

A

Dissertation Report

On

**Design of BS - 6 complaint Urea Tank for Exhaust system of an
Automobile**

For partial fulfilment of the degree of

Master of Engineering
in
CAD/CAM Engineering
by

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July 2019

CERTIFICATE

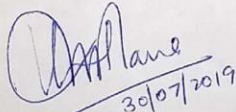
I hereby declare that the work done in thesis report entitled, "**Design of BS - 6 complaint Urea Tank for Exhaust system of an Automobile**" submitted towards partial fulfilment of the requirement for the award of *Master of Engineering* in *CAD/CAM Engineering* in *Mechanical Engineering Department* of *Thapar Institute of Engineering and Technology, Patiala* is an authentic record of work carried out by me under the supervision and guidance of *Dr. Vineet Srivastava, Assistant Professor, Mechanical Engineering Department, Thapar Institute of Engineering and Technology, Patiala*. The contents of this thesis report, in full or in parts have not been submitted to any other institute or university for the award of any degree.

Date: 30/07/2019



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This is to certify that above declaration made by the student is correct to the best of my knowledge and belief.



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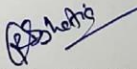
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Abstract

The need of the Urea tank in an automobile arise with the introduction of the Selective Catalytic Reduction (SCR) technology in the exhaust system. The use of Selective Catalytic Reduction is necessary so that new emission norms were introduced by Government of India can be met. The tank is a component of the SCR technology without which it could not be a functional part. To reduce the pollutants to the permissible limits the technology is being introduced in the automobiles which will become an integral part of the exhaust system of an automobile. The design of urea tank and its mounting brackets is done for TATA Ultra 1518 vehicle.

Keywords: Selective Catalytic Reduction, Urea Tank, Mounting Bracket, Exhaust System

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Nomenclature

IC: Internal Combustion

NO_x: Nitrogen Oxides

SO_x: Sulphur Oxides

CO: Carbon Monoxide

PM: Particulate Matter

EPA: Environmental Protection Agency

CARB: California Air Resource Board

EURO: European Emission Norms

ADR: Australian Design Rules

NTC: National Transport Commission

BSES: Bharat Stage Emission Standards

BS: Bharat Stage

EGR: Exhaust Gas Recirculation

HC: Hydrocarbons

SCR: Selective Catalytic Reduction

DPF: Diesel Particulate Filter

DOC: Diesel Oxidation Catalyst

NSCR: Non-Selective Catalytic Reduction

WHO: World Health Organization

GOI: Government of India

ILCV: Intermediate and Light Commercial Vehicles

CAE: Computer Aided Engineering

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Chapter 1

INTRODUCTION

We are living in the age of technology which is being enhanced day by day and due to these enhancements' things are getting changed affecting the human life. One such technology is of the automotive vehicles which are receiving updates every other day. Automobiles play an unimaginable role in the socio-economic and industrial growth of the country; also, automotive vehicles have become one of the basic necessities of a human which helps in the transportation of passengers and goods from one place to another. The advancements in the technologies have also affected the automobile industry making it more and more eco-friendly and consumer friendly.

Automobile is a self-propelled vehicle which is required for the movement of the goods and passengers on the ground. A self-propelled vehicle is one which requires some power for propulsion produced from within. There are many examples of self-propelled vehicles like plane, car, bus, truck, locomotive, ship, etc. but the ones which runs on the surface are known as automobiles [1] The vehicle propulsion is due to either the engine or the motor provided within the vehicle. The business of making and servicing automobiles is one of the largest businesses in the world. Automobile industry provides jobs to millions of people around the globe. In India about 50 lacs vehicles are produced every year which includes engine powered machineries for various purposes like passenger travel, goods carriage, agricultural purposes, construction purposes, etc. and about 22 crore vehicles are registered with Indian Government [W1].

1.1 History of Automobiles:

The history of automobiles started back in 17th century with a steam powered vehicle which was made in the year 1672 for a Chinese emperor as a toy. It was a small scale but can be called as first steam operated vehicle [2]. But the actual vehicle which could be big enough to carry passengers and cargo was made in the late 18th century. Since then many iterations were made to make a full-fledged automobile. A brief history is given in below table.

Table 1.1. Chronology of an Automobile [1,2]

Year	Vehicle	Designer
1672	Small Scale Steam Powered Toy	Ferbinand Verbiest
1770-71	Steam Driven First Road Vehicle	Nicolas-Joseph Cugnot
1784	Steam Carriage	William Murdoch
1789	First Automobile Patent	Oliver Evans
1801	First Steam Powered Road Carriage	Richard Trevithick
1807	Internal Combustion (IC) Engine Invented	Francois Isaac de Rivaz
1867	First Successful IC engine which burned fuel in Piston Chamber	Nikolaus August Otto
1870	First Internal Combustion Engine Vehicle	Siegfried Marcus
1885	Tricycle propelled by IC Engine	Karl Benz
1886	IC engine Patented	Gottlieb Daimler
1906	First Affordable Vehicle Made i.e. Ford Model T	Henry Ford

Since the Ford Model T was introduced in the market lots of research and developments have been taken place to make a modern automobile which is much more efficient and safer in every aspect as compared to the models made earlier.

The first automobile on the Indian soil appeared in the year 1897 however the manufacturing of automobiles in India started in 1943 with the factory of Hindustan Motors Limited in Calcutta. Till then the vehicles were only imported in the country. Since the setup of first factory, India now has over 75 automobile manufacturing units spread across the country.

The vehicles which are now available in the market are the vehicles of the modern era which started in the mid 1960's. Since then the work in automobile industry is of making a cost saving, standardized vehicle designed with the help of computers and sharing the platforms with one another. The modern era vehicles have been focussing on the fuel-efficient vehicles with much improved engine output. Also works are being done to make vehicles environment friendly by adopting the emission norms present in the world. Few of the vehicles of the modern era are the ones which are still being produced and sold by

improving them and making more efficient and safer from the first time they were produced.

1.2 Types of Automobiles:

The automobiles are classified on various fronts like purpose, capacity, fuel used, transmission type, etc.

A brief classification of an automobile on the basis of purpose is as below:

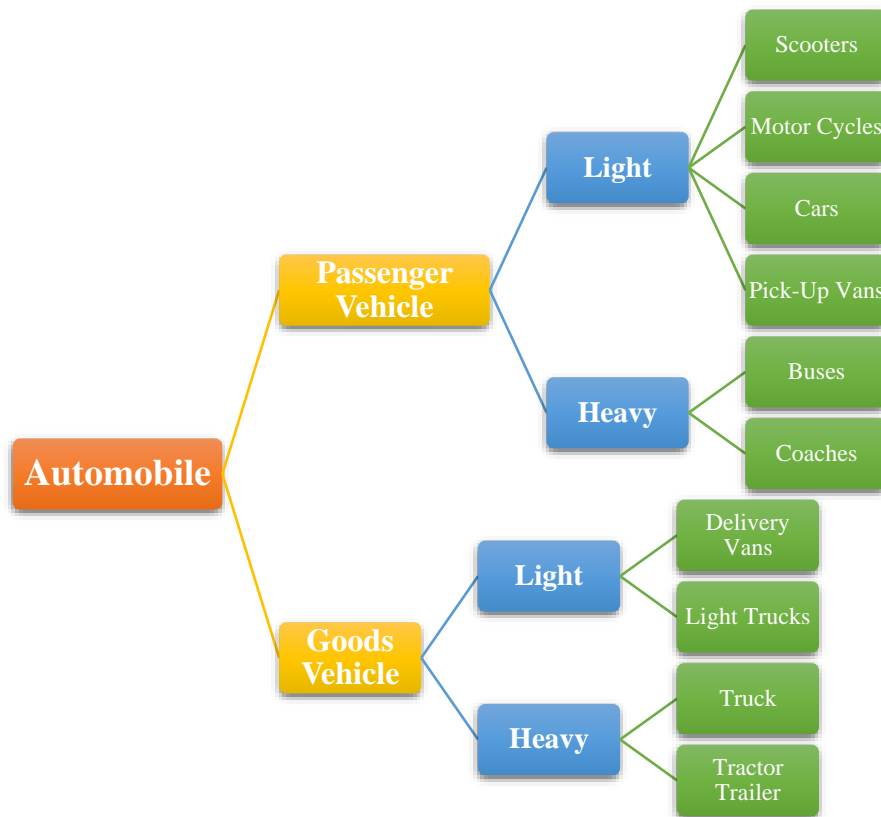


Figure 1.1 Classification of the Vehicle on the Basis of Purpose [1]

The classification of the vehicle on the basis of capacity is as follows:

- Light Motor Vehicles: Scooters, Motorcycles, Cars, etc.
- Heavy Motor Vehicles: Buses, Trucks, Tractors, etc.

The classification of the vehicle on the basis of fuel used is as below [1]:

- Petrol Vehicle: The vehicles which are powered by a petrol engine for e.g. scooters, cars, mopeds, motorcycles, etc.
- Diesel Vehicle: The vehicles which are powered by a petrol engine for e.g. Trucks, buses, pickups etc.
- Solar Vehicles: The vehicles which run on the sun's power for e.g. Solar powered cars.

- **Electric Vehicle:** the vehicles which use electricity as the power source are the electric vehicles for e.g. Electric Cars, Electric bikes, etc.
- **Steam Powered Vehicles:** the vehicles powered by the steam engines are the steam powered vehicles for e.g. Steam boat, Steam locomotive etc.
- **Hybrid Vehicles:** These are the vehicles which use two or more distinct fuels for the propulsion for e.g. Hybrid Bus which uses diesel and batteries, hybrid cars, etc.

1.3 Breakup of an Automobile

A vehicle or an automobile is made up of different aggregates or components which when connected in a proper combination makes a perfect vehicle. The major components of a vehicle are listed below:

- **Engine:** It is the power source of any vehicle which is plying on the road. The function is to convert the chemical energy of the supplied fuel to mechanical energy to drive the wheels of the vehicle.
- **Transmission:** It is also known as the powertrain of the vehicle. It includes components like Gearbox, Clutch, Differentials, Propeller Shafts, etc. These help in transmitting the power generated by the engine to the wheels.
- **Suspension:** It is the system which attaches the wheels of the vehicle to the chassis or the frame of the vehicle and helps in absorbing the shocks coming to the vehicle.
- **Chassis or Frame:** It is the base of the vehicle on which every component of the vehicle is mounted.
- **Fuel & Exhaust:** This is the system in which the fuel is filled and supplied to the engine and exhaust is emitted from the engine to the environment by the exhaust system.
- **Wheels:** It helps in moving the vehicle on the road.
- **Steering:** This is the system which helps in controlling the directions of the vehicle in which vehicle is to be moved
- **Brakes:** The system which helps in stopping the vehicle is the braking system.
- **Electricals:** This system of the vehicle includes components like lights, turn indicators, horns, emergency signals, etc.

An image showing the components of a vehicle is shown in the Figure 1.2:

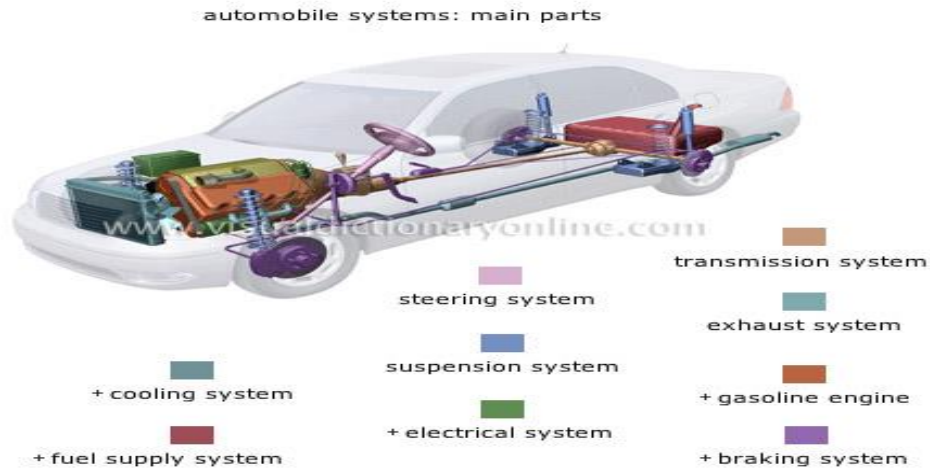


Figure 1.2. Configuration of a vehicle [W2]

1.4 Major Problems in Modern-Day Vehicles:

The modern-day vehicle is an example of the advancements in technology but then also there are some of the issues which needs to be taken care of. The major problems in the vehicles are as below:

- Poor fuel economies of vehicles.
- Emissions from a vehicle.
- Safety of a vehicle.
- Brake failures.
- Transmission issues.

The above listed are a few major problems but there are many more problems than what is written in the above points. One of the above point concerns about the emissions of the vehicle which are a major source of pollution as the exhaust gases from the automobiles consists of air pollutants like Nitrogen oxides (NO_x), Sulphur Oxides (SO_x), Carbon Mono-Oxide (CO), Particulate Matter (PM), etc. [3] In the past few years due to increase in the number of vehicles on the roads the pollution is also on an increase which led the governments to make laws for the emissions from the vehicles. The introduction of these laws ensured that the emissions from the vehicles are under a controlled rate. With this measure the problem of increasing pollution is getting curbed.

1.5 Emission Standards:

These are the legal requirements which a vehicle manufacturer should adhere so as the fulfil the requirements of the standards set by these agencies. The agencies which keep an eye on

the legal requirements are in general government agencies. These agencies are set to monitor the situation and to set up the laws for the emissions.

The laws are made in such a way that the current situation of the location can be met with the environmental requirement. As the time passes the laws are made more and more stringent as per the requirement. Once the emission standards are in place the controlled emission from the vehicle is the responsibility of the manufacturer of the vehicle.

The emission standards were brought because of increasing level of pollution on the earth and by setting the standards the controlled release of exhaust particles started, helping the world to curb the problem of the pollution. The first country to implement the emission standards was Japan. Since then many other countries implemented the laws and are successful in reducing the amount of the polluting agents which are being released from the vehicles on the roads. As said earlier the first country to implement the emission norms was Japan. Since then many other countries started implementing the laws as well. Looking at the environmental conditions becoming worse different countries started implementing more and more stringent laws. The international standards being followed are different from country to country and are listed as follows:

- ***American Emission Standards:*** The standards followed by most of the American states are constituted by the Environmental Protection Agency (EPA) which was established in the year 1970 to keep a check on the increasing anti-environmental activities which were going on in the states. The norms set by EPA were not so stringent so some states came up with their own laws to curb the increasing level of pollution. The level of pollution in the city of Los Angeles in the California state was at a very high level so the California Emission Standards were enforced by California Air Resource Board (CARB) in the state which were more stringent than the EPA standards. After this other state were free to choose between which norms to be implemented in the state as they were having a choice between EPA norms or CARB norms. By the year 2011 states like New York, Washington, Massachusetts, etc., implemented the Californian norms and were referred as the CARB states. When the pollution level started to increase EPA also adopted the Californian norms as the national standards in the year 2016 to implement stricter laws and help in reducing the pollution [3].
- ***European Emission Standards (EURO):*** These are the standards which are being followed by the European Countries. These standards were set in the year 1992 when

the emissions from the vehicles started polluting the environment beyond limit. Since then Iterations are being done to make the laws stringent and make the environment friendly exhaust systems. As of today, the EURO 6c norms are in play for both light and heavy vehicles. These norms were set as EURO 6 in the year 2014 and are being revised to new standards every other year keeping the global conditions in mind [4].

- **Chinese Emission Standards:** China set its first emission standards in the year 2000 which were equivalent to the norms of EURO 1. Since the number of vehicles are on the rise in China as of today EURO 4 norms are in place for all the Chinese vehicles.
- **Hong Kong Emission Standards:** Hong Kong follows Euro 4 standards for the passenger cars with spark ignition engines and US EPA Tier 2 standards for compression ignition engine powered vehicles.
- **Australian Emission Standards:** Australia standards are based on the European Regulations for both light duty and heavy-duty vehicles. The Australian Design Rules (ADR) and National Transport Commission (NTC) are the two agencies which coordinate in development of the emission regulations and as of today, EURO 5 norms are the national emission standards for the Australia.
- **South African Emission Standards:** The South Africa's programme of clean fuel was implemented in the year 2006 with banning lead from petrol and reduction of sulphur from diesel to 500 ppm from 3000 ppm. This standard was revised in the year 2017 as Clean Fuel 2 Standard to further reduce the amount of sulphur and other harmful elements in the fuel.
- **Japanese Emission Standards:** The Japanese were the first ones to set the emission standards back in the year 1973 and along with setting the standards they have also a policy of replacing the vehicle after a certain period or retrofitting the latest norms complaint components in the old vehicles. A maximum period of 12 years is what they have given as the age of a vehicle.
- **Bharat Stage Emission Standards (BSES):** The national standards for India were set in 1991 for petrol and in 1992 for diesel vehicles. But these were not too stringent norms and on April 29th, 1999 the Supreme Court of India gave a ruling that all vehicles must comply with the EURO 1 standards starting April 2000. The below table is a timeline of the emission norms along with the areas of implementation of these norms [5].
The standards followed in the country are on the basis of EURO norms and have been revised time to time to maintain a balance in the pollution level. The latest set of norms which is going to be implemented is the Bharat Stage – 6 or commonly known as BS6.

The standard is on the base of EURO 6 standard limiting the amount of harmful pollutants to a bare minimum value so as to get a clean environment.

Table 1.2. Chronology of the Indian Emission Standards [5]

Standard	Reference	YEAR	Region
1991-1992 Norms	-	1991-92	Nationwide
1996 Norms	-	1996	Nationwide
India 2000	Euro 1	2000	Nationwide
Bharat Stage II	Euro 2	2001	NCR, Mumbai, Kolkata, Chennai
		April-2003	NCR, 13 Cities†
		April-2005	Nationwide
Bharat Stage III	Euro 3	April-2005	NCR*, 13 Cities†
		April-2010	Nationwide
Bharat Stage IV	Euro 4	April-2010	NCR*, 13 Cities†
		April-2017	Nationwide
Bharat Stage V	Euro 5	To be skipped	
Bharat Stage VI	Euro 6	April-2018	Delhi
		April-2019	NCR
		April-2020	Nationwide
† Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Lucknow, Sholapur, Jamshedpur and Agra			

1.6 Motivation

It has been observed that the use of automobiles (buses, trucks, cars and 2 wheelers) have increased in multi-fold and therefore huge amount of pollutants are released into the atmosphere in form of emissions making day to day life difficult, in order to control this menace governments are introducing more stringent standards for the industry. The most recent standard is BS-6 which aims to reduce the emissions from the BS-4 standards i.e.

NO_x from 3 gm/kwh to 400 mg /kwh and Particulate Matter (PM) from 0.03 gm/kwh to 10 mg/kwh [5].

A major component of this new standard is the introduction of urea tank in the exhaust for 4 wheelers. The main challenge is to integrate the urea tank with exhaust system without altering the overall design of the vehicle. Therefore, the present work is an effort to design a suitable urea tank and its fixtures for fitting into the exhaust system of the vehicle.

1.7 Breakup of Thesis

The thesis comprises of six chapters which are listed as follows:

- Chapter 1 presents the introduction to the automobiles, a brief history of the automobiles and its basic components along with the major problems of a modern-day automobile. Then this chapter explain about the emission standards of the various countries along with the Indian emission standards which are popularly known as the Bharat Stage Emission Standards.
- Chapter 2 tells about the literature study which is done for the design and testing of a BS – 6 complaint urea tank and its mounting brackets.
- Chapter 3 deals with the design of the urea tank along with its analysis which is done for the validation of the design.
- Chapter 4 presents the design of the urea tank mounting and holding brackets and their validation by the testing.
- Chapter 5 presents the major conclusions of this work and the scope for future work has also been highlighted.

Chapter 2

LITERATURE REVIEW

Ever since an automobile is invented, continuous research and development is going on to improve the components and the major problem areas of the automobile. Keeping the actual configuration of the vehicle as it is, the changes are being made to the aggregates of the vehicle. A continuous work is being conducted to improve the exhaust system of the automobile so that less amount of pollutants is released in the atmosphere. The research for the emissions started back in the 1990's and is still going on. The basic mode is to make more and more stringent norms and the norms are to be met by the advancements in the technology.

Zelenka et al. [3], in the year 1996 studied about the emission standards present at that time and expressed the need of tightening of the emission standards due to rise in the number of vehicles plying on the road. He in his work told about the polluting agents present in the exhaust gases and how they have been affecting the working of the heavy-duty diesel engines and how they can be eliminated in the future.

Best et al. [6] in the year 2001 studied about the diesel fuel which was present at that time and expressed the need of low sulphur diesel fuel so as to get cleaner and greener environment. This study was conducted at the very beginning, when India was introducing the new emission norms which was based on the emission norms implemented in the European countries.

Koli et al. [7] in the year 2005 observed that the need of a new kind of after treatment system was required as new emission norms (BS – 2) were implemented and to achieve them it was required that the technology of exhaust gas recirculation (EGR) has to be incorporated on the vehicle.

Nesamani [8] in the year 2010, when the Indian emission norms were made somewhat stringent by the introduction of Bharat Stage-3 by the government, studied on the automobile emissions and how they can be controlled. For this purpose, the city of Chennai was chosen for the data collection. After collecting the data, he found that the main polluting agents are being released from the diesel vehicles and the major constituent were Nitrogen Oxides (NO_x), Particulate Matter (PM), Carbon Monoxide (CO), Hydrocarbons (HC) etc.

Herner et al. [9] in the year 2011 studied about the effects of after treatment system for Nitrogen oxides (NO_x) and Particulate Matter (PM) on Heavy Duty Diesel Engines and found out that after treatment systems which were using the technologies of Selective Catalytic Reduction (SCR) and Diesel Particulate Filter (DPF) are the best technologies to be used for reduction of NO_x and PM respectively.

Wu et al. [10] in the year 2012 tested the EURO – 1, EURO – 2 and EURO – 3 complaint vehicles and found that they were not up to the mark as the emissions they were emitting were more than the specified values by the government and suggested to make some stringent norms and implement them with proper technology so that the emissions meet the norms which have been implemented.

Chandrashekhra et al. [11] studied the vehicle emission in the year 2013 and proposed a sensor-based system which can detect the amount of pollutants coming out of the vehicle. With the help of this sensor, the driver of the vehicle can come to know about when something is going wrong with the vehicle exhaust system and needs to be corrected.

Sharaf [12] in the year 2014 studied about the different technologies like Exhaust Gas Recirculation (EGR), Diesel Oxidation Catalyst (DOC), Selective Catalytic Reduction (SCR), Non-Selective Catalytic Reduction (NSCR) for controlling the emissions and found out that by using integrated technologies instead of using a single technology can be more beneficial and can help in reducing the emissions significantly.

Ghodke and Suryawanshi [13] in the year 2014 tested an engine fitted with different exhausts system which included the technologies like Exhaust Gas Recirculation (EGR), Selective Catalytic Reduction (SCR) and Diesel Particulate Filter (DPF). These technologies were tested for BS – 4, BS – 5 and EURO – 6, and they found out that SCR technology has up to 60% efficiency to meet the stringent EURO – 6 norms over EGR or DPF technologies.

Guttikunda et al. [14] in the year 2014 studied about the air quality of 39 different cities which includes cities like Hyderabad, Delhi, Patna, Trivandrum, Bhopal, Vadodara, Amritsar, Kolkata, etc. Their emission sources and how the pollution can be curbed by taking some effective measures. In their studies, they found that according to the World Health Organization (WHO) list of 100 most polluted cities, 37 Indian cities are on the list with Delhi, Raipur, Lucknow and Gwalior being in top 10 list. The major issue was the pollution from the automobiles. They suggested that more stringent norms for emission should be made and implemented as soon as possible.

Bashirnezhad et al. [15] in the year 2016 tested the influence of the urea-based Selective Catalytic Reduction (SCR) technology on biodiesel fuel and found that the Nitrogen Oxides (NO_x) emissions from the biodiesel fuel were reducing as compared to the ones which do not use the urea-based SCR technology and suggested to use the same technology as results were good enough.

Chatterjee et al. [16] in the year 2017, when the government of India announced that the BS - 6 norms are to be implemented in the country nationwide, studied how the norms can be met. They suggested urea based Selective Catalytic Reduction (SCR) to be implemented on the vehicle so that they can meet the norms set by the government.

Greigoratos et al. [17] in the year 2018 studied about the real-world performances of heavy-duty vehicles plying on the roads having EURO - 6 emission standard control kits having urea-based Selective Catalytic Reduction (SCR) technology they were working satisfactorily and the emissions required from the vehicles were meeting the norms.

From the study of literature, it can be seen that the emission norms have been changing periodically with reference to control the pollutants emerging out of an automobile. The new emission norms are becoming more stringent and environment friendly. In order to fulfil these norms new technologies are being developed like Exhaust Gas Recirculation (EGR), Selective Catalytic Reduction (SCR), Diesel Particulate Filter (DPF), Diesel Oxidation Catalyst (DOC), etc. Further urea-based technology is being heavily suggested by various researchers. Further Government of India (GOI) in the new emission norms BS6 is also recommending the use of urea-based emission system.

2.1 Gap in literature:

From the literature survey certain gaps have been identified where this research can make signify contribution:

- Although basic technology of urea-based system is there, but how to integrate the technology into automobile is not been reported in ILCV segment.
- There is lack of process planning in design guideline regarding the of urea tank.

There is no existing knowledge of how to integrate this urea tank without altering the existing automobile configuration.

2.2 Research Objectives:

The objectives are detailed below:

- To design a urea tank for the new exhaust system for TATA ULTRA 1518.
- To design the mounting and holding brackets to hold the urea tank within the exhaust system.
- To test and validate the dimensions of the designed components and its functional testing.

2.3 Methodology

The work done to achieve the research objectives have been broken into following steps:

- Evaluated the earlier exhaust system (BS-4) to understand the components and configuration of exhaust.
- To determine the size of urea tank based on calculations obtained from engine.
- To design and validate the various mounting and holding brackets for holding of urea tank
- Fabricate the mountings.
- A urea tank of 25 litre capacity was designed and dimensions were validated.
- The urea tank was fabricated.
- The urea tank with the help of mounting brackets was adjusted on the chassis and functionally tested.
- Optimization of dimensions of urea tank and mounting brackets done for final fitment.

Chapter 3

VARIOUS EXHAUST CONTROLLING TECHNOLOGIES

The exhaust coming out of a vehicle is a major pollutant if the environment and hence it needs to be controlled. In the second chapter many researchers used various exhaust control technologies. These technologies are basically a part of the exhaust system and are known as the after-treatment systems. The following are the various after treatment systems:

- Exhaust Gas Recirculation (EGR)
- Diesel Oxidation Catalyst (DOC)
- Diesel Particulate Filter (DPF)
- Selective Catalytic Reduction (SCR)
- Lean NO_x Trap (LNT)

The above listed technologies are combined together to get the proper amount of the residuals from the exhaust system.

3.1 Exhaust Gas Recirculation

EGR is a technique in which a portion of exhaust gases is recirculated back to the engine cylinders. This helps in dilution of oxygen and provides combustion gases to work as an absorbent to reduce the topmost in-cylinder temperatures. NO_x is generally produced at high temperatures and at maximum pressure.

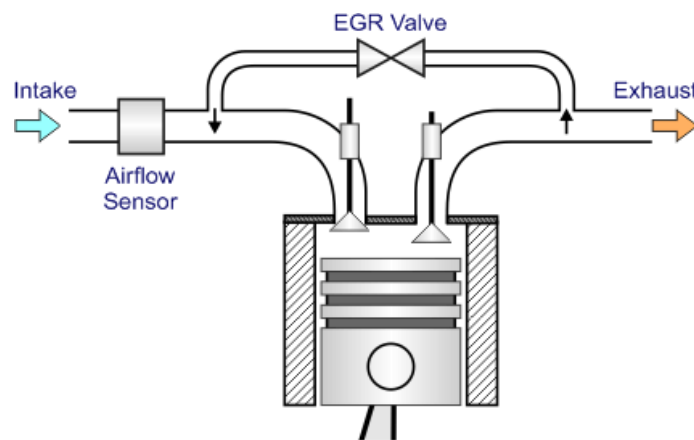


Figure 3.3 Exhaust Gas Recirculation

For diesel engines, the gases in the EGR are cooled with heat exchangers in order to have a large amount of recirculated gases. As diesel engines always works with excess of air the NO_x controlling rates are about 50%. The exhaust gases which are recirculated back to the engine cylinders increase the wear rate because the carbon particulates in the exhaust gases degrades the piston rings and the cylinder walls.

The process of EGR is shown in figure 3.1.

3.2 Diesel Oxidation Catalyst:

DOC helps in oxidation of various exhaust gases components which are present in sufficient amount in a diesel exhaust. CO, HC and Organic Diesel Particulates can be oxidized to harmless products using the DOC. The DOC is does not helps in controlling the NO_x but it reduces the other pollutants to a minimal level.

The following reactions takes place inside a DOC chamber.

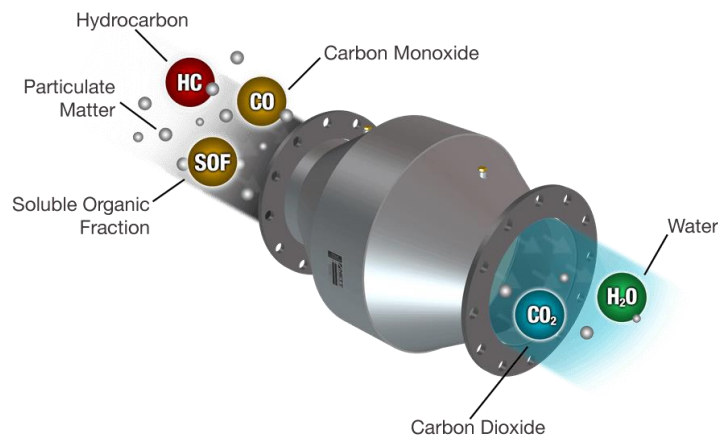
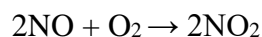
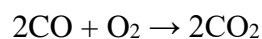
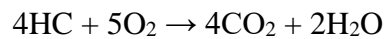


Figure 3.4 Diesel Oxidation Catalyst

The use of DOC alone is not recommended as the harmful NO_x are not being controlled by DOC hence it is used as an auxiliary system for other after treatment systems.

3.3 Diesel Particulate Filter

Diesel Particulate Filter is the most effective method to remove soot or the particulate matter from the exhaust of a diesel engine. It captures the particulates of diesel in order to prevent their discharge in the atmosphere. Diesel particulate filter materials filters with an efficiency of more than 90%, and also have a good mechanical and thermal durability.

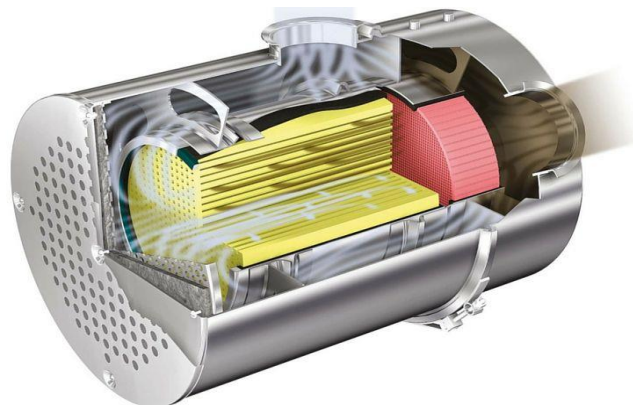
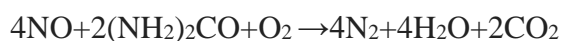
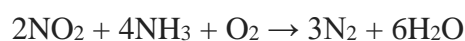
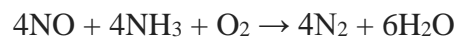


Figure 3.5 Diesel Particulate Filter

In diesel engines, due to the incomplete combustion, fuel air mixture generates different types of particles. These particles are known as DPM (Diesel particulate matter) that generates black carbon particles known as soot. With optimal DPF, these soot emissions can be reduced to 0.0012 g/km or less.

3.4 Selective Catalytic Reduction

The technology is the most efficient technology to reduce the NO_x contents from the emission of an engine. Selective Catalytic Reduction is a technology that injects urea – a liquid-reductant agent – through a catalyst into the exhaust stream of a diesel engine. The urea reacts with nitrogen oxides and converts them into nitrogen and water, which is then released to the atmosphere through the vehicle tailpipe. The chemical reactions taking place are as follows:



The schematic of an SCR is shown below

Diesel Emissions Control System

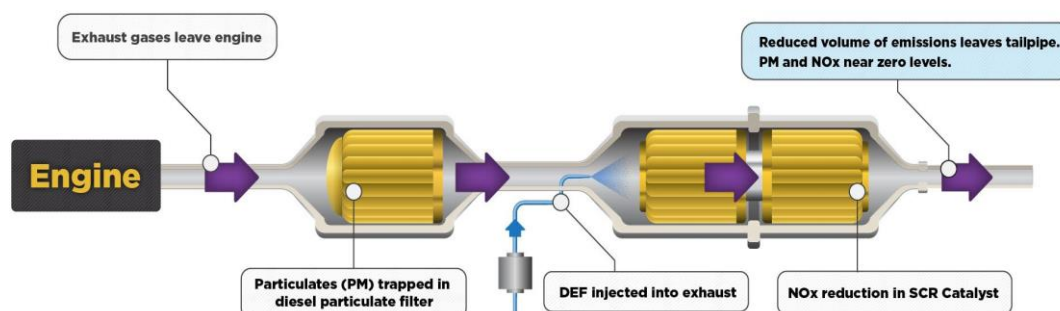


Figure 3. 6 SCR technology

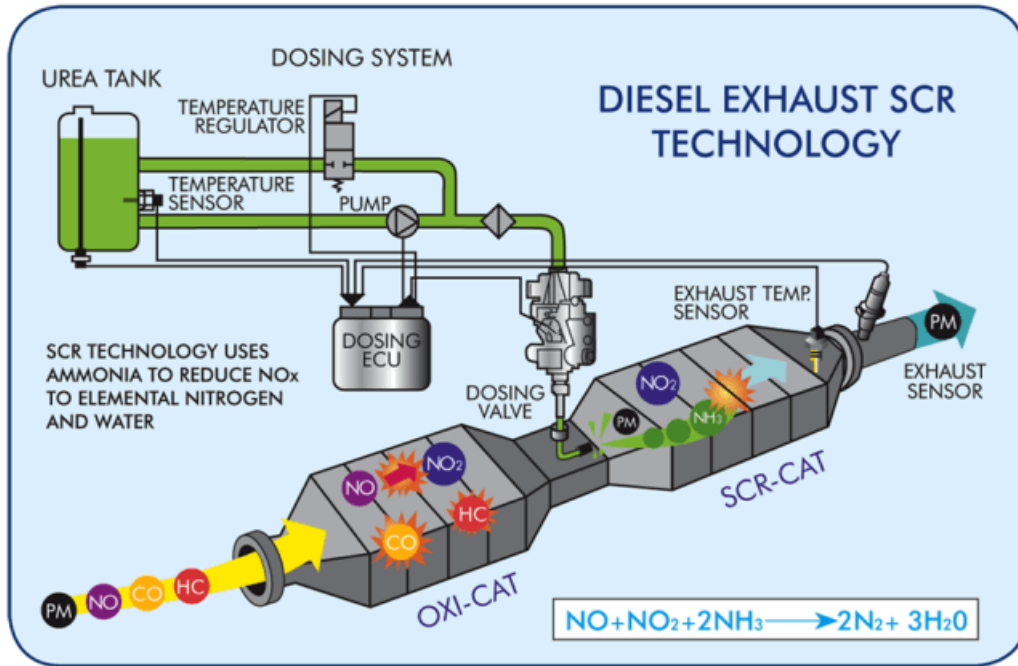


Figure 3.7 Schematic of a SCR system

3.5 Lean NO_x Trap

LNT is a device used to reduce NO_x emissions coming from lean burnt fuel in IC Engine using adsorption. Lean burnt fuel in diesel engines, have higher levels of oxygen content in the exhaust gases. The LNT was designed due to the limited effectiveness of EGR and variable supply of reductant into the exhaust. Adsorbent for e.g. Zeolite traps NO_x molecules and behaves like a molecular sponge. Reactants are trap is diesel fuel injection before the absorber regenerates it. This will make NO_x to desorb and within rich conditions to react with hydrocarbons, and produce nitrogen and water.

Chapter 4

DESIGN OF UREA TANK

The designing of the tank was a major task as the shape of the urea tank could be any of the shapes such as cylindrical, cuboidal, capsule like etc. These are all standard shapes which can be and are, used in industry for the tanks. So, keeping the standard shapes as a factor, initially various design iterations were carried out. The capacity of urea tank is decided on the basis of the fuel consumption of the vehicle. The urea consumption is dependent and calibrated on the fuel consumption. For heavy vehicles, the calibration has been done at 5% i.e. if 100 Litres of fuel is consumed on the vehicle, then about 5 litre of urea will be consumed. The ULTRA 1518 truck is fitted with a 160L of fuel tank which means that about 8 litres of urea will be used per fuel top-up. So instead of giving a top-up every time, it was decided to give a tank of about 25 litres, which means that for about three top-ups of the fuel tank, the consumer will have to top up the urea tank only once.

Initially two materials were selected as candidates for the urea tank. One of them was steel substrate coated with zinc-nickel. The other material chosen for the urea tank was a High Density Poly Ethylene (HDPE) which is currently being used to make the plastic fuel tanks on the automotive trucks. It was observed that steel-based tank was heavier as compared to HDPE based tank. Further HDPE is also resistant to many of the solvents like petroleum products. Therefore, it became the first choice for the material of the tank. The tank is designed in PTC Creo 3.0 software and involved three iterations.

4.1 First Iteration:

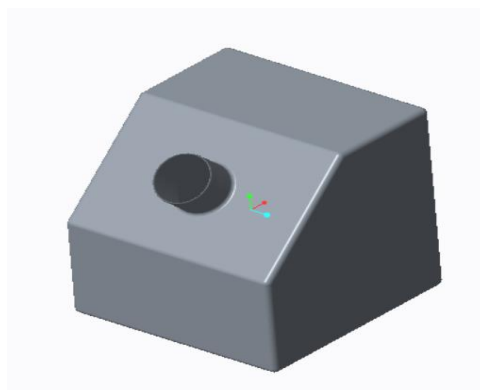


Figure 4.1 Model of Urea Tank

In the first iteration for designing the tank, a cubical profile was chosen. The dimensions of which were 300 mm across the cross section that is it was 300 x 300 x 300 mm each side. The total volume of the urea tank is 3% more than what is required because if exact volume is provided to a pressurised tank, it can explode due to excess pressure generated by the solvents. Therefore, it is always recommended that extra volume should be provided as a tolerance. The cad model of the first iterated tank is shown in figure 4.1 and the cross sectional dimensional are provided in figure 4.2:

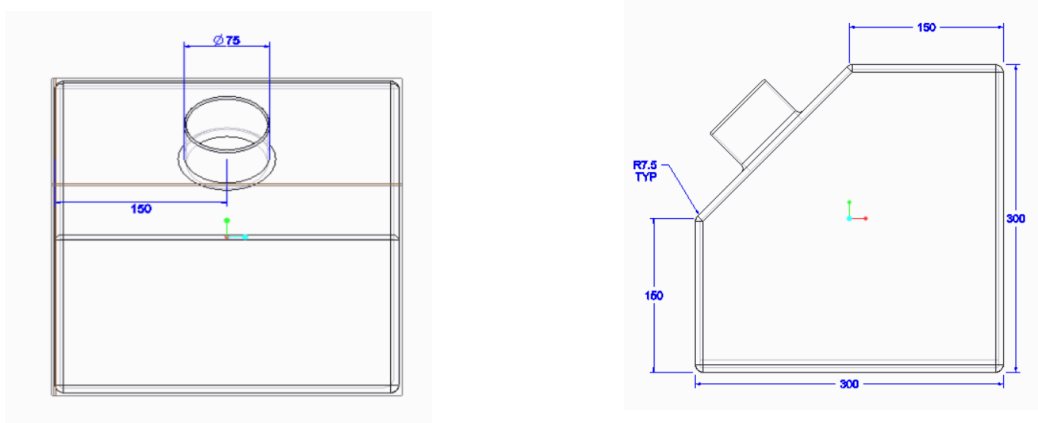


Figure 4.2 Front and Side View

The generated model was then tested for modal analysis. The analysis of the tank was done for the structural analysis and modal analysis for frequency response as per JIS 1601-1995 standard. The analysis was done in ANSYS software. The settings of the analysis have been shown in figure 3.3.

Details of "Analysis Settings"	
[-] Options	
Max Modes to Find	5
Limit Search to Range	Yes
Range Minimum	0. Hz
Range Maximum	500. Hz
[+] Solver Controls	
[+] Rotordynamics Controls	
[-] Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Calculate Reactions	No
Store Modal Results	Program Controlled
General Miscellaneous	No
[+] Analysis Data Management	

Figure 4.3 Analysis Settings for First Iteration

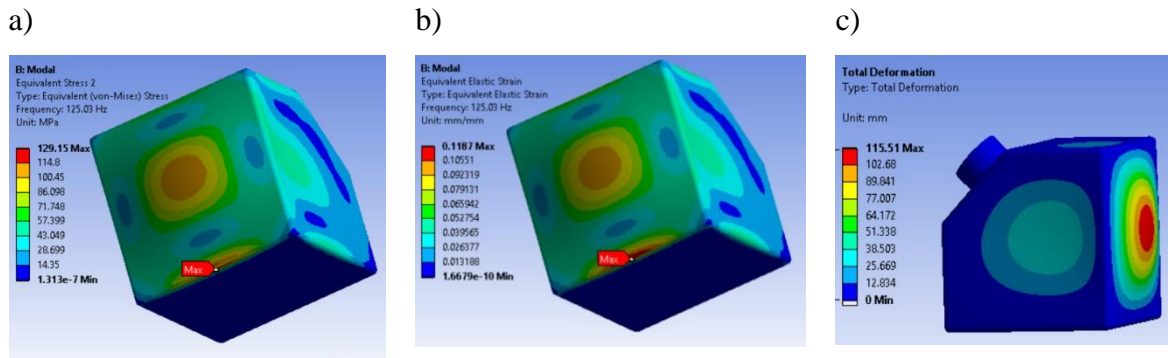


Figure 4.8 (a) Equivalent Stress Curve; (b) Equivalent Strain Curve; (c) Total Deformation Curve

The results of the modal analysis include the analysis of stress, strain and total deformation whose outcomes are presented in figure 4.4. As the total deformation is coming around 115 mm and the maximum equivalent stress is 129.15 MPa, these values are out of the acceptable limit because the maximum yield stress of the material is 24 MPa. So further analysis of the model was not done. Due to the failure in the above model, there was a need to change the above design and so was done. Also, due to space constraint on the vehicle, a cuboidal shape tank has been chosen as the optimum design for the urea tank. Also, earlier models of TATA motors which had Urea based Selective Catalytic Reduction (SCR) have a cuboidal shaped urea tank [18].

4.2 Second Iteration:

For the second iteration of the tank, a cuboidal design was selected making it more compact in shape resulting in taking lesser space on the vehicle. The tank was again designed keeping 3 % extra volume. The dimensional views of the tank along with the cad model are as follows.

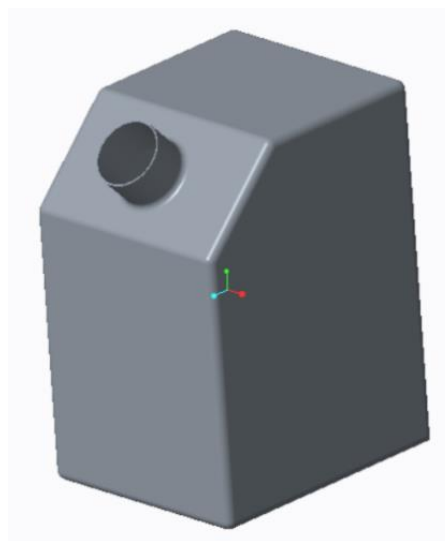


Figure 4.9 Modelled Urea Tank

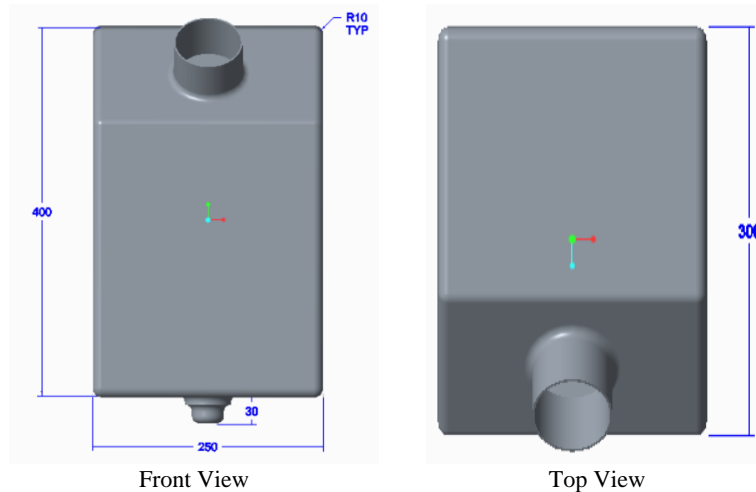


Figure 4.10 Dimensional View of Second Iteration

The analysis of the tank was done for the structural analysis and modal analysis for frequency response as per JIS 1601-1995 standard. The analysis was done in ANSYS software. The settings of the analysis have been shown in figure 4.7.

Details of "Analysis Settings"	
Options	
Max Modes to Find	5
Limit Search to Range	Yes
Range Minimum	0. Hz
Range Maximum	500. Hz
Solver Controls	
Rotordynamics Controls	
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Calculate Reactions	No
Store Modal Results	Program Controlled
General Miscellaneous	No
Analysis Data Management	

Figure 4.11 Analysis Setting for Second Iteration

The modelled tank had a reduced stress and deformation as compared to the first design but it was also failing as the deformation was coming out to be 76 mm and stress was 41.96 MPa, which was again beyond the permissible limit.

As the model in the Figure 4.8 is failing very near to the boundary limit so it was decided to keep the shape but do some modifications in the current shape only. So, the new shape modelled was similar in design but with some different dimensions.

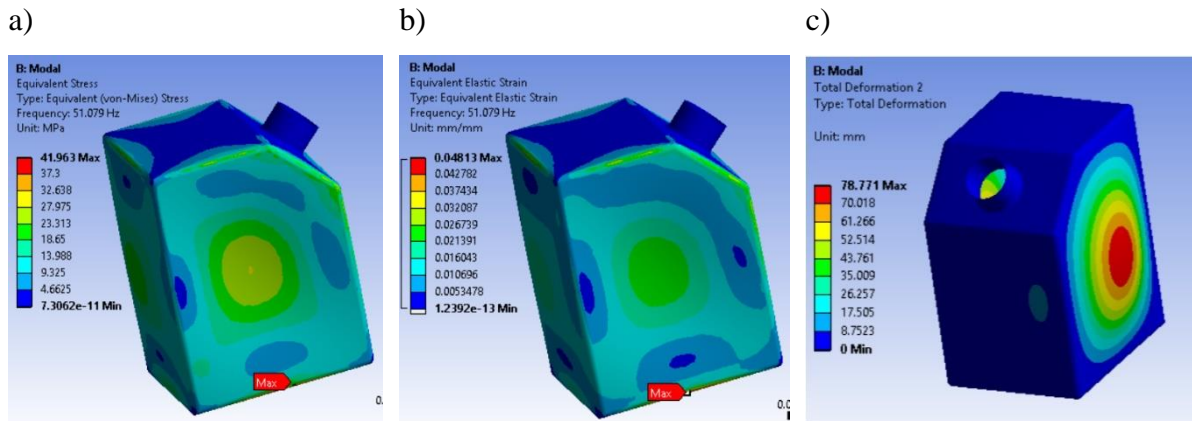


Figure 4.12 (a) Equivalent Stress Curve; (b) Equivalent Strain Curve; (c) Total Deformation Curve

4.3 Third Iteration:

In this iteration, the modelled shape is similar to the second design but the dimensions were changed so as to make minor changes in the profile of the tank. The modelled shape is as follows:



Figure 4.13 Model of Third Iteration

The dimensional views of the urea tank are as follows:

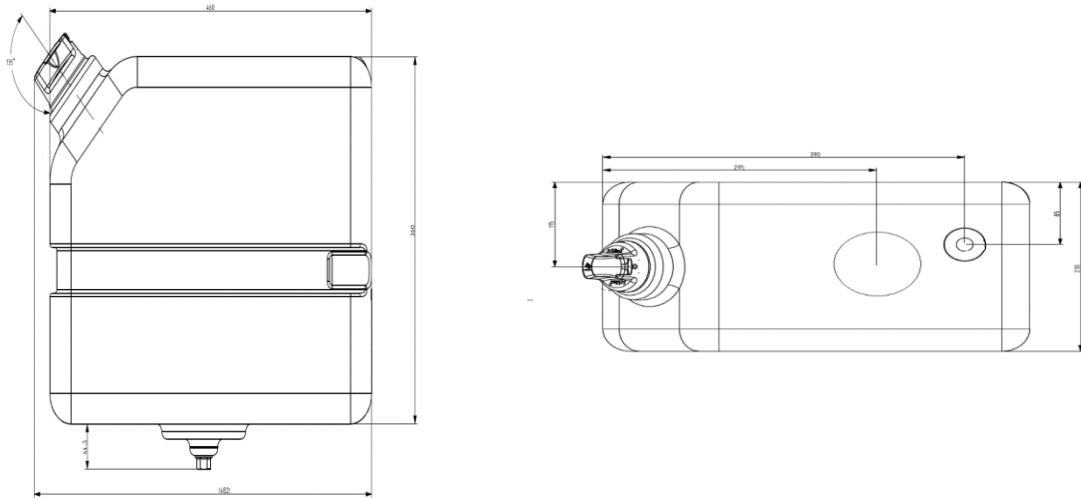


Figure 4.14 Dimensional View of Third Iteration

The analysis of the tank was done for the structural analysis and modal analysis for frequency response as per JIS 1601-1995 standard. The analysis was done in ANSYS software. The settings of the analysis have been shown in figure 4.11

Details of "Analysis Settings"	
Options	
Max Modes to Find	5
Limit Search to Range	Yes
Range Minimum	0. Hz
Range Maximum	500. Hz
Solver Controls	
Rotordynamics Controls	
Output Controls	
Stress	Yes
Strain	Yes
Nodal Forces	No
Calculate Reactions	No
Store Modal Results	Program Controlled
General Miscellaneous	No
Analysis Data Management	

Figure 4.15 Analysis Setting for Third Iteration

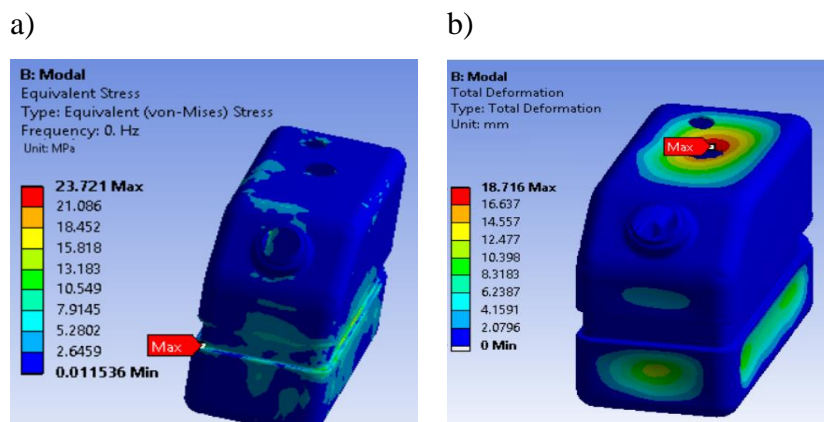


Figure 4.16 (a) Equivalent Stress Curve; (b) Total Deformation Curve

The remodelled tank had a reduced stress and deformation as compared to the first and second design. The deformation is coming out to be 18.71mm which is within the permissible limit and stress is 23.721MPa which is lesser than the Tensile Yield Strength of the material at 24 MPa. Therefore, this design was finally selected to be mounted in the bracket which will be further fabricated for it with the help of straps and other auxiliary brackets.

Chapter 5

DESIGN OF MOUNTING BRACKET FOR UREA TANK

The mounting of the urea tank designed in the previous chapter requires a mounting bracket so that it can be fitted in the exhaust system. The main requirement of the mounting bracket is that it should be structurally strong enough to maintain the urea tank in a fixed position and also remain rigid enough. In view of the above-mentioned criteria's, the initial design of the bracket was done by taking the reference from the urea tank mounting of another vehicle. A similar kind of packaging of the tank was tried but the same packaging could not be done due to unavailability of the space, so a new design was done. The location of the mounting bracket was selected in such a way that it was near the exhaust pipe in which the urea is to be dosed. The designing of the bracket was done using the software PTC Creo 3.0.

The design of the bracket is a simple bend bracket with holes being provided at certain locations so as to mount it on the frame of the vehicle and also to fit in the urea tank and its dosing control unit. For making the bracket, the material selected was the hot rolled steel. The material was selected because this is the material which used to fabricate these kinds of brackets in TATA motors. The first design made was made with 4 mm thickness of material with cuts being provided in it so save the weight. The design being as follows in figure 5.1.



Figure 5.1 Designed Bracket

The bracket designed was of Left-Hand part of the complete mounting bracket. A 100 % similar bracket was made for the Right-Hand part of the urea tank mounting bracket and was then assembled using the smaller auxiliary brackets like baseplate, top strap, front strap and back strap. The design of the baseplate is with length as 214 mm and width as 100 mm with a 4 mm thickness. The bends provided has a hole of 12 mm diameter for the bolting this bracket to the main bracket. Two base plates are present in the design one in the front and one at the back. Both of the plates are joined to the bracket using grade bolts.

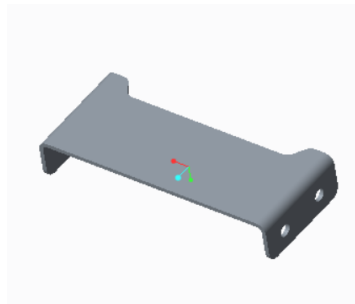


Figure 5.5 Baseplate

Along with these baseplates there are three straps namely front, back and top in the assembly. The top and back straps are of same size and shape. These are the straps are also bolted to the main bracket. The straps are 4 mm thick with a length of 170 mm and width of 45 mm.

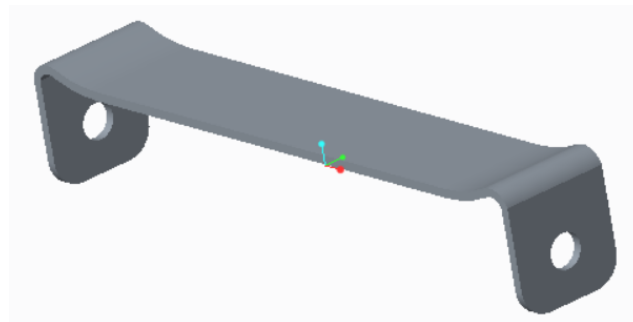


Figure 5.6 Back and top strap

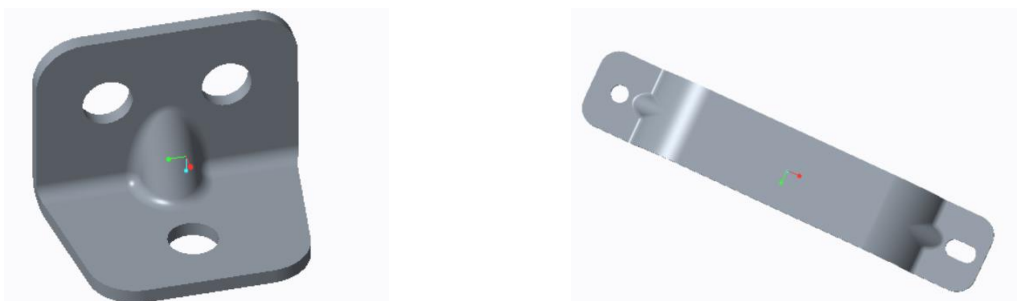


Figure 5.7 (a) Side bracket of Front Strap; (b) Front Bracket

The front strap is an assembly of 3 brackets i.e. 2 side brackets and one main bracket. This is done because of the design of urea tank.

Both of the brackets are 4 mm thick. Both of the brackets were then assembled together using the bolts and then were attached to the final bracket assembly. The final bracket assembly is as follows.

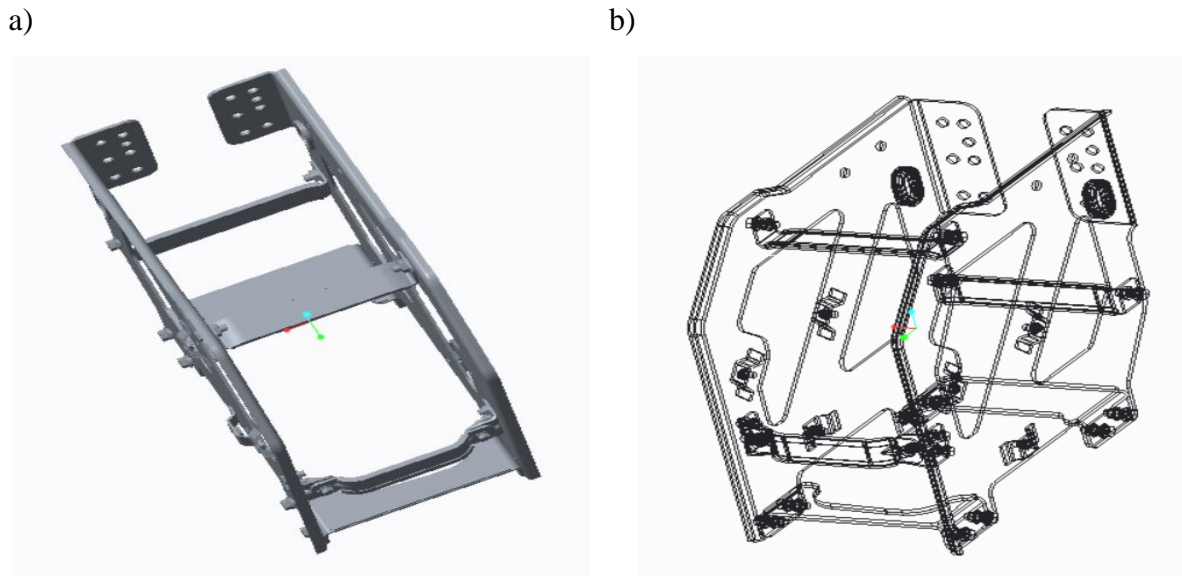


Figure 5.8 (a) Urea tank mounting bracket assembly (b) Wireframe Model

Then the complete assembly of the bracket was done with all the components joined together and then the bracket designed was tested for the vibration endurance test by the help of CAE and it was found out that the bracket assembly is failing the analysis so the bracket assembly was not suitable for the production. The CAE analysis is as follows

5.1 First Iteration of the Analysis:

The analysis was done in accordance to JIS 1605-1995 standard which states that any part mounted on the motortruck must be tested for the vibration endurance testing. In the first iteration of the test modal analysis was performed and it was found that the stresses induced in the bracket were at the borderline condition as shown in the figure 5.9

As it was a case of failed design, changes like addition of reinforcements were suggested to make it strong. A reinforcement of 7 mm thickness was designed. The profile of the reinforcement is kept same as the bend of the bracket having similar holes. Once the reinforcement was added the analysis was done once again.

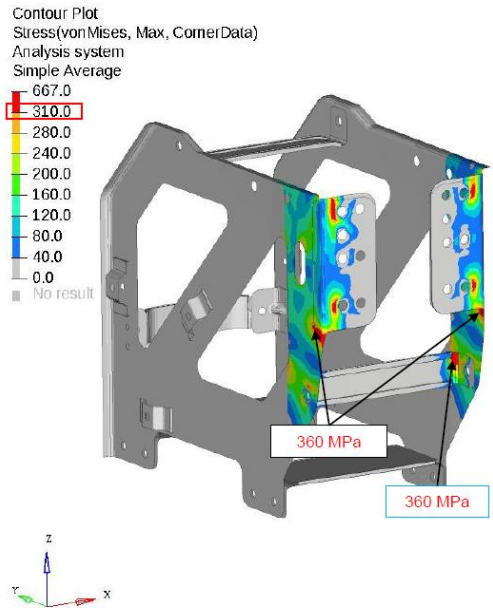


Figure 5.9 Stress Plot for the designed bracket

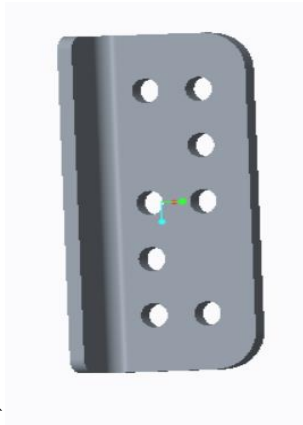


Figure 5.10 Reinforcement of the bracket

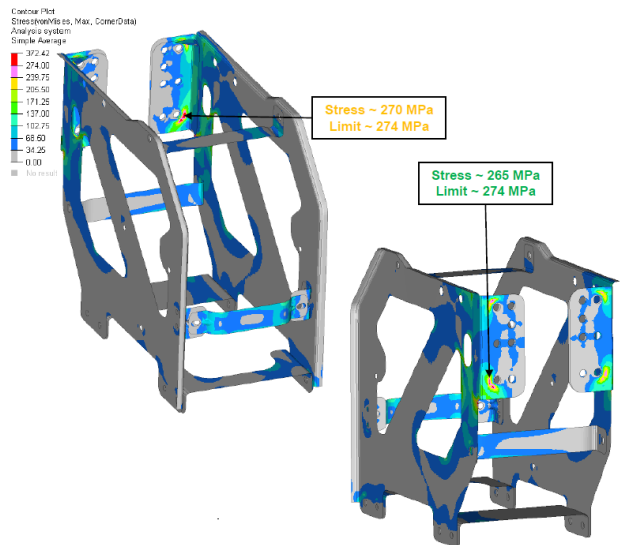


Figure 5.11 Stress plot after addition of reinforcement

5.2 Second Iteration of the Analysis:

Similar analysis was performed after the addition of the reinforcement to the bracket but then also the overall stresses were coming as a borderline case as shown in Figure 5.11. Therefore, design changes were incorporated.

5.3 Third Iteration of The Analysis:

As the second iteration of analysis of the bracket was a borderline case it was suggested to add ribs near the bends. So, a rib was made up of same thickness and was added to the bracket. The design of the rib is as follows.

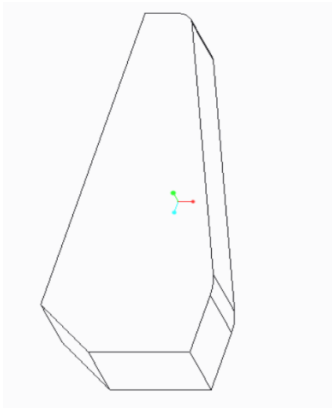


Figure 5.12 Rib of the bracket

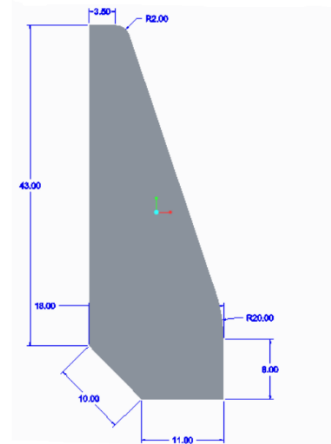


Figure 5.13 Dimensional View of the rib

The rib was then attached to the reinforcement of the bracket with the help of welding. And the reinforcement was also welded to the original bracket. The bracket was then taken for CAE analysis and was found out strong enough to hold the filled urea tank. The final designed urea tank mounting bracket is as follows:

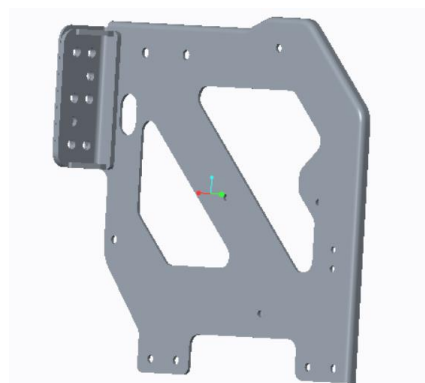


Figure 5.14 Final designed bracket

After the addition of the suggested components the bracket was modelled once again and was submitted for CAE the following results were obtained.

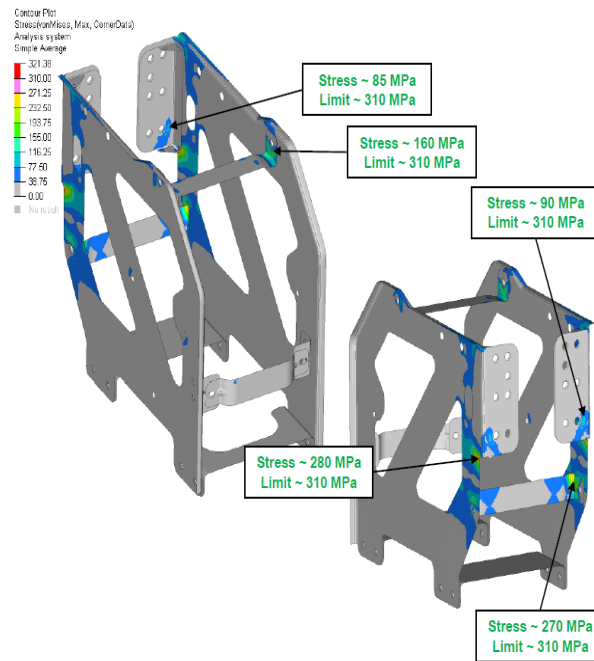


Figure 5.15 Final testing of the bracket

The stress limit was 310 MPa the stresses were within acceptable limits hence; the final design of bracket was submitted for the fabrication and the final testing by mounting it on the actual vehicle.

Chapter 6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusions

- 1) The urea tank once designed was then fabricated and tested in real world conditions and it was found optimal in design and utilization hence the final dimensions of the urea tank are shown in figure 6.1.

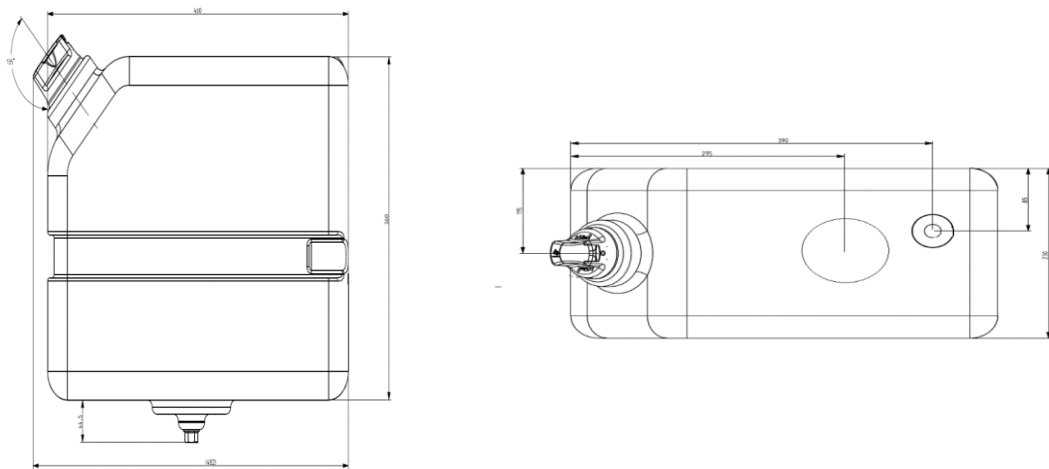


Figure 6.1 Dimensional View of Third Iteration

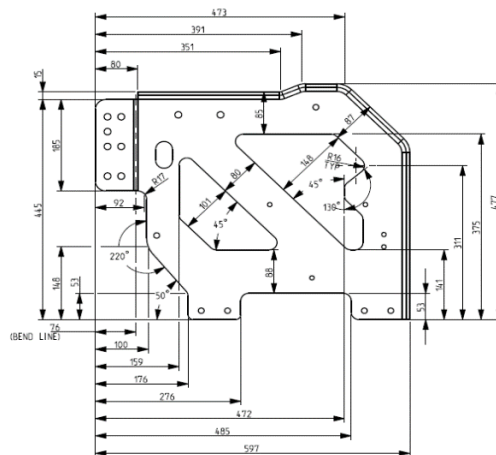


Figure 6.2 Developed Dimensional View of the Bracket

- 2) The mounting and holding bracket were also fabricated and tested in the real world conditions and was found optimal in holding the filled urea tank and its dosing unit. So,

the bracket was also released for final fabrication. Once fabricated it will be mounted on future ULTRA 1518 BS-6 vehicles.

6.2 Future Scope

1. Weight reduction of urea tank.
2. Weight reduction of the mounting and holding brackets

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