International Engineering Research Journal

Material and Volume Optimization of Conventional Fuel Tank

Komal Jejurikar[1], Dr. (Mrs.) P. S. Gajjal[2]

[1]PG Student, Mechanical Engineering, Sinhgad College of Engineering, Pune 41.
[2]Associate Professor, Mechanical Engineering, Sinhgad College of Engineering, Pune 41.

Abstract

Fuel tanks range in size and complexity from the small plastic tank of a butane lighter to the multi-chambered cryogenic Space Shuttle's external tank. For each new vehicle a specific fuel system is developed, to optimize the use of available space. According to the EURO VI norms to be implied in the year 2020, there is requirement of more fuel consumption in the ongoing range of commercial vehicles but also restriction in the space available for a fuel tank as need to package an Ad Blue tank additionally in the limited space. Two parameters are explored here for a new fuel tank that are, material optimization and volume optimization. The systematic study of conventional fuel tanks with respect to size and material have been done and enhanced material for fuel tank with increased size have been suggested for implementation. The feasibility of using plastic (HDPE/XLPE) as the material for the fuel tank have been discussed in the research along with the optimization of volume of the fuel tank for the range of commercial vehicles.

Keywords: *Fuel Tanks, Commercial Vehicles, Volume Optimization, Plastic, XLPE, Weight Reduction.*

1. Introduction

A fuel tank is a safe container for flammable fluids. Though any storage tank for fuel may be so called, the term is typically applied to part of an engine system in which the fuel is stored and propelled (fuel pump) or released (pressurized gas) into an engine. Fuel tanks range in size and complexity from the small plastic tank of a butane lighter to the multi-chambered cryogenic Space Shuttle external tank. The maximum distance a combustion-engine powered vehicle with a full tank can cover is the product of the tank capacity and its fuel efficiency (as in miles per gallon). While larger tanks increase the maximum distance, they also take up more space and (especially when full) add to the total weight, requiring higher fuel consumption for the same performance. Fuel-tank capacity is therefore the result of a trade-off in design considerations. For most compact cars, the capacity is in the range 45–65 litres (12–17 US gal); SUVs and trucks tend to have considerably larger fuel tanks.

For each new vehicle a specific fuel system is developed, to optimize the use of available space. Moreover, for one vehicle model, different fuel system architectures are developed, depending on the type of the vehicle, the type of fuel (gasoline or diesel), nozzle models, and region.

Two technologies generally used to make fuel tanks for automobiles:

i. Plastic high-density polyethylene (HDPE) fuel tanks made by blow molding. This technology is increasingly used as it now shows its capacity to obtain very low emissions of fuel (see Partial zero-emissions vehicle). HDPE can also take complex shapes, allowing the tank to be mounted directly over the rear axle, saving space and improving crash safety. Initially there were concerns over the low fracture toughness of HDPE, when compared to steel or aluminum. Concern for safety and long term ability to function should be considered and monitored.
ii. Metal (steel or aluminum) fuel tanks welded from stamped sheets. Although this technology is very good in limiting fuel emissions, it tends to be less competitive and thus less on the market, although until recent times automotive fuel tanks were almost exclusively made from sheet metal.

Ryan Craig and Tony (YI) Qu (Ford Motor Co.) shows the multilayer thermoplastic fuel tank simulation. The weight of the entire fuel system including the fuel is considered in this study to improve the modelling of the contact tightness between the fuel tank and tank straps. Validated by fuel tank sled tests, the proposed fuel tank modelling approach, incorporating the latest ALE method, manufacturing and assembly processes, and gravity effect, helps improve the correlation between CAE and physical tests significantly(1). Fatigue behavior of the high-density polyethylene applied to fuel tanks was analyzed by Hiroaki Himeki et. al., under low-level cyclic loading that simulated fuel tank pressure changes. The correlation between fatigue life and stress, temperature and frequency (the major influencing factors) was expressed quantitatively using fatigue test data for test pieces. This expression was then verified in fatigue tests conducted on plastic fuel tanks. The validity of this equation for predicting the fatigue life of plastic fuel tanks was thus confirmed(2). Erin Marie Shipp gives a revised location for the fuel system and fuel tanks to improve crashworthiness and reduce the occurrence of tank failure, fuel spillage, fire and/or explosion while still providing a sufficient range for the vehicle. The fuel tanks are protected from damage from the side, bottom and between the tanks. Masilamani R. gives the design and analysis of HDPE fuel tank. The main objective of that work was to design and numerically examine the impact strength and develop a modular prototype using high density polyethylene plastic, which is a strong and lightweight material, enable manufacturers to substantially reduce the overall weight of their vehicles & making the vehicles more fuel efficient. Omar A. Usman gives the detailed study of recent advances in reducing fuel permeability and leakage into the environment from automotive fuel systems. Recent efforts on how the automotive industry is responding to meet challenges are also presented in this work.

2. Conventional Fuel Tank

The requirement for new optimized fuel tank was arise due to following reasons:

(1) Limited fuel tank capacity which affects on distance travelled.
(2) Additional space requirement for packaging the Urea Tank for BS-IV & BS-VI.
(3) Fuel tanks for shorter wheel base variants.
(4) Material optimization.

Table 1 Current varients of fuel tank used

Model	250	350	417
Filling Capacity (Lit.)	235	330	400
Sheet Length (mm)	915	1250	1500
X-Section H x W (mm)	500 x 600		

3. Global Benchmarking

The global survey regarding different materials used for fuel tanks have been carried out. The OEMs from all over the world uses different kind of materials with different shapes and sizes. Table 2 shows the global benchmarking regarding materials used for fuel tank and their shape and size. Most of the OEM uses aluminum material as a material for fuel tank. The properties of aluminum shows the better performance against crashing of tank and leakage defect. Some of them like Volvo, HINO and Hyundai uses steel material as material for fuel tank. Plastic and steel are the materials which are being implemented for the leakageproof and crash resistant fuel tanks.

Table 2 Global Benchmarking of Fuel Tanks

OEM (Model Name)	Material of Tank	Shape of Tank	Capacity of Tank
Isuzu (EXY 510 GigaMax)	Aluminium	Rectangular	1000L = 1 x 550L(LH) 1 x 450L(RH)
VOLVO (FH Series)	Aluminium/Steel	D-shaped (mostly)	150L-900L
VOLVO (FE 6x2 Rigid)	Plastic/Steel/ Aluminium	D-shaped	160L-630L
SCANIA (P320)	Aluminium/Steel	Rectangular	400L(LH)
SCANIA (R620)	Aluminium	Rectangular	970L = 1 x 670L(LH) 1 x 300L(RH)
FRIEGHTLINER (CASCADIA)	Aluminium	Cylindrical	570L(RH)
KENWORTH (t880)	Aluminium	Cylindrical	170-670L (LH)
INTERNATIONAL (9900i)	Aluminium	Cylindrical	530-1140L
WESTERN STAR (4900)	Aluminium	Cylindrical	227-567L (RH or LH)
HINO (338)	Steel	Rectangular	190L(LH) (Opt.-Dual 190L/ Single265L/360L)
Hyundai (Trago Xcient 6x4 Tractor)	Steel/ Aluminium	Rectangular	{400L(Steel) 500L(Al)}RH/ {500L+300L(Al)}RH+LH
FAW (CA3252 6x4)	Aluminium	Rectangular	400L(RH)

4. Technical Properties of Materials

Table 3 shows the technical comparison between materials used for fuel tanks.

Table 3 Technical comparison between materials

Properties	Material →	Stainless Steel		Aluminum	Plastics	
		202	409	Al 5052-H32	HDPE	XLPE
Mechanical	Ult. Tensile Strength (MPa)	515	448	228	15.2 -45.0	17-26.5
	Yield Strength (MPa)	275	238	193	13.0 - 200	18-26
	% Elongation	40	32.5	8	3.00 - 1900	350
Chemical	Melting Point(°C)	1400-1450	1425-1510	607-649	124 - 135	150-170
Weight /Ltr capacity		169 g/L	166.7g/L	105g/L	91g/L	
Thermal Conductivity (Fuel cooling)		Good	Good	Excellent	Poor	Poor
Weldability		Good	Fair	Good	-	-
Formability		Fair	Fair	Excellent	Good	Good
Corrosion protection		Good	Good	Excellent	Excellent	Excellent
Density g/cm3		7.8	7.7	2.7	0.97	0.93
Weight of 330L fuel tank (kg)		55.8	55	34.7	-	30
Material availability in Indian Market		Not readily available	Available	-	Available	Available
Local Modification		Possible			Not possible	
Repairability		Possible			Not possible	

It shows that, the plastic material will be beneficial over stainless steel and aluminum. The properties like weight per liter capacity, formability, corrosion resistance, density shows greater advantage over the same properties of other two materials.

5. Volume Optimization

The future of automobiles have to be designed by taking the norms under consideration. After skipping BS V norm, the innovations must follow BS VI, which is originally proposed to come in by 2024 has been now advanced to 2020, instead. The main concern of BS norms and research is the SCR and higher fuel requirement. SCR module reduces oxides of nitrogen by injecting an aqueous urea solution (AUS 32, which contains ammonia) into the system when the exhaust is moving.

Table 4 Volume comparison between materials used for fuel tanks

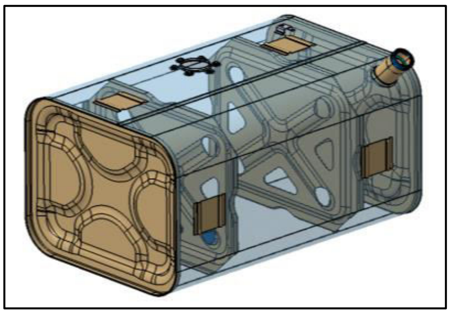
Current Fuel Tank	Enhanced Volume-Metallic	Plastic Fuel Tank
235 L	360 L	400 L
330 L	498 L	550 L
400 L	600 L	650 L

The volume comparison of metallic and plastic fuel tanks as shown in table 4. 50% volume increment from Current Fuel Tank to Enhanced Volume Metallic FT and 10% volume increment from Enhanced Volume Metallic FT to Plastic Fuel Tank.

6. Design Proposals

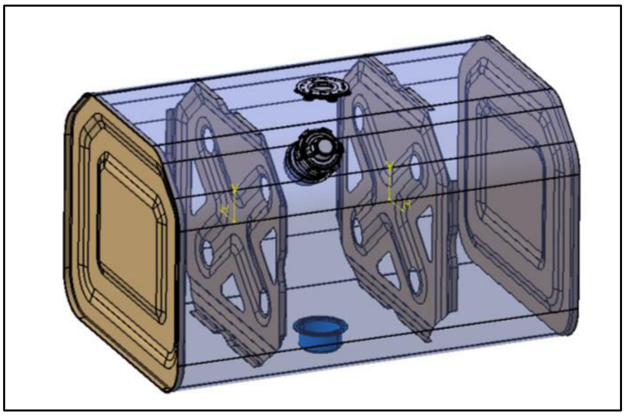
The brief study of design requirement have been done systematically and the conceptual designs have been proposed with optimized material and volume and suggested for future implementation. Following figures shows the concept evolution of optimum design of fuel tanks.

6.1 Current fuel tank:



- Width : 600 mm
- Height : 500 mm
- Thickness : 1.6 mm

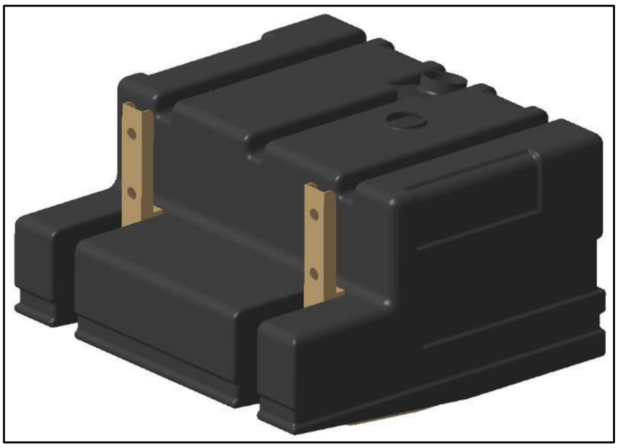
6.2 Enhanced volume metallic fuel tank:



- Width : 670 mm
- Height : 650 mm
- Thickness : 1.6 mm
- Deletion of SUPD (Side Under ride Protection Device)

But deletion of SUPD may be harmful for fuel tank under accidental conditions.

6.3 Plastic fuel tank:



- Width : 1025 mm
- Height : 650 mm
- Thickness : 5mm
- Integration of SUPD

Here, the SUPD is integrated with fuel tank i.e. that much strength of SUPD is integrated with the plastic fuel tank and it is done at the time of manufacturing.

7. Fuel tank position for BS VI

The possible positions are suggested for commercial vehicles under BS VI norms. Those are as follows:

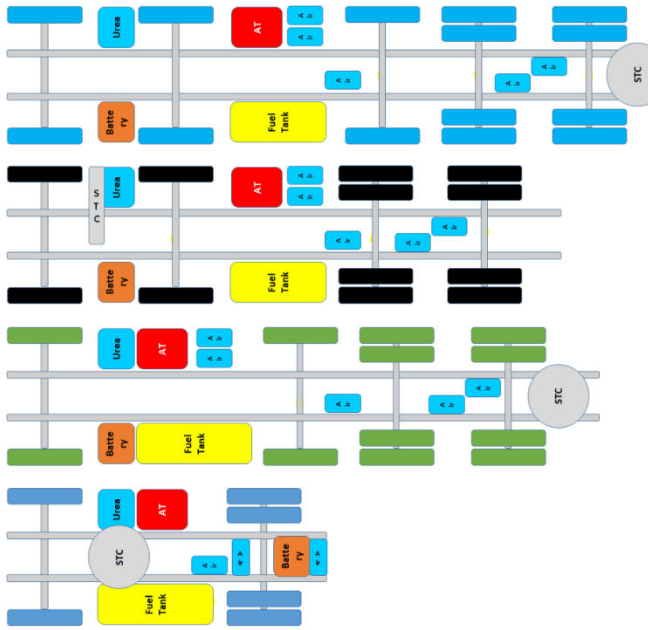


Fig. 1 Possible locations for fuel tank on the vehicle chassis (Left Hand Side)

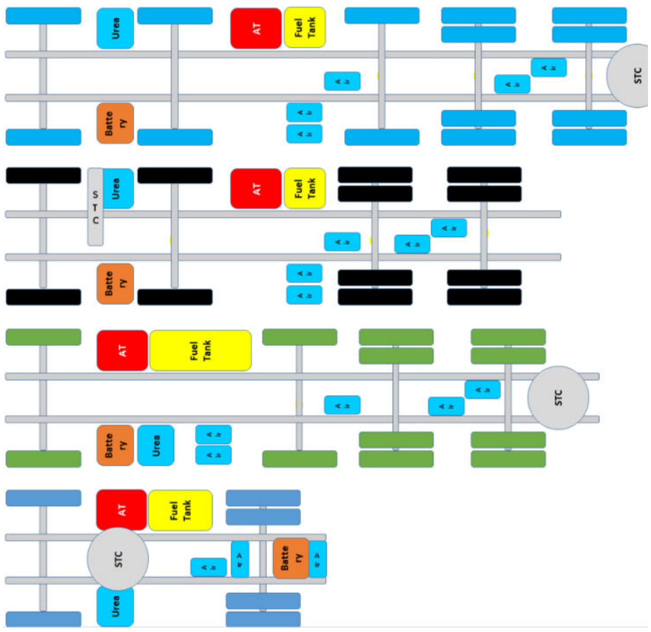


Fig. 2 Possible locations for fuel tank on the vehicle chassis (Right Hand Side)

Conclusions

The main moto of the research was to optimize the material as well as volume of the fuel tank, which is successfully completed and further suggested for the manufacturing the same. Amongst possible materials, plastic material (HDPE and XLPE) seems to be suitable for the application on commercial vehicles. The integration of SUPD is the most advantageous feature which is suggested for improvement. The optimized volume designs have been proposed (as shown in previous figures) and planned for implementation. Thus, the material as well as volume optimized.

References

(1) Ryan Craig, Tony (YI) (2012) 'Crash performance simulation of a multilayer thermoplastic fuel tank with manufacturing and assembly considerations'.

(2) Hayashi, K., Mikami, M., and Miura, K., 'Development of Multi-Layer Plastic Membrane (Bladder Membrane) for Vapor Reducing Fuel Tank', SAE Technical Paper 2001-01-1120, 2001. doi:10.4271/2001-01-1120.

(3) Dr.Nabih Bedewi (2011), 'Fire Exposure, Impact Tests, Finite Element Modeling of Plastic Fuel Tanks', Southwest Research Institute, Vol II.

(4) ed. Michael Scarlett, 'Fuel Supply Systems for a Healthier Environment', Bundy International, *Automotive Technology International '94,* pp. 37-40.

(5) "Plastic PZEV Fuel Tank System" Visteon Corporation. March 23,2001. http://www.visteon.com/technology/automotive/plastic_pzevtank.html

(6) "Description of HDPE and EVOH multi-layer barrier" Solvay America Inc. March 24, 2001. http://www.plastics-car.com/tour/solvay.html

(7) Ed Fead, Ravi Vengadam, Giuseppe Rossi, Albert Olejnik, and John Thorn, 'Speciation of Evaporation Emissions from Plastic Fuel Tanks', Society of Automotive Engineers, Inc. International Spring Fuels & Lubricants Meeting & Exposition; Dearborn, Michigan, May 4-6, 1998.

(8) "Eliminating Emissions: Plastic fuel tank helping achieve 'greener' cars" Visteon Corporation. March 23,2001. http://www.visteon.com/news/features/091300.html