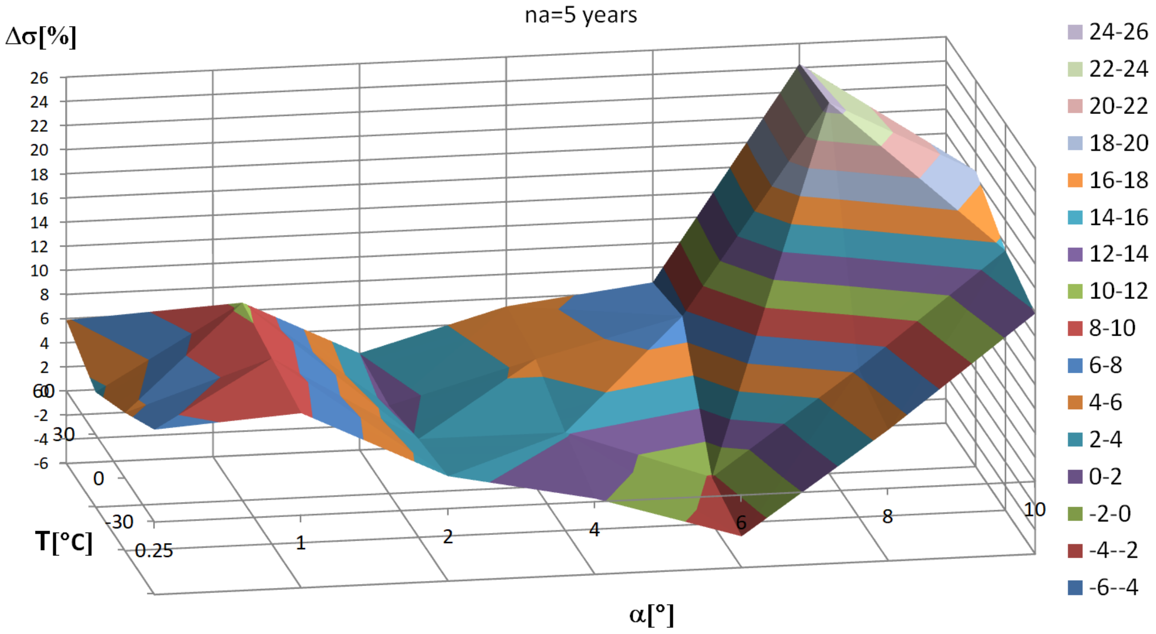


Fig. 6. $\Delta\sigma/\sigma_0$ (T, α, n_a = 5 years) [%]

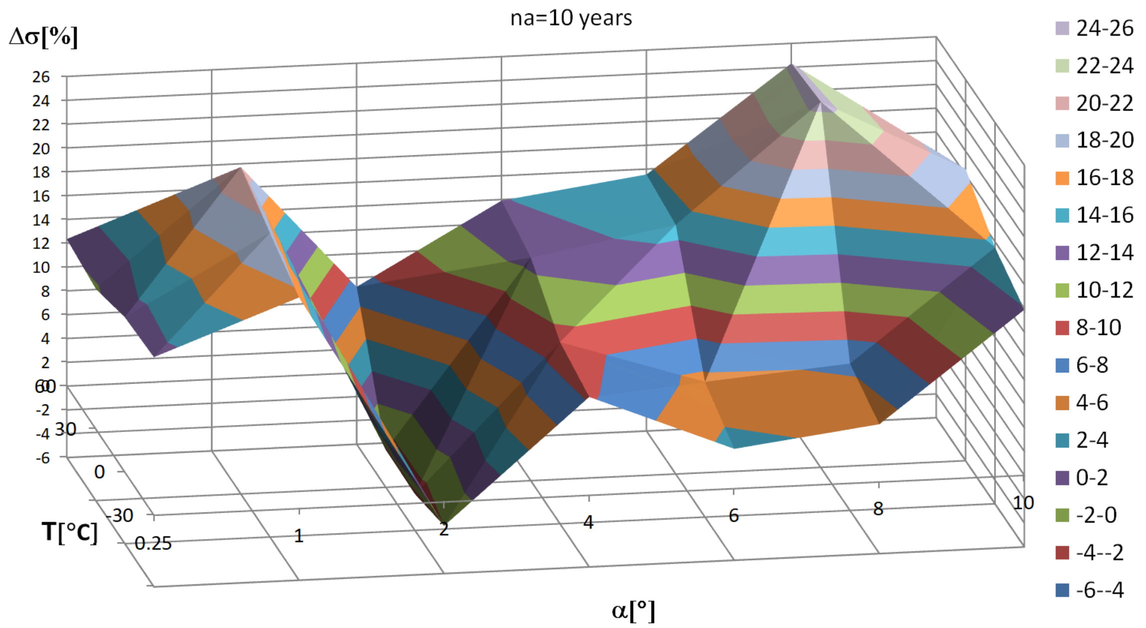


Fig. 7. $\Delta\sigma/\sigma_0$ (T, α, n_a = 10 years) [%]

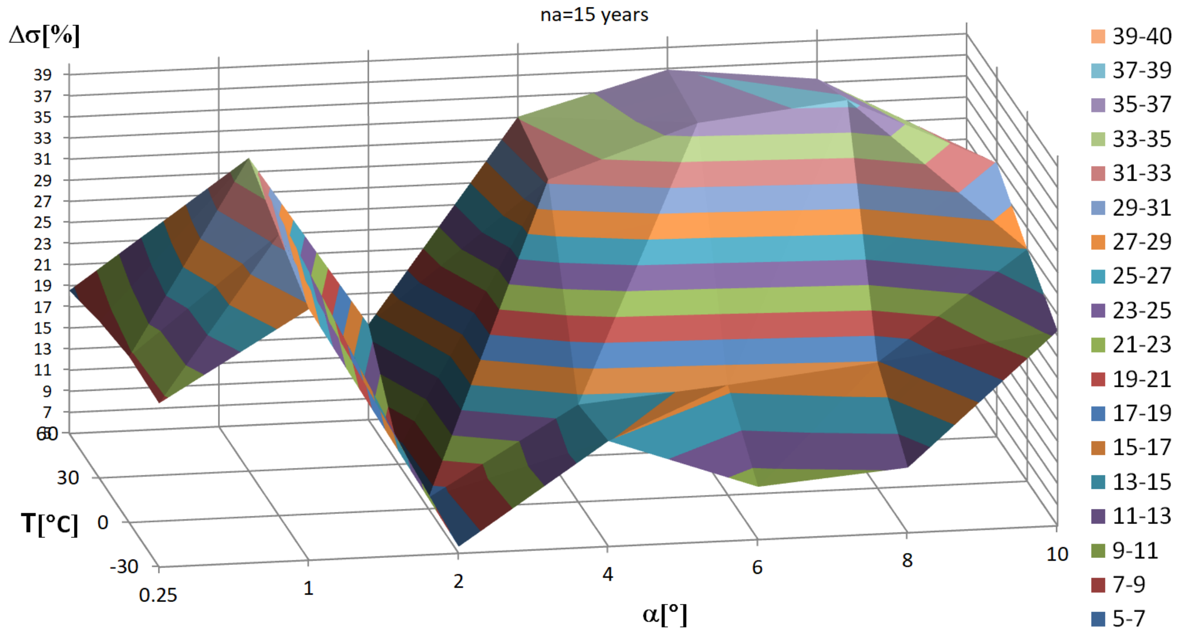


Fig. 8. $\Delta\sigma/\sigma_0$ (T, α, n_a = 15 years) [%]

Also the corresponding resultant linear deformations associated with these stresses, as a function of temperature, flexion angle and corrosion, are shown in Table 3.

Table 3: The resultant linear deformations of geometrical 3D model u (T, α, n_a)

u [mm]	n_a = 0 years				n_a = 5 years			
	T [°C]				T [°C]			
α [°]	-30°	0°	30°	60°	-30°	0°	30°	60°
0	0.66101	0.64168	0.62444	0.60879	0.71848	0.69716	0.69972	0.66404
1	0.66554	0.65167	0.6393	0.62851	0.72933	0.71502	0.70207	0.69057
2	0.78179	0.78864	0.79774	0.80987	0.72880	0.7098	0.6929	0.67731
4	0.78854	0.79728	0.80724	0.81838	0.87615	0.88465	0.89426	0.90494
6	0.79353	0.80305	0.81375	0.82561	0.88274	0.8897	0.89776	0.90686
8	0.80324	0.81117	0.82028	0.83051	0.89097	0.89823	0.90709	0.91697
10	0.69279	0.66939	0.65723	0.64675	0.75547	0.74217	0.73064	0.72025

u [mm]	n_a= 10 years				n_a= 15 years			
	T [°C]				T [°C]			
α [°]	-30°	0°	30°	60°	-30°	0°	30°	60°
0	0.77366	0.7552	0.73816	0.72248	0.85164	0.83065	0.81152	0.7941
1	0.79510	0.78095	0.76806	0.75651	0.85524	0.84237	0.83142	0.82191
2	0.79109	0.77242	0.75505	0.73889	0.85889	0.84037	0.82289	0.80652
4	0.96917	0.97821	0.98824	0.99924	1.08660	1.09410	1.10250	1.11780
6	0.98008	0.98897	0.99885	1.00967	1.09767	1.10397	1.11114	1.11919
8	0.98923	0.99746	1.00664	1.01676	1.1066	1.11324	1.12073	1.12906
10	0.83282	0.82092	0.81052	0.80138	0.93383	0.92238	0.91184	0.90221

The graphs of the resultant linear deformations are shown in figs. 9-12.

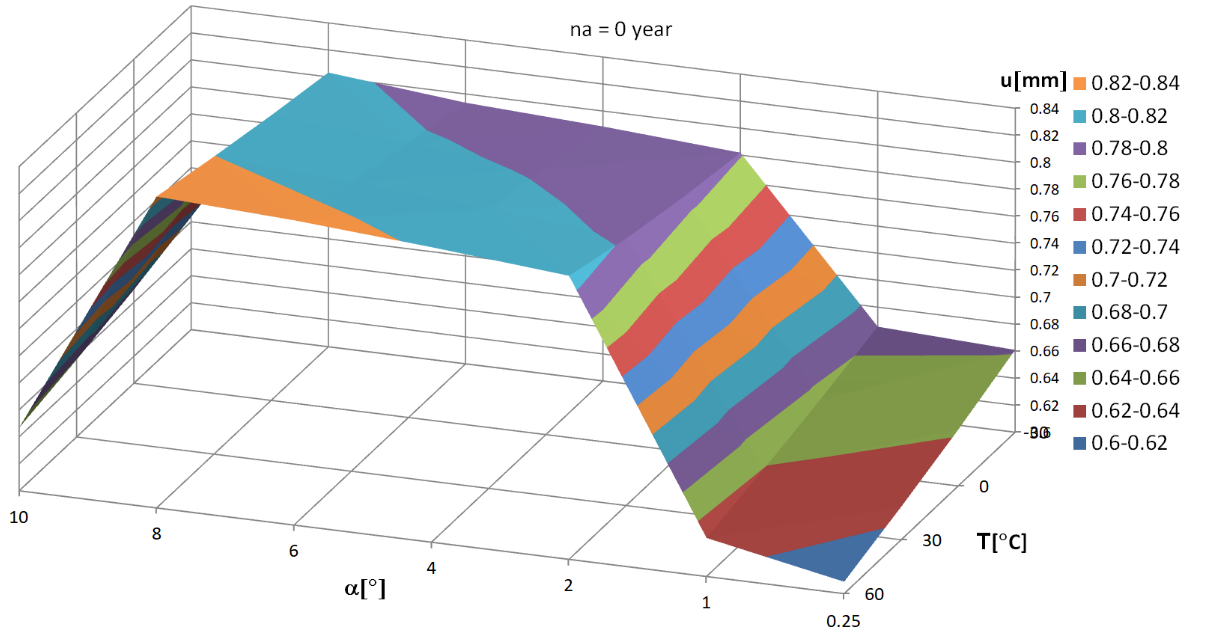


Fig. 9. u (T, α, n_a = 0 year) [mm]

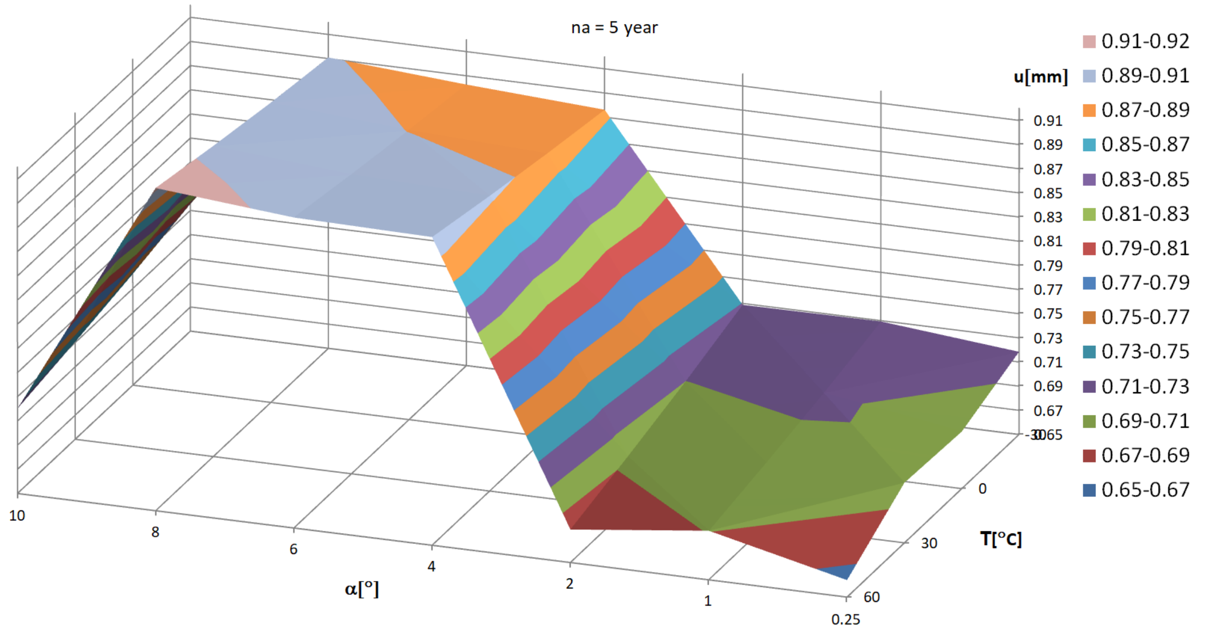


Fig. 10. u (T, α, n_a = 5 years) [mm]

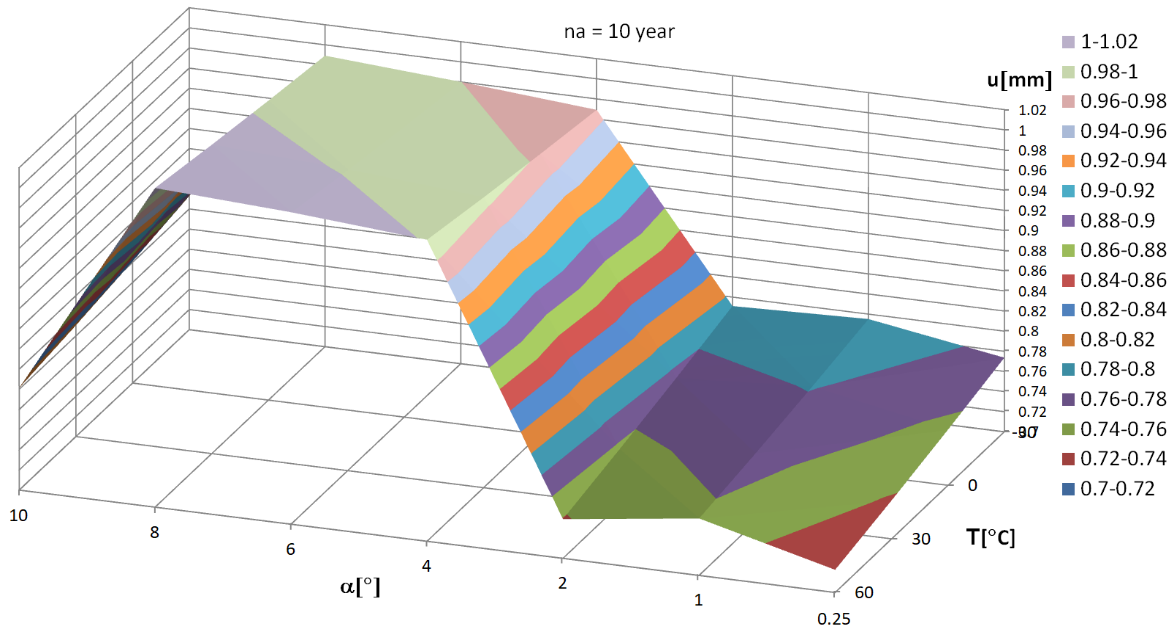


Fig. 11. u (T, α, n_a = 10 years) [mm]

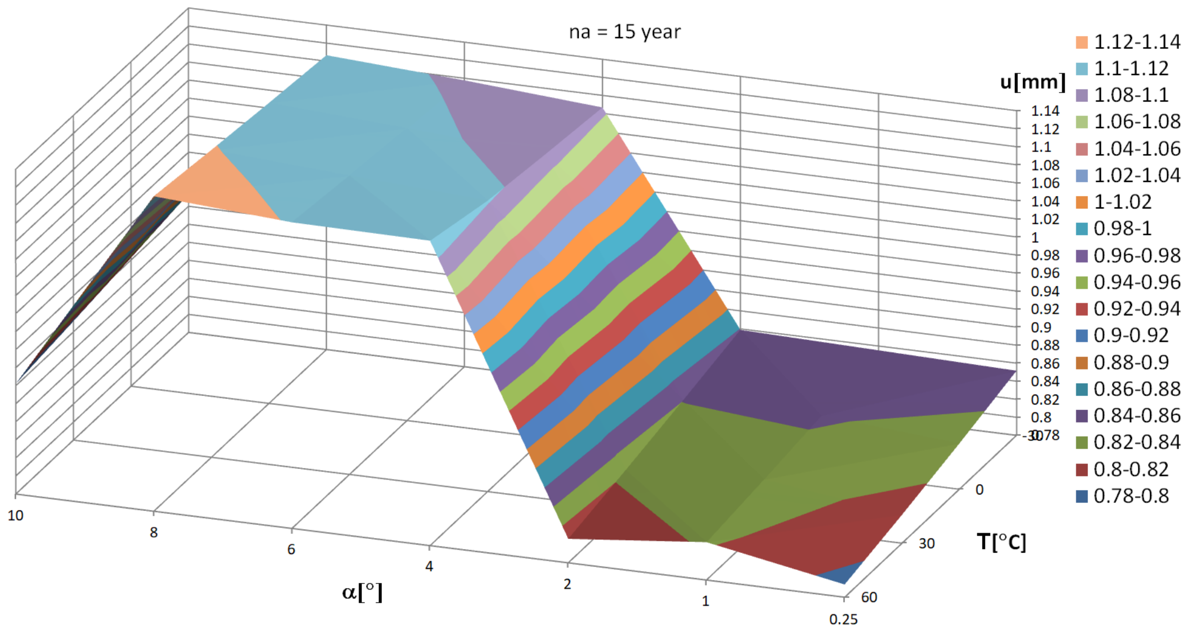


Fig. 12. u (T, α, n_a = 15 years) [mm]

Table 4: The resultant linear deformations percentage relative to the initial state of geometrical 3D model, $\Delta u/u_0$ (T, α, n_a) [%]

$\Delta u/u_0$ [%]	n_a= 5 years T [°C]				n_a= 10 years T [°C]				n_a= 15 years T [°C]			
α [°]	-30	0	30	60	-30	0	30	60	-30	0	30	60
0	8.69	8.64	12.05	9.07	17.04	17.69	18.21	18.67	28.83	29.44	29.95	30.43
1	9.58	9.72	9.81	9.87	19.46	19.83	20.14	20.36	28.50	29.26	30.05	30.77
2	-6.77	-9.99	-13.1	-16.3	1.18	-2.05	-5.35	-8.76	9.86	6.55	3.15	-0.41
4	11.11	10.95	10.77	10.57	22.90	22.69	22.42	22.09	37.79	37.22	36.57	36.58
6	11.24	10.79	10.32	9.84	23.50	23.15	22.74	22.29	38.32	37.47	36.54	35.55
8	10.92	10.73	10.58	10.41	23.15	22.96	22.71	22.42	37.76	37.23	36.62	35.94
10	9.04	10.87	11.16	11.36	20.21	22.63	23.32	23.90	34.79	37.79	38.73	39.49

The graphs of the resultant linear deformations percentage relative to the initial state of geometrical 3D model, $\Delta u/u_0$ (T, α, n_a) [%] are shown in figs. 13-15.

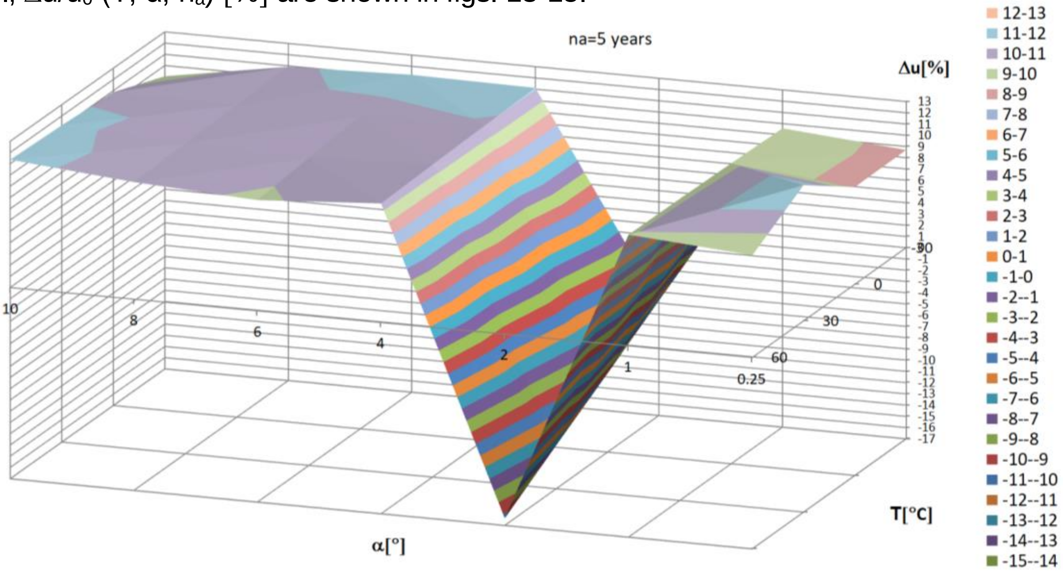


Fig. 13. $\Delta u/u_0$ (T, α, n_a = 5 years) [%]

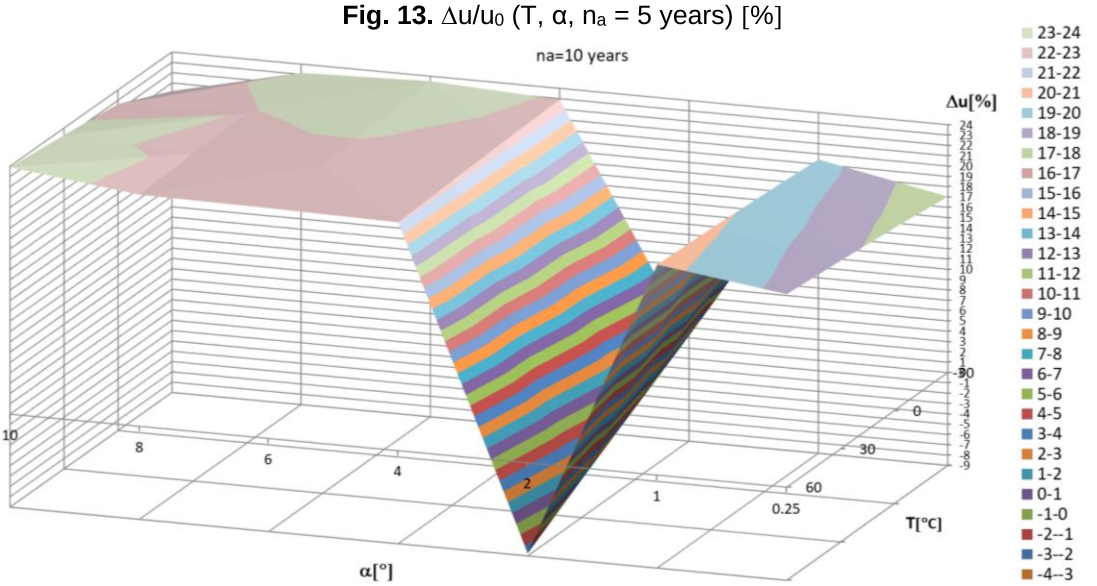


Fig. 14. $\Delta u/u_0$ (T, α, n_a = 10 years) [%]

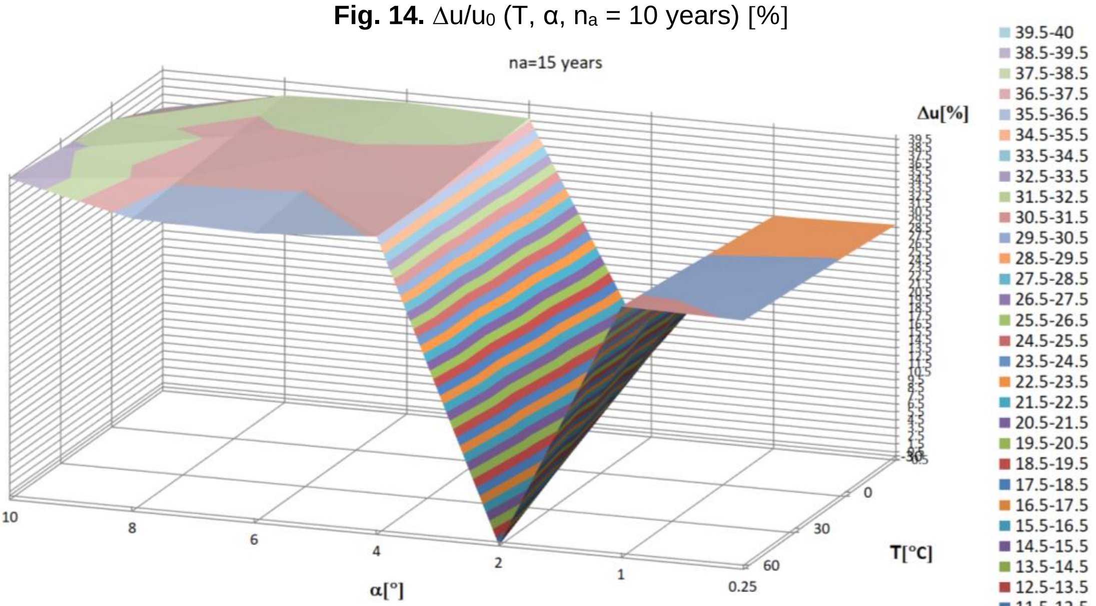


Fig. 15. $\Delta u/u_0$ (T, α, n_a = 15 years) [%]

4. Discussion

The problems of the optimization of LPG storage tanks, due to their diversity and complexity, cannot be described simply or analyzed by one method. Various factors such as safety, reliability, low weight, and economics require appropriately detailed computer analyses, according to the adopted optimization criteria. The adopted parametric model in this analysis is a numerically controlled representation of the design solutions.
Following the results of analyzed numerical cases and the resulting graphs for the deformed bent 3D structure through the method of finite elements it has been found that:
- the determination of the resultant Von Mises stress distributions and resultant linear deformation distributions is necessary for determining the level of performance of the product.
- in the initial state of the exploitation the resultant Von Mises stress distributions and resultant linear deformation distributions have the lower valuest.
- at the end of the exploitation period (n_a = 15 years), there are the highest values of the resultant Von Mises stresses (according to the Table 1); the highest percentage value relative to the initial state $\Delta\sigma/\sigma_0$ = 37.56 [%] is obtained for α = 8° and T = 30 °C (according to the Table 2).
- at the end of the exploitation period (n_a = 15 years), there are the highest values of the resultant linear deformations (according to the Table 3); the highest percentage value relative to the initial state $\Delta u/ u_0$ = 39.49 [%] is obtained for α = 10° and T = 60 °C (according to the Table 4).

5. Conclusions

Product designers and engineers can use these models for an intuitive understanding of the deformed bent 3D structure and as well as computational efficiencies to our solution approaches that affect the competitiveness of the final product.
This construction adopted from feasible constructive variants and determined by the finite element method is characterized by low weight and safety that permits to reduce the production costs. Numerical solutions found by using the finite element method for the parametric 3D model structure are much less time-consuming for many constructional variants and permit to choose the optimal variant. Furthermore, in the analyzed cases the numerical results give a measure of the structural significance of each data set and can assist in the process design, control and product quality evaluation.

References

[1] Ghiţă, C. Mirela, Anton C. Micu, Mihai Ţălu and Ştefan Ţălu. "Shape optimization of a thoroidal methane gas tank for automotive industry." *Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, Hunedoara, Romania*, Tome X, Fascicule 3 (2012): 295-297.
[2] Bică, Marin, Mihai Ţălu and Ştefan Ţălu. "Optimal shapes of the cylindrical pressurized fuel tanks." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 4 (December 2017): 6-17.
[3] Domanski, Jerzy and Zywica Grzegorz. "Optimization of the construction of a pressure tank using CAD/CAE systems." *Technical Sciences* 10 (2007): 41-59. DOI: 10.2478/v10022-007-0006-4.
[4] Ghiţă, C. Mirela, Anton C. Micu, Mihai Ţălu and Ştefan Ţălu. "Shape optimization of vehicle's methane gas tank." *Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, Hunedoara, Romania*, Tome X, Fascicule 3 (2012): 259-266.
[5] Izaki, T, Y. Sueki, T. Mizuguchi and M. Kurosaki. "New steel solution for automotive fuel tanks." *Rev. Met. Paris*, 102(9) (2005): 613-619.
[6] Ghiţă, C. Mirela, Anton C. Micu, Mihai Ţălu, Ştefan Ţălu and Ema I. Adam. "Computer-Aided Design of a classical cylinder gas tank for the automotive industry." *Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, Hunedoara*, *Romania*, Tome XI, Fascicule 4 (2013): 59-64.
[7] Düren, Tina, Sarkisov Lev, Yaghi M. Omar and Snurr Q. Randall. "Design of new materials for methane storage." *Langmuir*, 20(7) (2004): 2683-2689. DOI: 10.1021/la0355500.
[8] Ghiţă, C. Mirela, Anton C. Micu, Mihai Ţălu and Ştefan Ţălu. "3D modelling of a gas tank with reversed end up covers for automotive industry.", *Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, Hunedoara*, *Romania*, Tome XI, Fascicule 3 (2013): 195-200.

[9] Ghiţă, C. Mirela, Ştefan C. Ghiță, Ştefan Ţălu and Simona Rotaru, “Optimal design of cylindrical rings used for the shrinkage of vehicle tanks for compressed natural gas.“ *Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, Hunedoara*, Tome XII, Fascicule 3 (2014): 243-250.
[10] Gopi, Gemya and Beena B R. “Finite Element Analysis of GFRP LPG cylinder.” *IJEDR*, 3(4) (2015): 642-649.
[11] Vintilă, Daniela, Mihai Ţălu and Ştefan Ţălu. “The CAD analyses of a torospheric head cover of a pressurized cylindrical fuel tank after the crash test.” *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 4 (December 2017): 57-66.
[12] Ţălu, Mihai. "The influence of the corrosion and temperature on the Von Mises stress in the lateral cover of a pressurized fuel tank." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 4 (December 2017): 89-97.
[13] Abbasi, Erfan and Mohammadreza Salmani. “Investigation and improvement of corrosion resistance in automotive fuel tank.” *Advanced Materials Research*, 41-42 (2008): 491-497.
[14] Ţălu, Ştefan and Mihai Ţălu. "The influence of deviation from circularity on the stress of a pressurized fuel cylindrical tank." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 4 (December 2017): 34-45.
[15] Multhoff, Jorg. "Integrated structural analysis of composite pressure vessels: a design tool." ASME 2016 Pressure Vessels and Piping Conference, vol. 6A: Materials and Fabrication, Vancouver, British Columbia, Canada, July 17–21, 2016. Paper no. PVP2016-63603, pp. V06AT06A045; 10 pages. DOI: 10.1115/PVP2016-63603.
[16] Ţălu, Mihai and Ştefan Ţălu. "Design and optimization of pressurized toroidal LPG fuel tanks with variable section." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 1 (March 2018): 32-41.
[17] Patel, Pankit and Jaypalsinh Rana. "Design & optimization of LNG-CNG cylinder for optimum weight." *IJSRD - International Journal for Scientific Research & Development*, 1(2) (2013): 282-286.
[18] Ţălu, Mihai and Ştefan Ţălu. "Analysis of temperature resistance of pressurized cylindrical fuel tanks." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 1 (March 2018): 6-15.
[19] Jani, J. Dipakkumar, Gupta M. Kumar and Trivedi R R. "Shape optimization of externally pressurized thin-walled end dome closures with constant wall thickness of cylinder vessel with help of Bezier curve." IJESIT, 2(3) (2013): 466-475, 2013.
[20] Ţălu, Ştefan and Mihai Ţălu. "Algorithm for optimal design of pressurized toroidal LPG fuel tanks with constant section described by imposed algebraic plane curves." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 2 (June 2018): 14-21.
[21] Hirz, Mario, Dietrich Wilhelm, Gfrerrer Anton and Lang Johann. "Integrated Computer-Aided Design in Automotive Development." Springer-Verlag Berlin Heidelberg, 2013. DOI: 10.1007/978-3-642-11940-8.
[22] Ţălu, Mihai and Ştefan Ţălu. "The optimal CAD design of a 3D hexagonal toroid with regular hexagonal cross-section used in manufacturing of LPG storage tanks." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 2 (June 2018): 49-56.
[23] Gavačová, Jana, Vereš Miroslav and Grznár Matus. "Computer Aided Generative Design of automotive shaped components." *Acta Tehnica Corviniensis - Bulletin of Engineering*, Tome VII, Fascicule 2 (2014): 19-22.
[24] Ţălu, Mihai and Ştefan Ţălu. "The influence of corrosion and temperature variation on a CNG storage tank with a combined form consisting of a torus and a sphere." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 4 (December 2019): 93-104.
[25] Balas, O. Maria, Radu Balas and Vasile C. Doicin. "Study regarding the influence of the fuel tank constructive characteristics on slosh-noise effect." *Applied Mechanics and Materials*, 834 (2016): 22-27.
[26] Oprițoiu, Petre. PhD thesis: *Cercetări privind transferul termic și a pierderilor de presiune la un schimbător de căldură din metal poros (Research on heat transfer and pressure losses through porous metal heat exchanger)*, Technical University of Cluj-Napoca, Romania, Faculty of Mechanics, 2014.
[27] Oprițoiu, Petre. “Fluid flow and pressure drop simulation in aluminium foam heat exchanger”, *Acta Tech. Napocensis: Civil Eng. & Arch*., no. 50 (2007): 101-112.
[28] Oprițoiu, Petre. "Heat transfer performance analysis in porous heat exchanger." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 3 (August 2015): 32-41.
[29] Oprițoiu, Petre. "Rans simulation of combined flow and heat transfer through open-cell aluminum foam heat sink." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 3 (August 2013): 15-25.
[30] Oprițoiu, Petre. "Prediction of turbulent flow using upwind discretization scheme and k-ε turbulence model for porous heat exchanger." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 2 (June 2016): 88-97.

[31] Oprițoiu, Petre. "Validation of porous heat exchanger simulation model", Proceedings of HERVEX 2014, "International Conference and Exhibition of Hydraulics & Pneumatics", Călimăneşti, 5-7 noiembrie 2014, vol. 21, pp. 208-216, ISSN 1454-8003.
[32] Ţălu, Mihai and Ştefan Ţălu. "Optimal design of a CNG storage tank with a combined form consisting of a torus and a sphere." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 4 (December 2019): 73-82.
[33] Chen, Chin-Jung and Usman Mohammad. "Design optimisation for automotive applications." *International Journal of Vehicle Design*, 25(1) (2001). DOI: 10.1504/IJVD.2001.001912.
[34] Ţălu, Mihai and Ştefan Ţălu. "The influence of corrosion and temperature variation on the minimum safety factor of a 3D hexagonal toroid with regular hexagonal cross-section used in manufacturing of LPG storage tanks." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 3 (August 2018): 16-25.
[35] Ţălu, Ştefan and Mihai Ţălu. "The influence of corrosion and pressure variation on the minimum safety factor of a 3D hexagonal toroid with regular hexagonal cross-section used in manufacturing of LPG storage tanks." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 3 (August 2018): 39-45.
[36] Kim, Jaenam, Bo-mi Son, B.S. Kang, Sangmoon Hwang and Hoon-Jae Park. "Comparison stamping and hydro-mechanical forming process for an automobile fuel tank using finite element method." *J. Mater. Process. Technol.*, 153–154: (2004) 550-557. DOI: 10.1016/j.jmatprotec.2004.04.048.
[37] Ţălu, Mihai and Ştefan Ţălu. "Study of temperature–corrosion–torsion affecting factors on the shape of a toroidal LPG tank using the finite element method." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 1 (March 2020): 21-32.
[38] Ţălu, Ştefan and Mihai Ţălu. "Numerical analysis of the influence of uniaxial compression loads on the shape of a toroidal LPG tank." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 1 (March 2020): 47-58.
[39] Ţălu, Mihai and Ştefan Ţălu. "Stress and deformation analysis under bending and torsional loads of a toroidal LPG tank based on the finite element analysis." *Magazine of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics (HIDRAULICA)*, no. 1 (March 2020): 88-101.
[40] Ţălu, Ştefan and Mihai Ţălu. "Constructive CAD variants of toroidal LPG fuel tanks used in automotive Industry." *Advances in Intelligent Systems Research,* vol. 159 (2018): 27-30. DOI: 10.2991/mmsa-18.2018.7.
[41] Ţălu, Mihai and Ştefan Ţălu. "3D geometrical solutions for toroidal LPG fuel tanks used in automotive industry." *Advances in Intelligent Systems Research,* vol. 151 (2018): 189-193. DOI: 10.2991/cmsa-18.2018.44.
[42] Ţălu, Mihai and Ştefan Ţălu. "Optimal engineering design of a pressurized paralepipedic fuel tank." *Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, Hunedoara, Romania*, Tome XVI, Fascicule 2 (2018): 193-200.
[43] Ţălu, Ştefan and Mihai Ţălu. "The Influence of corrosion on the vibration modes of a pressurized fuel tank used in automotive industry." *DEStech Transactions on Materials Science and Engineering,* (2018): 1-6. DOI: 10.12783/dtmse/icmsa2018/20560.
[44] Nedelcu, Dorian. *Proiectare și simulare numerică cu SolidWorks*. *(Digital Prototyping and Numerical Simulation with SolidWorks)*. Timişoara, Eurostampa Publishing house, 2011.
[45] Niţulescu, Theodor and Ştefan Ţălu. *Aplicaţii ale geometriei descriptive şi graficii asistate de calculator în desenul industrial. (Applications of descriptive geometry and computer aided design in engineering graphics).* Cluj-Napoca, Risoprint Publishing house, 2001.
[46] Bîrleanu, Corina and Ştefan Ţălu. *Organe de maşini. Proiectare şi reprezentare grafică asistată de calculator. (Machine elements. Designing and computer assisted graphical representations).* Cluj-Napoca, Victor Melenti Publishing house, 2001.
[47] Ţălu, Ştefan. *AutoCAD 2017*. Cluj-Napoca, Napoca Star Publishing house, 2017.
[48] Ţălu, Ştefan and Mihai Ţălu. "CAD generating of 3D supershapes in different coordinate systems." *Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, Hunedoara, Romania*, Tome VIII, Fascicule 3 (2010): 215-219.
[49] Ţălu, Ştefan and Mihai Ţălu. "A CAD study on generating of 2D supershapes in different coordinate systems." *Annals of Faculty of Engineering Hunedoara - International Journal of Engineering, Hunedoara, Romania*, Tome VIII, Fascicule 3 (2010): 201-203.
[50] *** Autodesk AutoCAD 2020 software.
[51] *** SolidWorks 2020 software.