Structural Strength Analysis of Plastic Fuel Tank under Pressure Loading using FEA

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Abstract - *Fuel Tank is the container from which an engine draws its fuel. Plastic fuel tanks have replaced metal fuel tanks because of its light weight, more durability, improved compartment space utilization, increased convenience, cost-efficiency and safety. The current prototype of fuel tank is modeled in CATIA V5. The fuel tank is then meshed effectively in Hypermesh. The fuel tank is then analyzed in ANSYS. Pressure analysis of basic fuel tank model is carried out to determine the structural strength. The basic fuel tank model is analyzed again by introducing NGTS (Next Generation Tank Stiffner), which reduced the maximum displacement and von misses stress at critical location.*

Key Words: Plastic fuel tank, Structural strength, Pressure analysis, Hypermesh, NGTS

1. INTRODUCTION

Fuel Tank is the container from which an engine draws its fuel. Usage of Plastic (high-density polyethylene HDPE) as a fuel tank material besides metals for construction has a long term potential because of its advantageous properties such as being light weight than most metals, flexible in manufacturing, corrosion resistant, offer improved compartment space utilization, more durable, cost-efficiency and safety due to being non-explosive.

2. Literature survey

Prof. A. P. Ganorkar[1] and Mohd Shadab Sheikh[2] have made a Review on HDPE Fuel Tank for Maruti Alto Car in which an Alternative for Conventional metal has been used extensively for manufacture of almost all the part of the vehicle but of late the Equipment manufacturers for looking for alternate viable options specifically plastic against metal which would improve the performance criteria due to reduced weight and cost [1]. Pavol Lengvarsky[1] and Miroslav Pastor[2] presented paper devoting to the static analysis water tank. Three different thicknesses of walls of the water tank are proposed and the structure is analyzed in order to find appropriate stress and deformation states of structure [2]. H. V. Chavan[1] and Prof. S. R. Gawade[2] in their study on Design and Analysis of Plastic Fuel Tank for Three Wheeler CNG Passenger Vehicle where the fuel tank is used in automobile industries to carry fuel and supply fuel to the engine via fuel filter, fuel pump. The aim of the project was to design plastic fuel tank for three wheeler vehicles. The study aimed at to make a new design of plastic fuel tank for three wheeler vehicles in order to reduce production cost of fuel tank and make most secure and safe fuel tank [3]. P. Laxminagaprasad[1], P. Shashidar[2] and Rajeev Achrya[3] have presented a study on Design and optimization of HTV fuel tank assembly by finite element analysis where they have used fuel tank made of steel because of their high strength and durability [4]. Gajendra G[1], Prakasha A M[2] and DR. Noor ahmed[3] Carried out design and optimization of HTV fuel tank assembly by finite element analysis and presented study methodology to improve the first natural frequency of a fuel tank brackets for heavy duty vehicles using FEA. To improve the performance of the fuel tank bracket series of design iteration was carried out by taking the account of base model structure. [5]

2.1 Problem statement

1. There is not much work, that is available for structural analysis of plastic fuel tanks, which is subjected to various pressure and vacuum conditions.

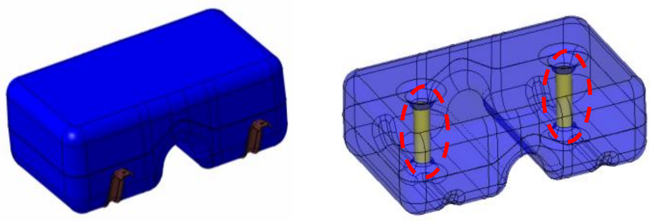
2. Tank safety is the prime criteria, as it contains flammable fluid. So, reducing the deformation and stress-strain values by any means will be beneficial.

3. Use of any kind of Stiffners in the tank would reduce the deformation in the tank.

3. Modeling of fuel tank

CATIA developed by French company Dassault systems is the design software used to model the current prototype of the Fuel tank. The tank is held in position by bolting the straps to the vehicle chassis. The current tank is a saddle type of fuel tank having a filling capacity of 81 litres (without NGTS) and 80 litres (with NGTS). NGTS (Next Generation Tank Stiffner) is the welded tank stiffner which reduces the deformation of the tank under high pressure conditions. It also withstands the pressure requirements needed for hybrid applications and eliminating the need for steel support.

NGTS

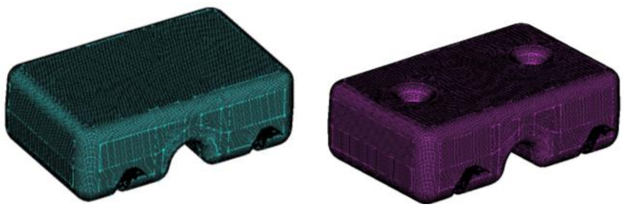


(a) (b)

Fig -3.1: Fuel Tank without NGTS (a)

Fuel Tank with NGTS (b)

The designed fuel tank is saved as CATPART, which is used as the input file for the preprocessing. The fuel tanks are then meshed effectively in Hypermesh as shown below.



(c) (d)

Fig -3.2: Fuel Tank meshed without NGTS (c)

Fuel Tank meshed with NGTS (d)

4. Structural analysis

Structural analysis is the determination of the effects of loads on physical structures and their components. The Current work focuses on Pressure Analysis of Plastic fuel tanks. The state of violent mixture of air and fuel can cause internal pressure increment during refueling of an automobile fuel tank. The multiphase or multi-component flow enters the tank where the liquid falls to the bottom of the tank and the gasses are fulfilling the vapor space of the automobile fuel tank causing the additional pressure inside the fuel tank. Gasoline expands in volume as it warms up and shrinks in volume as it cools down that will relieve both vacuum and pressure. As Vehicle drains fuel from the fuel system, fresh air must come into the gas tank to take its place. A small amount of suction is necessary to ensure an uninterrupted flow of fuel. Excess suction leads to a vacuum in the tank.

Table -1: Material Properties of Tank and Strap

	Material	Thickness (mm)	Youngs Modulus (MPa)	Density (kg/m^3)
Fuel Tank	COEX HDPE (Non-Linear)	5.5	850	946
Strap	Steel HX340	2	206050	7860

4.1 Displacement

The deformation of the Fuel tank without NGTS for a pressure of 22KPa at 23^{0}C is analyzed and the nodal deformations are as shown

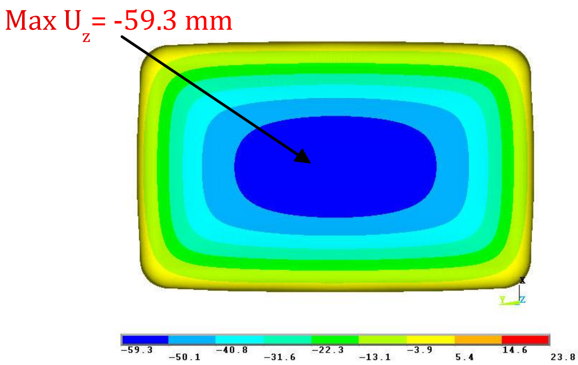


Fig - 4.1: U_z-Deformation [mm] – Tank Top

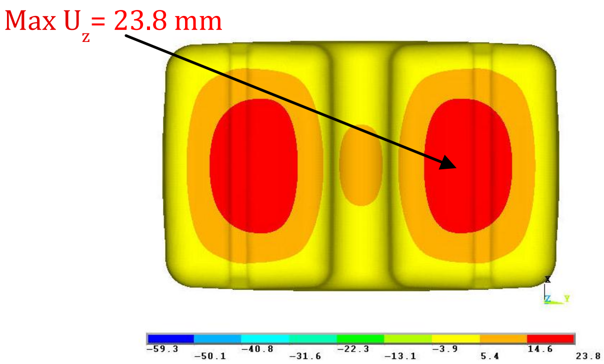


Fig - 4.2: U_z-Deformation [mm] – Tank Bottom

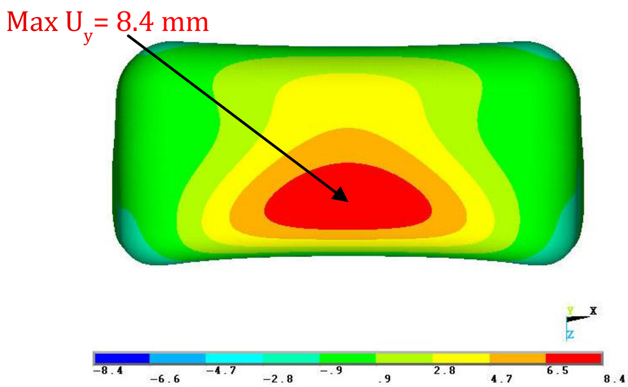


Fig - 4.3: U_y-Deformation [mm] – Tank Right

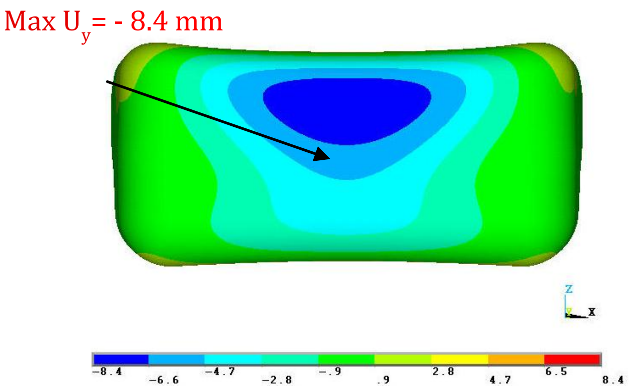


Fig - 4.4: U_y-Deformation [mm] – Tank Left

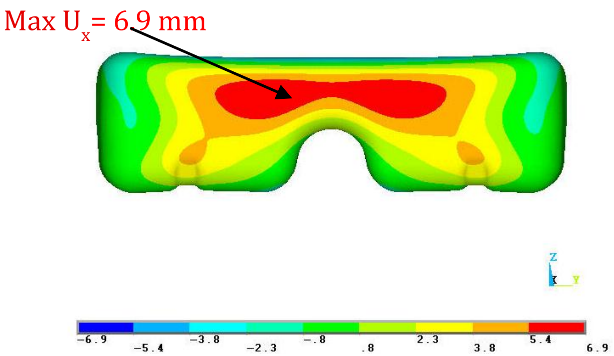


Fig - 4.5: U_x-Deformation [mm] – Tank Rear

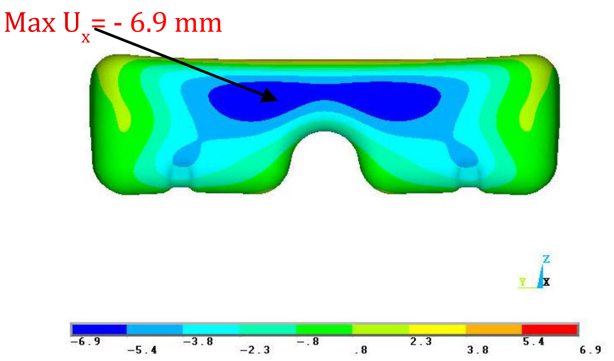


Fig - 4.6: U_x-Deformation [mm] – Tank Front

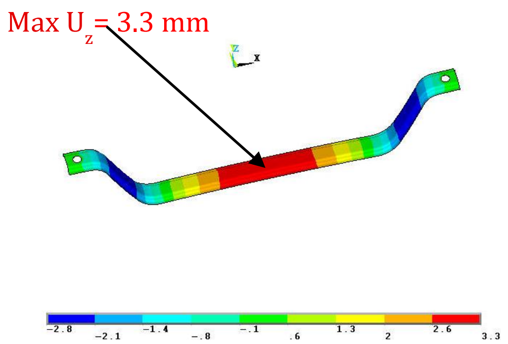


Fig - 4.7: U_y-Deformation [mm] – Right strap

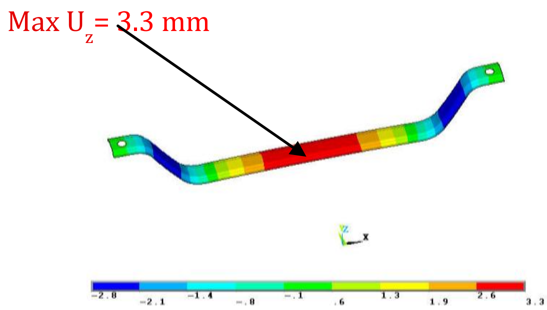


Fig - 4.8: U_y-Deformation [mm] – Left strap

The deformation of the Fuel tank with NGTS for a pressure of 22KPa at 23^{0}C is analyzed and the nodal deformations are as shown

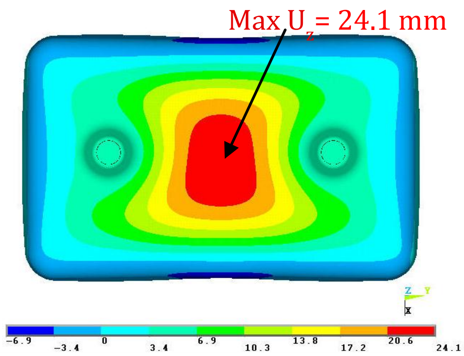


Fig - 4.9: U_z-Deformation [mm] – Tank Top

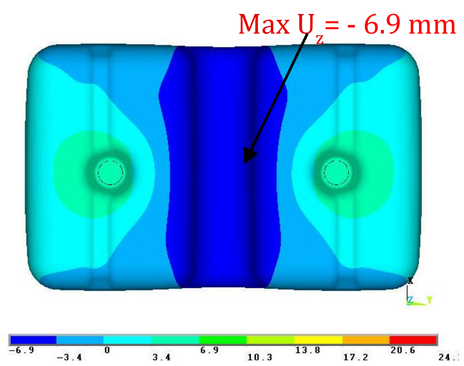


Fig - 4.10: U_z-Deformation [mm] – Tank Bottom

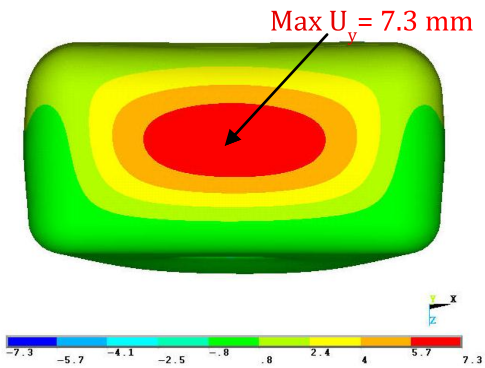


Fig - 4.11: U_y-Deformation [mm] – Tank Right

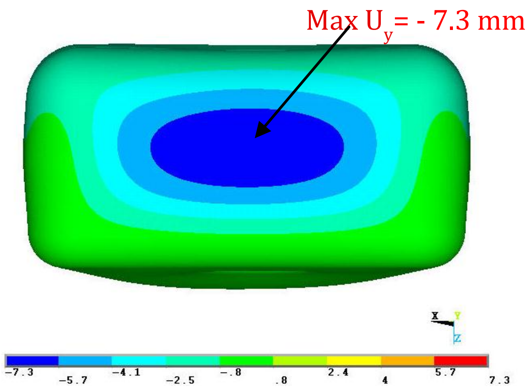


Fig - 4.12: U_y-Deformation [mm] – Tank Left

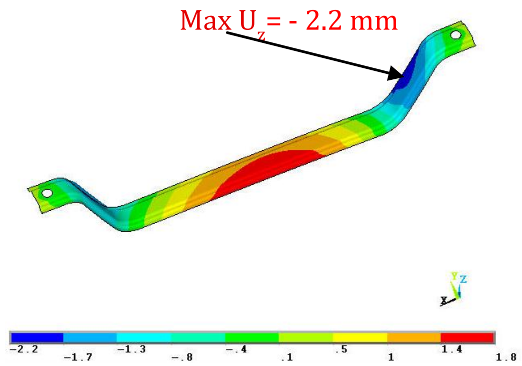


Fig - 4.15: U_y-Deformation [mm] – Right strap

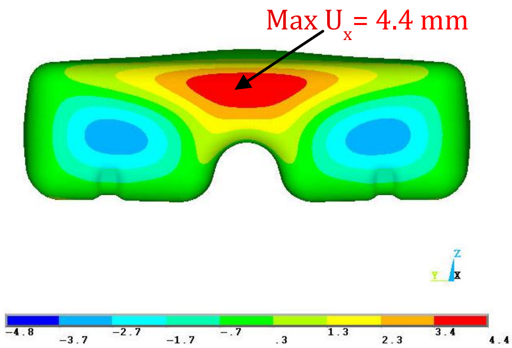


Fig - 4.13: U_x-Deformation [mm] – Tank Rear

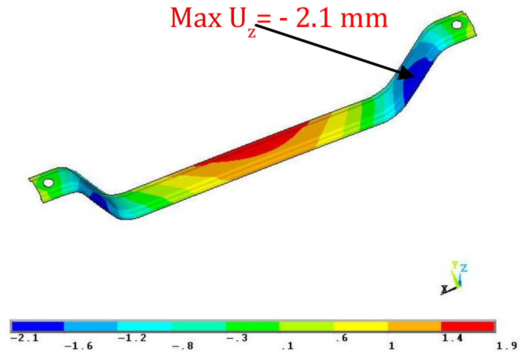


Fig - 4.16: U_y-Deformation [mm] – Left strap

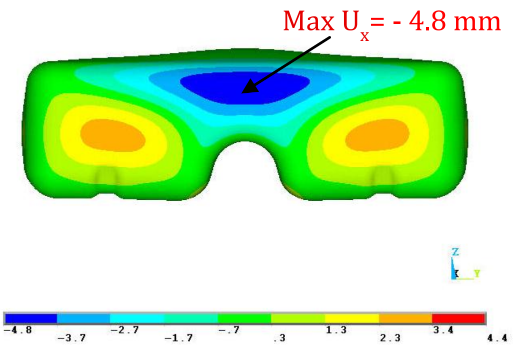


Fig - 4.14: U_x-Deformation [mm] – Tank Front

Table -2: Tank and Strap deformations

Job	Geometry	Tank deformation Uz in [mm]		Tank deformation Uy in [mm]		Tank deformation Ux in [mm]		Right Strap deformation Uz in [mm]		Left Strap deformation Uz in [mm]	
		Top	Bot	Left	Right	Front	Rear	Min.	Max.	Min.	Max.
1	Fuel Tank without NGTS	-59.3	23.8	- 8.4	8.4	- 6.9	6.9	-2.8	3.3	-2.8	3.3
2	Fuel Tank with NGTS	-6.9	5.7	- 7.3	7.3	- 4.8	4.8	-2.2	1.8	-2.1	1.9

4.2 Stress and strain

Von Mises stress is used to check whether the design is safe or not. The design will fail, if the maximum value of Von Mises stress induced in the material is more than strength of the material.

The von Mises stress and strain for fuel tank without NGTS and von Mises stress for strap for Pressure loading is observed as

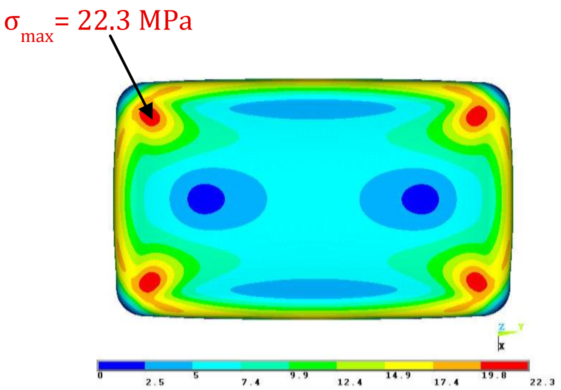


Fig - 4.17: Von Mises Stress [MPa]- Tank Top

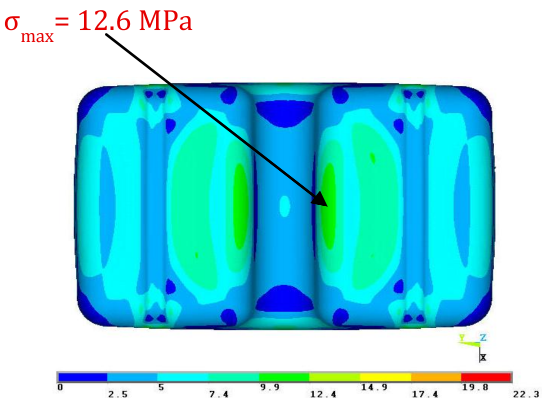


Fig - 4.18: Von Mises Stress [MPa]- Tank Bot

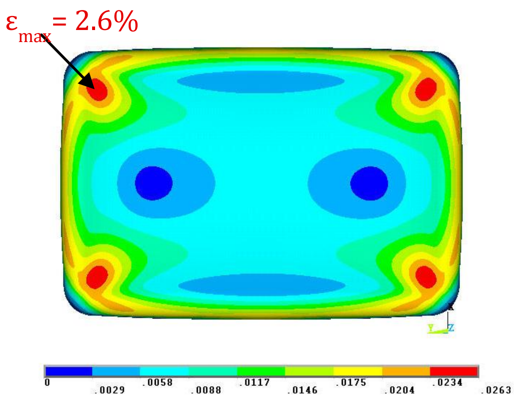


Fig - 4.19: Von Mises Strain [-]- Tank Top

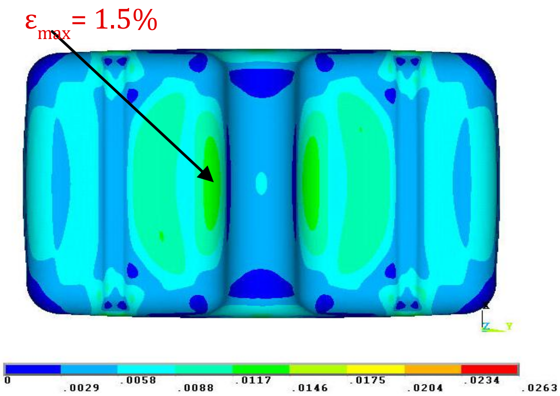


Fig - 4.20: Von Mises Strain [-]- Tank Bot

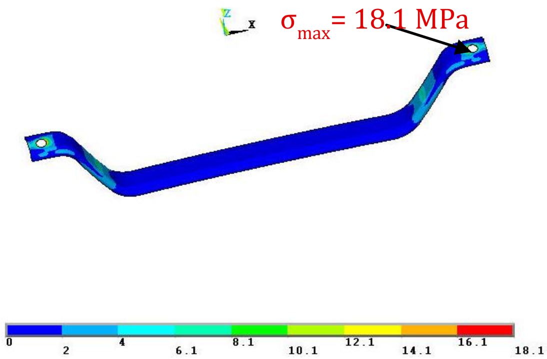


Fig - 4.21: Von Mises Stress [MPa]- Right strap

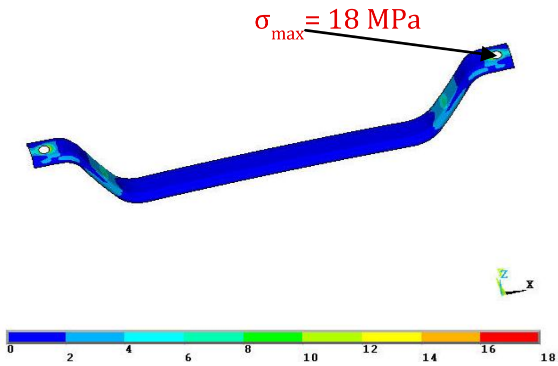


Fig - 4.22: Von Mises Stress [MPa]- Left Strap

The Von Mises stress also indicates whether the given design will withstand the given load condition. The allowable stress value for HDPE is 29.5 MPa[7] and the allowable strain value is 3%.[8] For Steel HX 340, the allowable stress value is 340MPa.[9]

The von Mises stress and strain for fuel tank with NGTS and von Mises stress for strap for Pressure loading is observed as

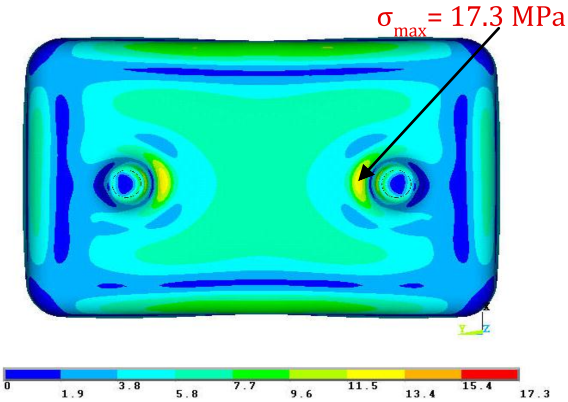


Fig - 4.23: Von Mises Stress [MPa]- Tank Top

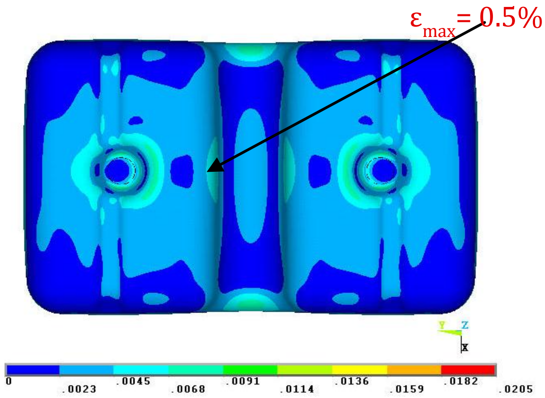


Fig - 4.26: Von Mises Strain [-]- Tank Bot

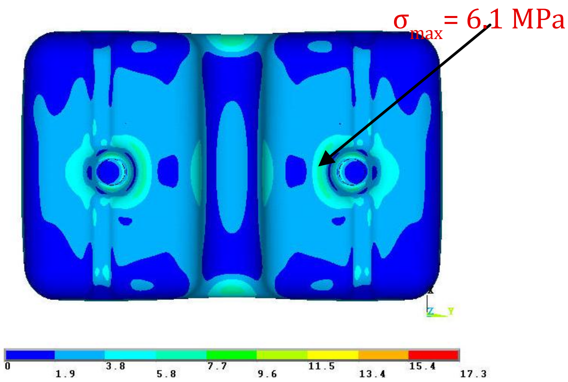


Fig - 4.24: Von Mises Stress [MPa]- Tank Bot

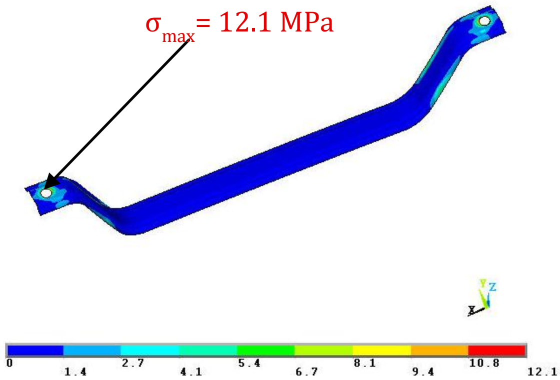


Fig - 4.27: Von Mises Stress [MPa]- Right strap

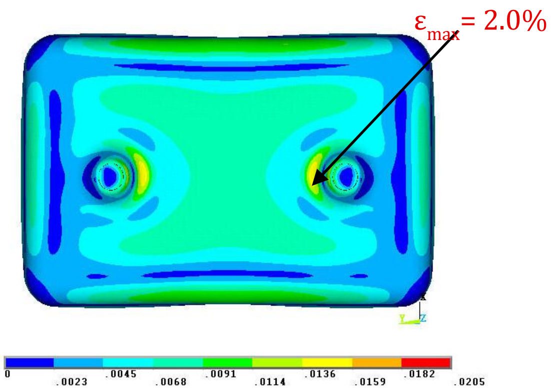


Fig - 4.25: Von Mises Strain [-]- Tank Top

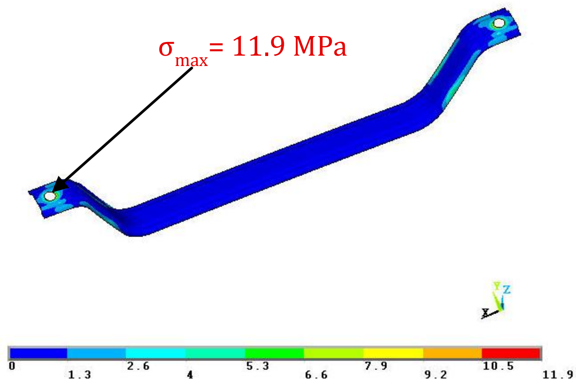


Fig - 4.28: Von Mises Stress [MPa]- Left Strap

Table -3: Stress and Strain

Job	Geometry	Tank Von Mises stress in [MPa]	Tank Von Mises Strain in %	Strap Von Mises stress in [MPa]	
				Right Strap	Left Strap
1	Fuel Tank without NGTS	2.3	2.6	18.1	18
2	Fuel Tank with NGTS	7.3	2.0	12.1	11.9

5. Conclusion

The deformations in the tank are reduced after assembling Next Generation Tank Stiffner (NGTS) within the tank. Nodal Deformations on the top side of the tank is maximum in Pressure condition (i.e., Deformation in Uz is 59.3mm) is reduced drastically after use of NGTS. (Reduced to 6.9mm in Uz). High deformation is observed on tank top surface wall without NGTS because of more surface area on the tank top side than the tank top surface with NGTS. Tank stresses are found to be below the critical limit (29.5MPa) and strap stresses are found to be below the critical limit (340MPa) for all load cases. Tank strains does not exceed the critical limit of 3% for all load cases at 23^0C.

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