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BSVI: Plastic fuel tank design challenges and improvements proposed with structural strength analysis & pressure loading using FEA

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Abstract
In commercial/passenger vehicles the fuel tank is major vehicle component to which major attention is given while vehicle development. In conventional design, the fuel tanks are made up of sheet metal which are robust in design but increase the vehicle kerb weight. In new vehicles plastic fuel tanks are introduced to replace the sheet metal fuel tanks. Plastic tanks have key advantage over sheet metal tanks in terms of weight, flexibility to achieve size and shape to suit critical packaging in the vehicle. Also, the plastic tanks have more corrosion resistance and have more crash resistance. The tank in this paper is HDPE (High density polyethylene) material and analysed in ANSYS for structural strength of plastic tank when subject to various operational conditions which it experience during life of the plastic fuel tank.

Keywords: FEA Fuel tank, Structural analysis fuel tank, fuel tank design, plastic fuel tank, CAE simulation plastic tank

Introduction

The fuel tank is used to store the fossil fuel and allow fuel to propel to the pump. Fuel tank should satisfy below functions

- The fuel tank able to storage the fuel of given quality of fuel. It should avoid leakage and limit evaporative emissions.
- The fuel tank should be filled in a secure way, without sparks.
- Fuel tank should provide the method to check fuel level.
- The tank should release the vapour to limit the pressure inside the tank by venting
- Supply to the fuel pump (to combustion chamber)
- Anticipate potentials for damage and provide safe survival potential.

Plastic fuel tank made by HDPE material for Passenger vehicle. Tank assembly mount on the vehicle chassis with the help of bolting and metal strip. Strip both sides bolted on chassis.

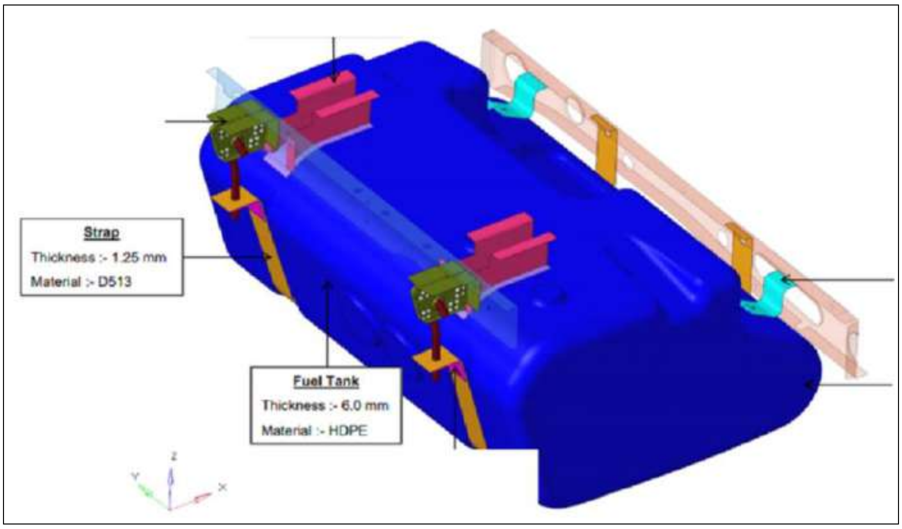

Fig 1: Plastic Fuel Tank mounting details

Background/History: -New design of plastic fuel and mounting bracket is proposed as replacement of metallic tank for BSVI application.

Problem Statement: –Plastic fuel tank is novel concept hence there is lack of study on Structure analysis considering different pressure and vacuum situations for Small Commercial vehicles. Fuel tank is critical part of automobile as it contains combustible fuel, so its safety is utmost important. As there is shortage of study on structure analysis of plastic fuel tank any method which will lower deformation and stress strain value will be useful.

Objective of analysis
To predict the strength performance of plastic fuel tank 60Ltrs & mounting bracket of Winger BSVI VAN application as per OEM standard

Analysis type
FE analysis is carried out as per linear static analysis, Non-linear static analysis & Fatigue analysis

Digital Mode of fuel tank:
Plastic fuel tank solid part model made in Creo (Design Tool). Tank assembly mount on vehicle chassis with the help of bolting & metal strip. Plastic fuel tank design for up to 60Ltrs fuel filling capacity.

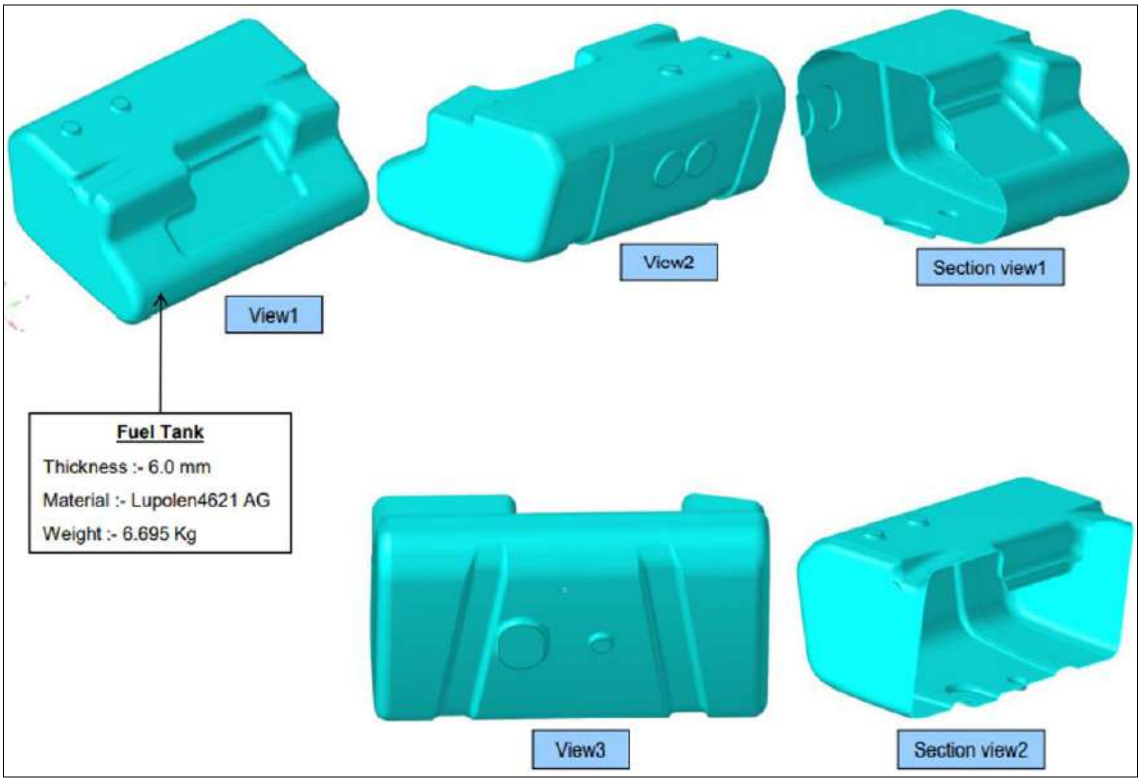

Fig 2: Plastic Fuel Tank

Fuel tank test conditions
Plastic Fuel tank test conditions and acceptance criteria for Winger BSVI AS PER OMS STD.

Test loading condition

- **Vacuum holding capacity test**
  Vacuum up to 250 mm of Hg
  (-0.333 bar) is applied
- **Pressure test – Leakage test**
  Internal pressure of 0.3 bar is applied
- **Pressure test – Vacuum cycle test**
  Pressure is applied in cycles of +4.6 KPa (+0.046 bar) to -4.6 KPa (-0.046 bar)
- **Over Pressure test**
  Internal pressure of 1.3 bar is applied
- **Impulse Pressure test**
  Internal pressure 0MPa to 0.03 MPa (0.3 bar)
- **Vibration test**
  Analysis carried out as per JIS1601- 1995

Criteria of acceptance

- **Vacuum holding capacity test**
  The tank shall not collapse till 250 mm of Hg (-0.333 bar)
- **Pressure test – Leakage test**
  The tank shell must not crack or leak
- **Pressure test – Vacuum cycle test**
  No cracks or permanent deformation are permitted for 10,000 cycles of test load
- **Over Pressure test**
  The tank shell must not crack or leak
- **Impulse Pressure test**
  Tank should pass 1,00,00 cycles without crack formation
- **Vibration test**
  There shall be no leakage and structural failure on the tank.

CAE converted acceptance criteria

- **Vacuum holding capacity test**
  No objective target to detect collapse in terms of allowable deformation CAE results show likely deformation at different loading, acceptance to be decided based on deformation along with test engineer. Plastic strains < 80% of percentage elongation at break
- **Pressure test – Leakage test**
  Plastic strains < 80% of percentage elongation at break.
- **Pressure test – Vacuum cycle test**
  Parent material fatigue: Minimum estimated life >= 3.0E+04 cycles to ensure no cracking after test Seam weld fatigue: Minimum estimated life >= 1.0E+05 cycles to ensure no cracking after test
- **Over Pressure test**
  Plastic strains < 80% of percentage elongation at break
- **Impulse Pressure test**
  Max life > 1,00,000
- **Vibration test**
  Maximum Stress should be below endurance limit of the material.

Test loading condition

- Vacuum holding capacity test
- Pressure test – Leakage test
- Pressure test – Vacuum cycle test
- Over Pressure test
- Impulse Pressure test
- Vibration test

Criteria of acceptance

- **Vacuum holding capacity test**
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  The tank shell must not crack or leak
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  No cracks or permanent deformation
- **Over Pressure test**
  The tank shell must not crack or leak
- **Impulse Pressure test**
  Tank should pass pressure cycles without crack formation
- **Vibration test**
  There shall be no leakage and structural failure on the tank.
- **Structural analysis**
  Plastic fuel tank of Structural analysis is the determination of the effects of loads on physical structures and their components. Base design focuses on Pressure Analysis of Plastic fuel tanks. To improve the performance of the fuel tank bracket series of design iteration was carried out by taking the account of base model structure.
  In this paper design, improvement for plastic fuel tank and mounting strap assembly is done by using finite element analysis and presented the study methodology to improve the first natural frequency of fuel tank and brackets for light duty vehicles using FEA. In fuel tank, fuel settles at the bottom and due to evaporation gases apply pressure on internal wall of fuel tank. As fluid cools and warms its volume changes, which relives both pressure and vacuum.

Carried out study on base design and further improvements are done two iterations. Material thickness and mounting strap thickness change to meet the required FOS.

FE model & Boundary Condition – Bolt Preload Analysis (Tightening torque): -

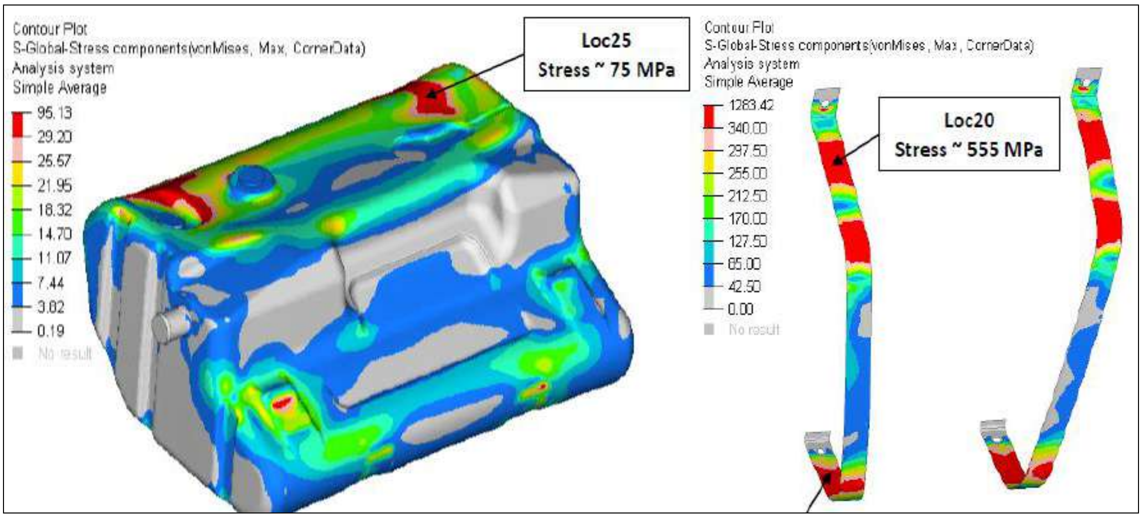


Fig 3: FE model & boundary condition – Bolt preload analysis

Bolt Pre-Load Analysis

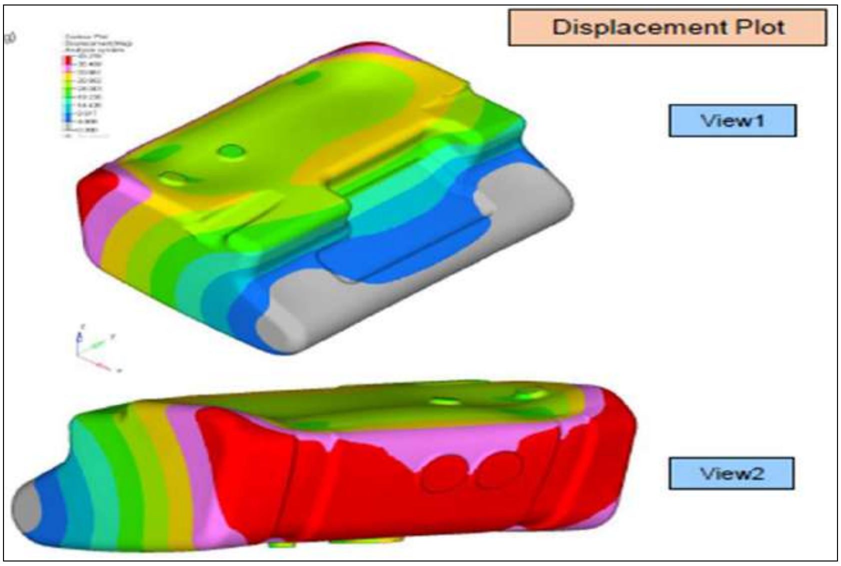


Fig 4: Bolt pre load analysis

Bolt Preload Analysis on Fuel Tank

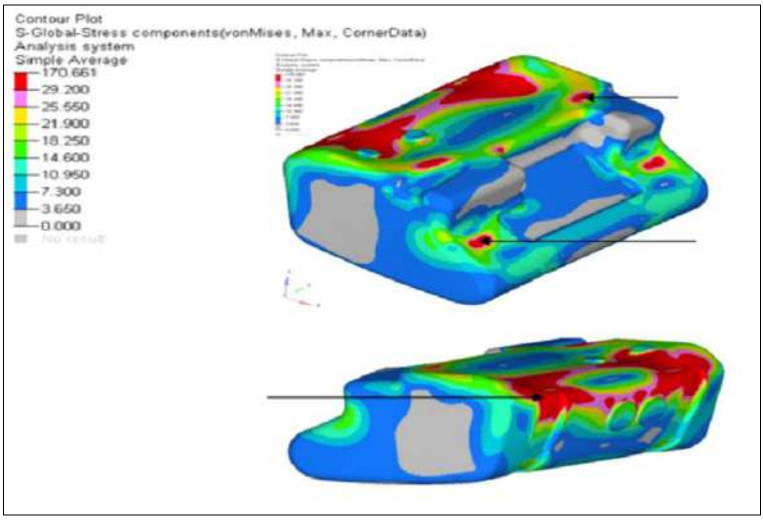


Fig 5: Bolt preload analysis on Fuel tank

Bolt Preload Analysis on Strip and Bracket's

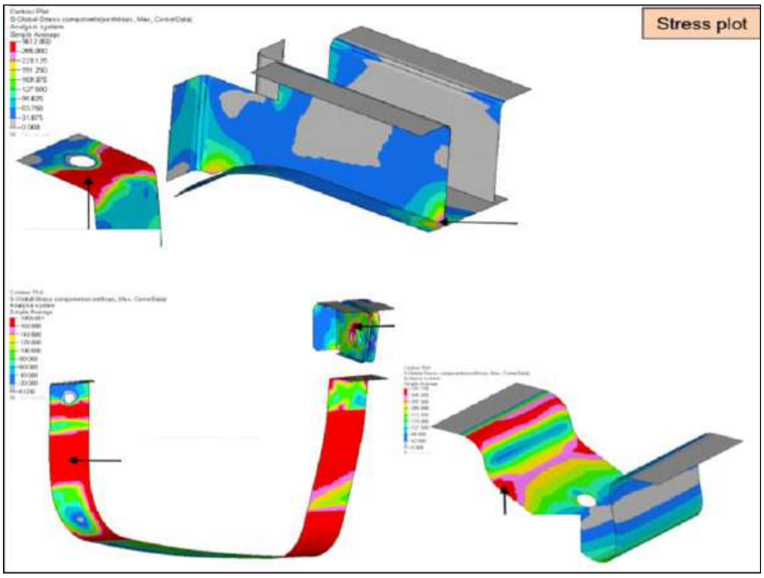


Fig 6: Bolt preload analysis on strip and bkt's

FE model & boundary condition of Base design For Dynamic analysis as per JIS
Resonance frequency detection test on base design (75% fuel filled condition): -

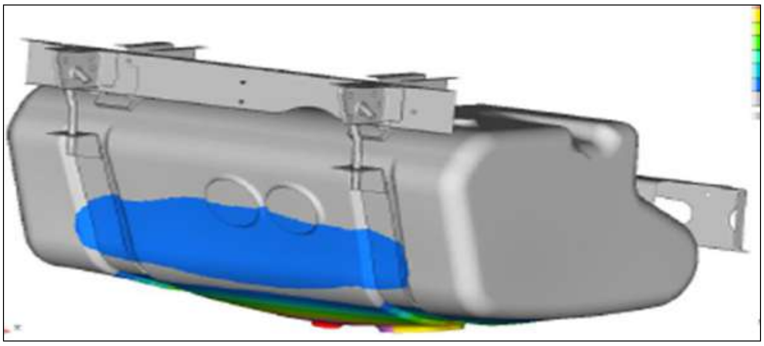


Fig 7: Resonance frequency detection test on base design

Resonance frequency detection test on concept 1

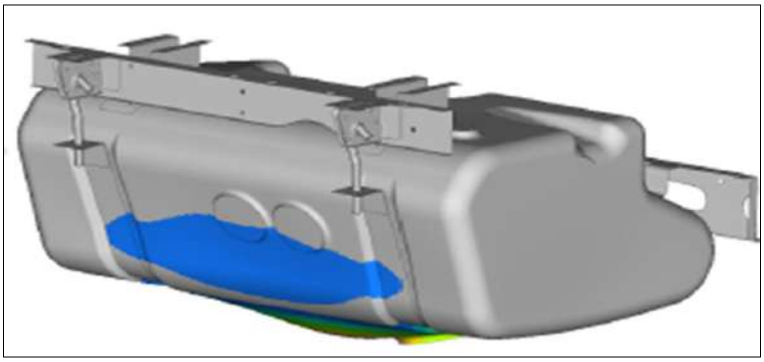


Fig 8: Resonance frequency detection test on concept 1 (75% fuel filled condition)

Vibration endurance test at 33 Hz (75% fuel filled condition)

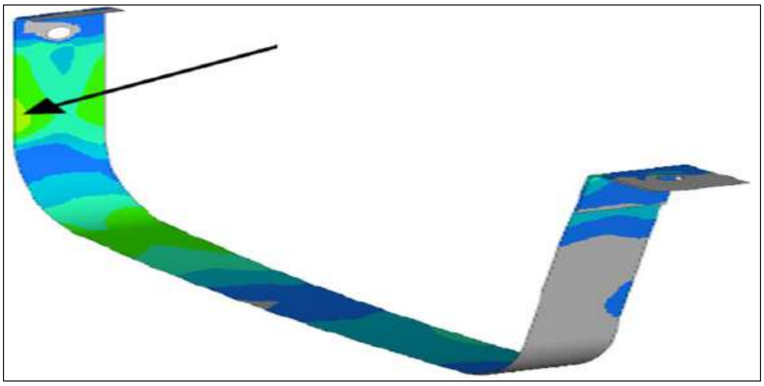


Fig 9: Vibration endurance test at 33 Hz (75% fuel filled condition)

FE Result Concept 2 as per OEM standard

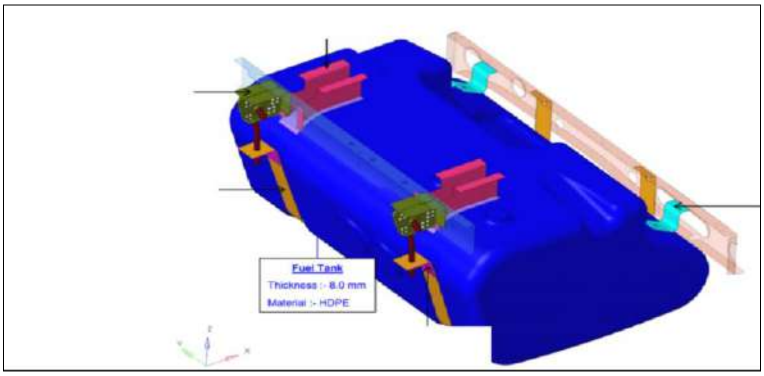


Fig 10: FE Result Concept 2 as per OEM standard

Resonance frequency detection test on concept 2 (75% fuel filled condition)

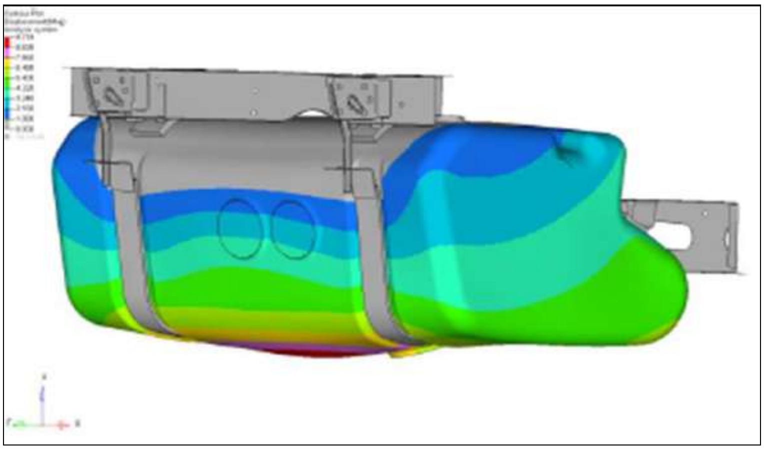
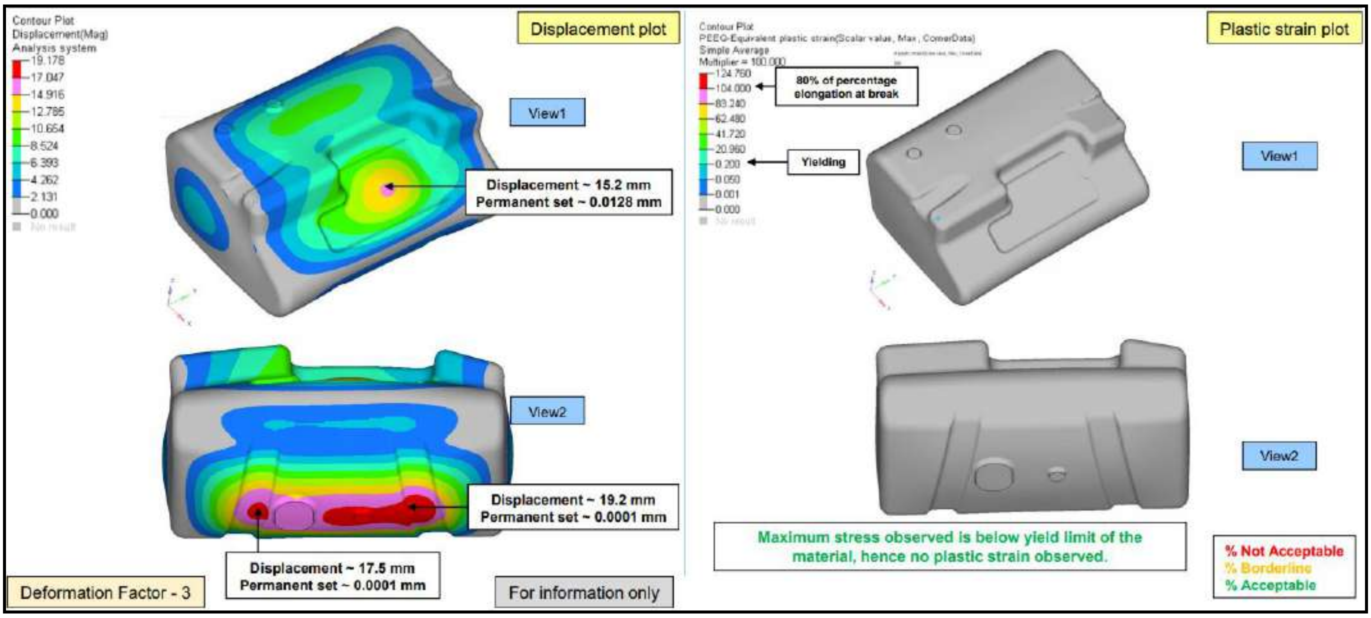


Fig 11: Resonance frequency detection test on concept 2 (75% fuel filled condition)

Displacement in tank top & bottom are 15.2 & 19.2 mm Permanent set-in tank top & bottom are 0.0128 & 0.0001 mm Plastic strain in tank top & bottom is approximate 0.2% (Maximum stress observed is below yield limit of the material, hence no plastic strain observed.)



Strap Structural analysis & material selection

Plastic fuel tank of winger BSVI (VAN) Structural analysis is the determination of the effects of loads on physical structures and their components. Base design focuses on Pressure Analysis of Plastic fuel tanks. To improve the performance of the fuel tank bracket series of design iteration was carried out by taking the account of base model structure.

In this paper design and optimization of plastic fuel tank, assembly is done by using finite element analysis and presented the study methodology to improve the first natural frequency of fuel tank and brackets for light duty vehicles using FEA. In fuel tank Gasoline settles at the bottom and due to evaporation, gases apply pressure on internal wall of fuel tank. As gasoline, fluid cools and warms its volume changes, which relives both pressure and vacuum.

We carried out study on base design and further improvements are done two iterations. In all three iterations strip (Material & Thk.) and tank wall thickness.

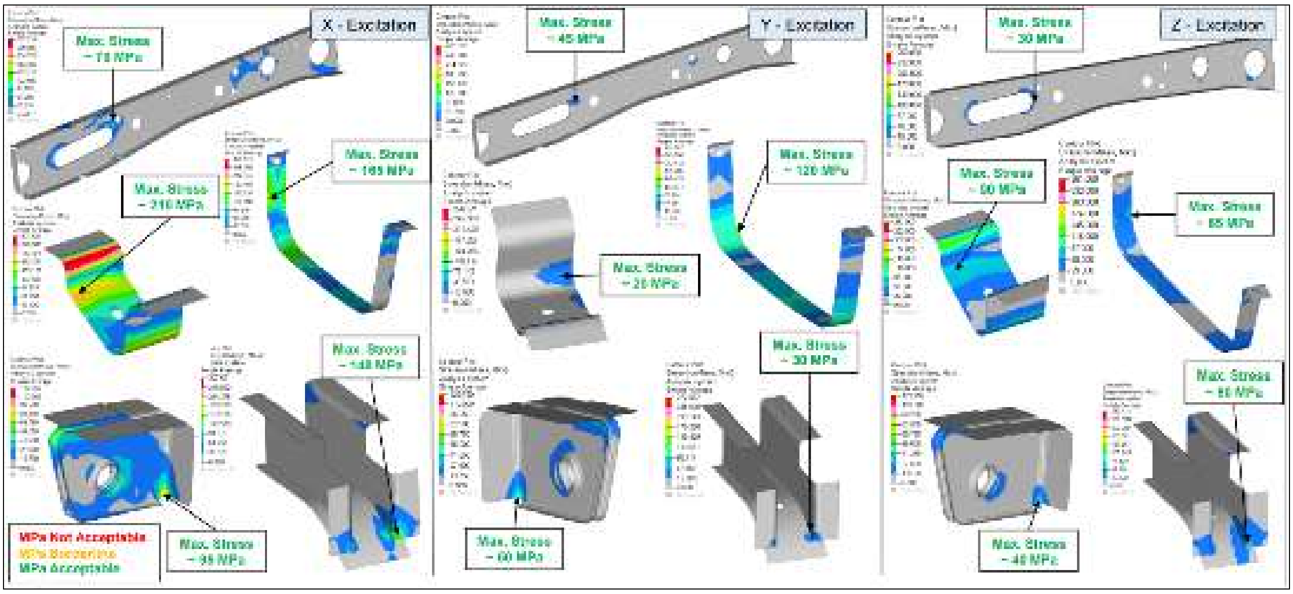


Table 1: Material properties of tank and strap

S No.	Iteration	Part name	Material	Thk. (mm)	Density (Kg/m^3)	Young modulus (Mpa)
1	Base Design	Fuel Tank	HDPE	6	945	1370
		Strip	D513	1.25		175/280
		Plate	DD1079	2.5		250
		BKT1	D513	1.2		
		BKT2	E34	1.6		
		BKT3	DD1079	1.6		250
2	Concept 1	Fuel Tank	HDPE	6	945	1370
		Strip	E34	3.15		
		Plate	E34	2.5		
		BKT1	D513	1.2		175/280
		BKT2	E34	1.6		
		BKT3	DD1079	1.6		250
3	Concept 2	Fuel Tank	HDPE	8	945	1370
		Strip	D513	3.15		175/280
		Plate	DD1079	2.5		250
		BKT1	D513	1.2		175/280
		BKT2	E34	1.6		
		BKT3	DD1079	1.6		250

Conclusion

1) Deformation on tank is maximum in pressure test condition, therefore, the tank need to be designed considering this worst case.
2) It is observed that frequency is improving after doing the modifications of strap thickness and tank shell thickness.
3) Firstly, bead design optimisation was done and then thickness was changed for strap and plastic shell to meet the desired criteria for structural load and pressure load on tank.
4) Concept 2 design iteration considered for final design selection and implementation

A part of the project that consists of the design, analysis and optimization of plastic fuel tanks used in the VAN is presented in this paper. Fuel tanks are subjected to varying dynamic loads due to severe road conditions. These loads may cause failures and cracks in the fuel tanks. To design desirable fuel tanks with high reliability, it is vital to have an idea about both the results of their failures and their life span. For this purpose, static and dynamic analyses are performed using finite element method. The aim of the project is defining the analysis methodology to prevent the damages. The project is ongoing until the analyses are verified by the tests. So far, an important part of the simulation method has been completed for plastic fuel tanks for VAN.

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