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Designing and Analysis of CNG Tank and Frame Structure for Two-Wheeler SI Engine

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Abstract- **Government of India's philosophy of going green to reduce emission levels, in cities there is a thrust to increase the gas distribution network. With an increase in naturel gas (CNG) vehicles. However, in last few year there are so many gas operated vehicle in automobile industry, manly it consist four wheeler, auto, bus, etc. but very few in two wheeler. It is one type of research gap in two-wheeler. Looking to Indian scenario population is increasing and economy the number of two-wheeler user also increasing very broadly, compare to any other wheeler. Which are major issue to increasing emission, which harm the environment. There for it is required to reduce exhaust emission and economic vehicle operation.**

To adopt CNG vehicle for current used, it is required new innovative design of gas storage tank, especially for two-wheeler. It also required to investigate enough space and proper location of storage tank for conventional vehicle. In this research, work doing on designing gas tank for two-wheeler with respect to safety aspects. And also protect to gas tank, we used trellis frame structure, which adequate space and safety with batter performance. The modelling is done on SOLID EDGE, and analysis done on ANSYS 16 software.

Keywords –CNG Gas Tank, Frame Structure, Two-wheeler, CNG Bike, alternate fuel .

I. INTRODUCTION

Air pollution refers to the contamination of the earth's environment with constituents that have considerable effects on human health. The quality of life or the natural environment gets affected when pollutants accumulate in the air at higher concentrations [1]. Vehicles emissions have become the fore most source of air pollutants including carbon monoxide, lead, nitrogen dioxide, sulphur dioxide, ozone and particulate matters [2]. Vehicles emission mainly from automobiles is responsible for about two third of air pollution in the urban area. Vehicles emission mainly from automobiles is responsible for about two third of air pollution in the urban area. Petrol engines exhaust contains high concentration of HC whereas the diesel vehicular exhaust has higher concentration of particulate matter, NOx and CO_2. The concentration of CO and unburnt HC in the diesel exhaust are slightly lower as compared to petrol engine [3]. The increase in the number of vehicles can be taken as a measure of the economic development of the Indian automotive industry. About 7-8 million vehicles are produced annually in the country today [4]. In 2004 country had reported 72.72 million registered vehicles whereas in 2013 it increased to 182.45 million, so the registered motor vehicles has almost more than doubled in last 10 years as is also shown in detail in Table 1 [5]. Motors Vehicles are the primary source of air pollution in India's major cities. Two-third (66%) pollutants are reported to be released from vehicles in Delhi alone, 52% in Bombay and close to one-third (33%) in Calcutta. The transportation sector in India consumes about 17% of total energy and responsible for 60% production of the greenhouse gases emission from various activities [4].

Categories	Co_2	Co	No_x	SO	PM	HC
	g/km/year					
Bus	28748.16	207.26	679.73	79.24	31.36	51.72
Omni Buses	8508.42	60.94	200.53	23.45	9.28	15.11
2-Wheeler	**8701.08**	**719.64**	**62.15**	**4.25**	**16.36**	**464.49**
LMV(Passenger)	4378.10	370.29	92.93	2.11	14.52	10.16
LMV(Goods)	44654.58	442.04	110.94	123.02	17.33	12.13
Cars and Jeep	23901.22	212.30	22.14	5.67	3.22	38.01
Taxi	2367.08	10.23	5.68	117.05	.80	1.48
Others	5705.22	57.41	64.54	32.19	3.98	8.96

Emission from different vehicles as reported in India [4]

A. Importence of two wheeler in india –

Now days in India population is increasing day by day, and number of auto vehicle user are also increasing. The two-wheeler is most popular vehicle to get to work in India. According to ice 2016 survey the chart table shows the different automobile vehicle user in various locations. It also shows, two-wheeler user is very huge compare to other vehicle in various locations. [10].

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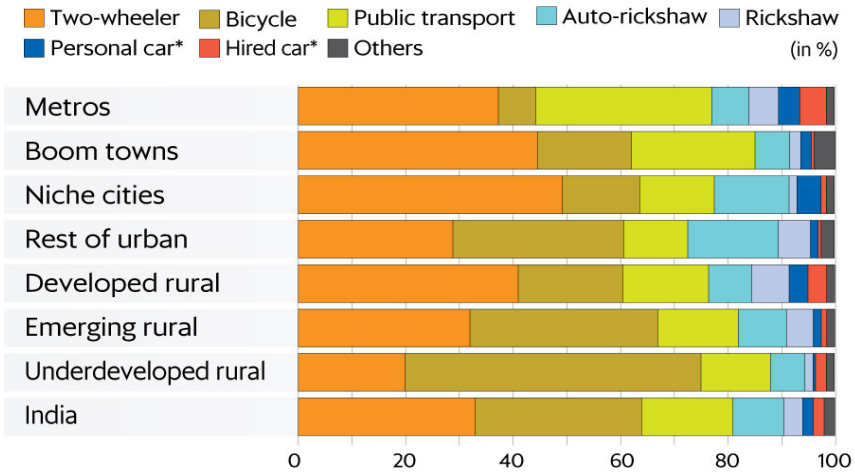


Chart Table Shows Different Vehicle Work with Various Location [30]

The large fleet share and rapid growth of two vehicles in India means that careful attention must be paid to reducing emissions and fuel consumption from these vehicles. As per the Society of Indian Automobile Manufacturers (SIAM) is the apex Industry body representing leading vehicle and vehicular engine manufacturers in India. Bellow chart shows two-wheeler operators are more and sailing of two-wheeler is increasing 12.26% in previous year 2016 as per SIAM source.

B. Designing a frame structer –

Among all this frame, best suitable frame for our resource is trellis frame, due to its tubular structure and high strength.

Figure 1. Trelis frame and model

Specification

Overall length: 1300mm
Overall width: 397mm
Material: aluminum alloy, composite material
Día of tubular pipe: 30mm
Thickness: 4mm
Weight:6.871kg
Overall Height:1165
Wheelbase: 1350
Ground Clearance: 150
Seat Height:790mm

Material Selection

Sl No	Material	Young's modulus E Gpa	Possion's ratio	Density Kg/m^3	Yield stress Mpa	Ultimate tensile stress Mpa
1	Steel	210	0.3	7850	350	490
2	Aluminium alloy 6063	68.9	0.33	2700	214	241
3	Carbon fibre	73.1	0.33	2780	324	469
4	Titanium	119	0.34	4430	880	900

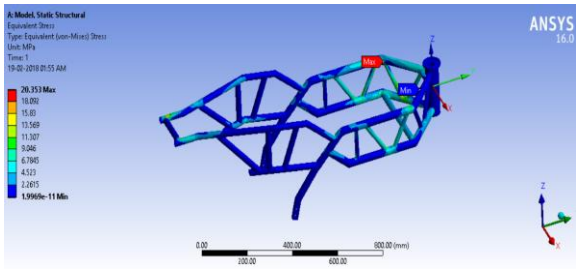
Material property [23]

Boundary Conditions

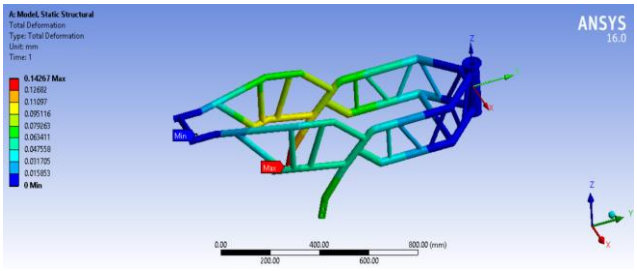
The rear end portion and portion of handle in front is made fixed (as shown in figure 4 by whitish portion) and then various loads are applied and the analysis was done.
Load Conditions Applied
Rider Weight=70kg
Pillion Weight=70 kg
Fuel Tank Weight=20 kg
Engine Weight=40 kg
Total load = 2000N

Stress analysis

Steel

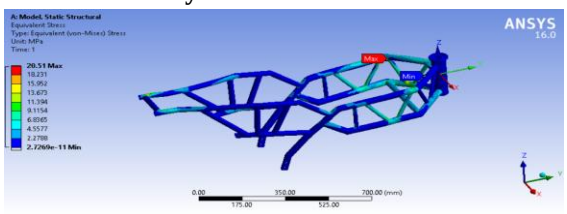


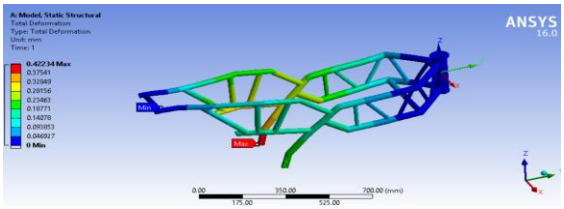
Stress Analysis



Deformation Analysis

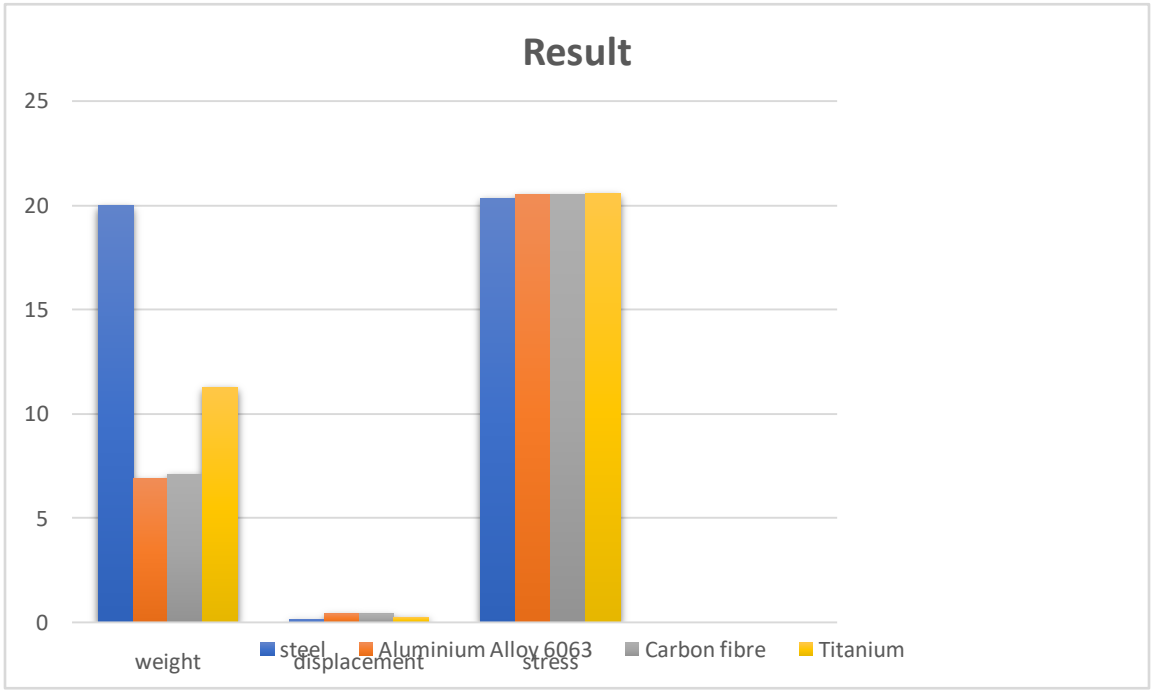
Aluminium Alloy 6063





Result comparison

Sl no	Material	Max. stress in Mpa	Max displacement in mm	Weight in kg
1	Steel	20.35	0.1426	19.991
2	**Aluminium Alloy 6063**	**20.51**	**0.431**	**6.8751**
3	Carbon fibre	20.51	0.410	7.079
4	Titanium	20.558	0.252	11.281

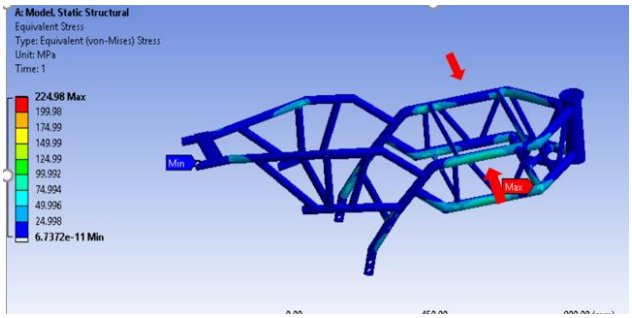


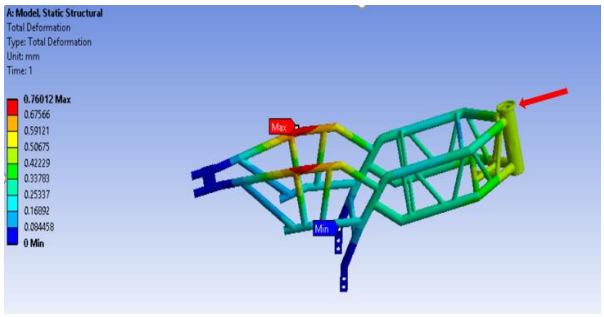
Stress Vs Displacement

Validation

From results of finite element analysis of chassis, it is observed that stresses are maximum at joint locations. It is also observed that all the materials have stress values less than their respective permissible yield stress values. So, the design is safe. [23]
Among this material, aluminium alloy 6063 is best suitable material for our frame structure, because it has similar stress and displacement with least weight compare to others material.

Impact Test on Frame Structure At 8000N





Impact test results

Direction	Deformation (mm)	Stress (Mpa)
Front	0.76012	78.866
Right and left	1.606	224.98

To increasing impact strength of frame, provided a many truss and cross member is designed to sustain various types of load. For front impact load, cross member is attached to frame, which Is more safety provided to tank, and it is shows in fig.

Designing gas tank

The innermost layer is made of High density polyethylene (HDPE) and is called Liner. The properties of HDPE are given below in the Table 1 (Zhang (2009)).

Material Property of HDPE Liner (34, 35)

Density (g/cm3)	Tensile Strength (Mpa)	Elastic Modulus (Gpa)	Poisson's ratio
0.92-0.95	10-16	69.2	0.499

The mechanical properties of glass/epoxy and carbon/epoxy laminated composite board used as the outer reinforcement layers are depicted in Table.2

Mechanical properties of glass/epoxy laminated composite board

Property	Unidirectional Glass/Epoxy
In-plane longitudinal modulus (GPa)	20.6
In-plane transverse modulus (GPa)	17.2
In-plane shear modulus(GPa)	17.3
In-plane Poisson's ratio	0.117
Out-of-plane Poisson's ratio	0.112
Out-of-plane Poisson's ratio	0.114
Longitudinal tensile strength (MPa)	380
Transverse tensile strength(MPa)	334

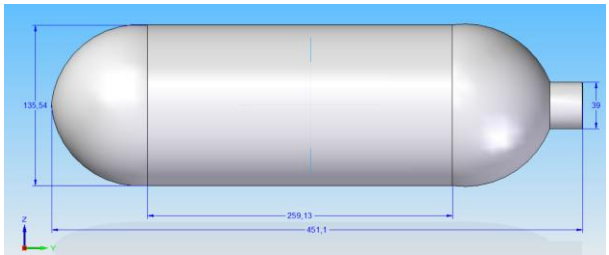
Load and Boundary Conditions

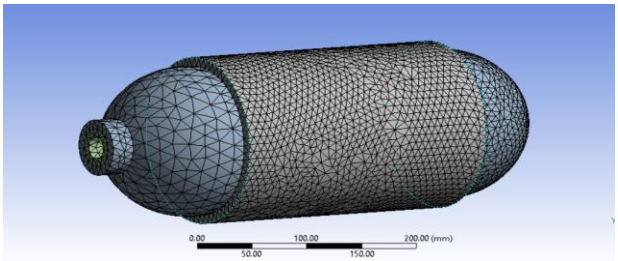
Tests were performed at three different pressures i.e. operating pressure of 20 MPa, water test pressure of 30 MPa and design bursting pressure of 73 MPa (Table 3) and hoop constraint is applied at the end of the cylinder. (ISO11439) (33)

Operating conditions of all-composite gas cylinder (Yue and Li (2012), ISO 11439) (33,34).

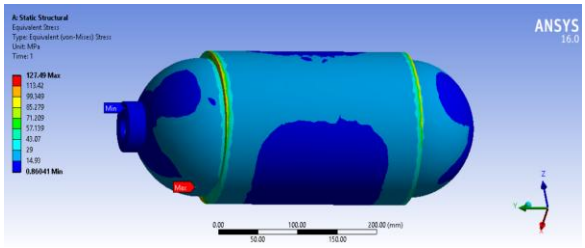
Operating temperature	Operating pressure	Filled medium	Water test pressure	Design bursting pressure
-40 ^{0}C to 60 ^{0}C	20Mpa	Natural gas	30 Mpa	73 Mpa

Design (cylinder)

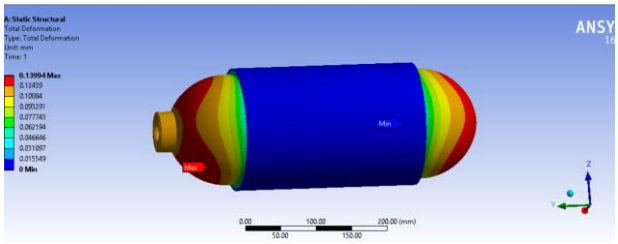




Operating Pressure of 20 Mpa



Stress distribution



Deformation

Similarly find the stress and deformation at 30Mpa and 70Mpa

Dimensions of Designed tank

Overall length:	460.14mm
Width:	171.54mm
inner volume:	$4.19e^{-12}mm^3$
Thickness:	7.5mm+9mm+9mm
Layer: 3 layers	HDPE+ epoxy(helical) +epoxy(hoop)
surface volume:	4.2181e+006 mm^3
weight (without gas):	6.29
gas capacity	600grm apox
Remaining volume in frame structure	$43.33e^{06}mm^3$
Running km	108km

Analytical Calculation of Principal Stress and Max Shear Stress (36)

Pressure (Mpa)	Strain at different direction ε	μ Strain value ($\frac{mm}{mm}$)
20	X	0.001173
	Y	0.001416
	Z	0.002012
30	X	0.001885
	Y	0.002108
	Z	0.002526
73	X	0.00321
	Y	0.00412
	Z	0.00361

For 20Mpa,

$\varepsilon_x = 0.001273$, $\varepsilon_y = 0.001396$, $\varepsilon_z = 0.002012$

$\acute{y}_{xy} = 2\varepsilon_y - \varepsilon_x - \varepsilon_z$

$\acute{y}_{xy} = 2(0.001396) - (0.001273) - (0.002012)$

$= -493$ **μ**

Principal Stress

$$\sigma_x = \frac{E}{1-\nu^2}(\varepsilon_x + \nu\varepsilon_y)$$

$$\sigma_x = \frac{69.2 * 10^9}{1-(0.499^2)}[0.001173 + (0.499 * 0.001416)]$$

$\sigma_x = 165.65$Mpa

$$\sigma_y = \frac{E}{1-\nu^2}(\varepsilon_y + \nu\varepsilon_x)$$

$$\sigma_y = \frac{69.2 * 10^9}{1-(0.499^2)}[0.001416 + (0.499 * 0.001173)]$$

$\sigma_y = 184.32$Mpa

Max shear stress

$\tau_{max} = \frac{\sigma_x - \sigma_z}{2}$ or $\tau_{max} = \frac{pr}{2t}$

where, p – is internal pressure(mpa)
r – inner radius of cylinder (mm)
t – thickness (mm)

$\tau_{max} = \frac{20*42}{2*7.5}$ = 56Mpa

Now, similarly find for another pressure

Principal Stress and Shear Stress at 30Mpa

σ_x =187.32Mpa
σ_y =241.65Mpa
τ_{max}= 84Mpa

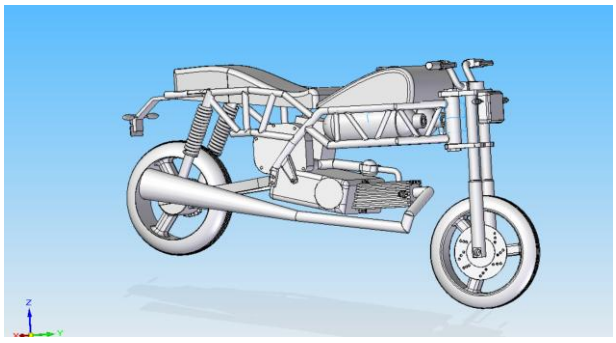
principal stress and shear stress at 73Mpa

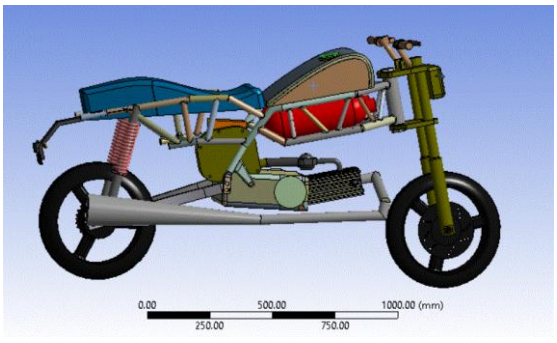
σ_x =483.35Mpa
σ_y =524.67Mpa
τ_{max}= 204.4Mpa

Result comparison

	Pressure (Mpa)	FEM Analysis	Analytical
Maximum Principal Stress (Mpa)	20	101.81	165.65
	30	153.34	187.32
	73	374.93	483.35
Maximum Shear Stress (Mpa)	20	53.606	56
	30	80.98	84
	73	198.76	204.4

Assembly of Frame Structure and CNG Gas Tank

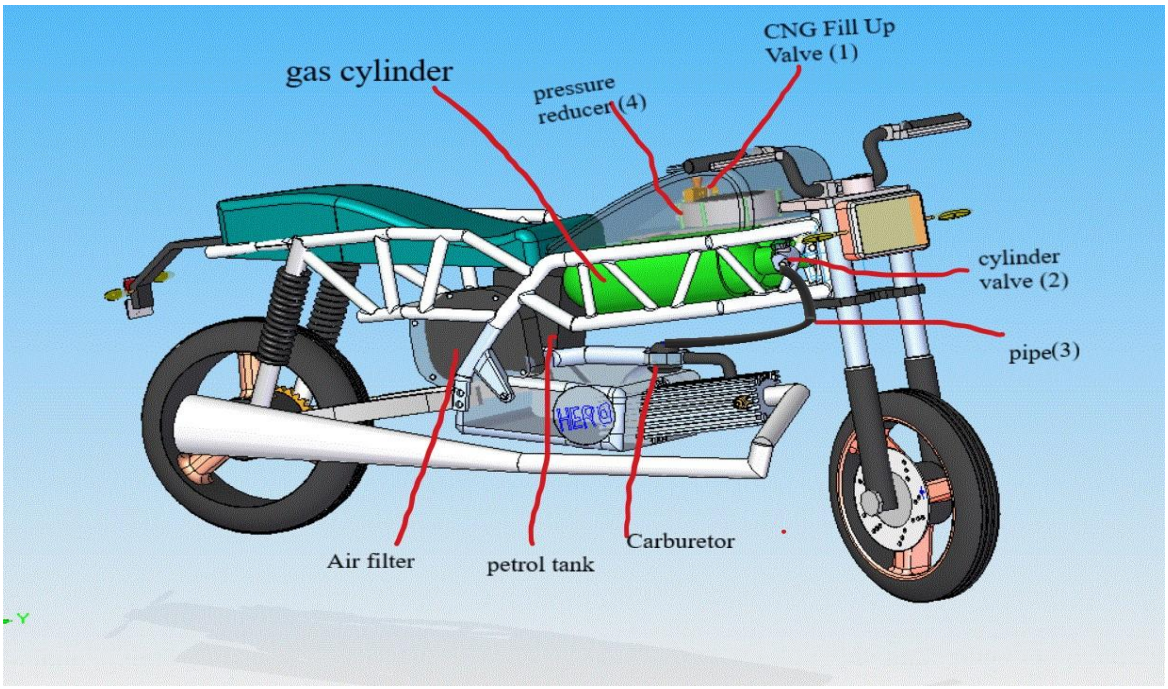




Important Specification

Fuel capacity	3liter petrol + 1.2 kg CNG gas
Over all weight	98.67 kg
Average	70km/ liter petrol and 90km / kg CNG
Total running kilometre	290km at full condition

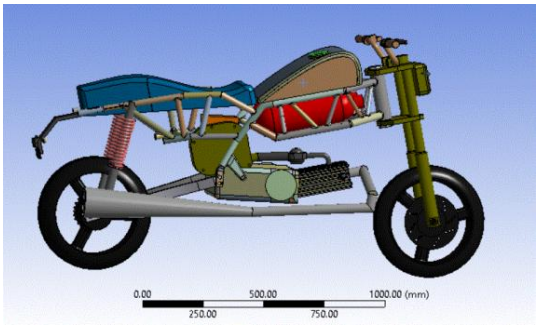
CNG Bike Layout (Management)



Final Compression

Hero splender

CNG motorcycle



DIMENSION		CNG BIKE
Length	1970mm	1870 mm
Width	720 mm	467 mm
Height	1040 mm	1020 mm
Saddle height	785 mm	700 mm
Wheelbase	1230 mm	1320
Ground clearance	159 mm	210 mm
Fuel tank capacity	11 litres petrol	Gas:2.9kg and petrol: 3 litres
Kerb weight	110 kg	107.26kg
Max payload	130 kg	130 kg
Chassis type	Tubular double cradle type	Trellis
Tyre Size Front	2.75 x 18 - 42 P / 4 PR	2.75 x 18 - 42 P / 4 PR
Tyre Size Rear	2.75 x 18 - 48 P / 6 PR	2.75 x 18 - 48 P / 6 PR
Service cost		
Cost	43,000/-	63000/-

Over All Mass Calculating

Petrol tank weight

Empty tank = 4.6 kg

Fuel mass = density * volume

= 0.77kg/ litter * 12 litter

= 9.24 kg

Total fuel tank weight = 13.84 kg

Frame weight =11.98kg

Total mass of petrol bike 110 kg

CNG tank weight total = 13.39 kg

Empty petrol tank mass = 600 gram

Fuel Mass = 0.77 kg/ litter * 3 litter

= 2.91 = 3 Kg

Pressure Reducer Weight = 2kg

Total Fuel Tank Mass = 13.39kg + 3kg

=16.39kg

Frame Wight = 6.8kg

Total mass of CNG bike 107.26kg

IV.CONCLUSION

In the present study of design, a frame structure for cng gas tank in two-wheeler, results are discussing bellow.

Structural analysis trellis frame has been done on by using four materials viz. steel, aluminium alloy 6063, carbon fibre and titanium. The maximum stress values are coming out to be 20.35 MPa, 20.51 MPa, 20.51 MPa, 20.55 MPa respectively. From the results it is observed that the stresses are maximum at joint locations and also for all the materials the stress values are less than their permissible yield stress values. So, the design is safe. By using aluminium alloy 6063 as the material has less density compared to other materials used and is also cheap in cost, this is the best suited alternate material for the chassis and is expected to perform better with satisfying amount of weight reduction. Impact stress analysis also done on frame structure, for safety of gas tank from impact loading. this impact test result is shows the strength of frame structure at deferent load condition. This strength is increased due to number of truss member are attached.

Designing a composite pressure vessel by utilize optimum space available in frame structure. Result of Stress analysis on various pressure condition, working pressure, test pressure and hydraulic burst. The maximum stress values are coming out to be 101.81 MPa, 153.34 MPa, 374.93 MPa, respectively. From result we observed that all the von miss stress is less than the allowable stress, so designed is safe. Correlation between the analytical prediction and numerical simulation result are presented and discussed. The analytical max principal stress and shear stress is calculated and compare with FEM model which are similar.

The manufacturing of CNG motorcycle by using of aluminum 6063 alloy trellis frame with CNG tank, so that safety of gas tank increased and motorcycle weight is similar to petrol bike.

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