ICSD/39

DESIGN OF COMPONENTS OF AIR POWERED VEHICLE

Trupti Chavan[1],
[1]Department of Mechanical Engineering, New Horizon Institute of Technology & Management, Thane, Maharashtra[1]Trupti Chavan: tc199789@gmail.com

Priyanka Chaugule[2],
[2]Department of Mechanical Engineering, New Horizon Institute of Technology & Management, Thane, Maharashtra priyankachaugule98@gmail.com

Pratiksha Vishwasrao[3],
[3]Department of Mechanical Engineering, New Horizon Institute of Technology & Management, Thane, Maharashtra

Prof. Pravin Alone[4]
[4]Department of Mechanical Engineering, New Horizon Institute of Technology & Management, Thane, Maharashtra pbalone_811@rediffmail.com

Abstract
The paper focuses on the design procedure and calculations of the main components of the compressed air vehicle. To reduce the emission of harmful gases from conventional vehicles, the use of a compressed air as fuel is the one alternate way. It can be used to travel on small campuses like an airport, golf ground, industrial areas, etc. Some more technologies are needed to introduce which will improve the performance of the compressed air engine.

Keywords: Compressed air vehicle, Chassis Design, Engine Design, Steering system Design

1. Introduction

The compressed air engine works similar to the conventional engines. It requires two strokes to complete one power cycle viz. suction (or expansion) stroke & exhaust (or compression) stroke. The compressed air stored in tank is supplied to the engine. Where air get expand causing piston to move down. Then air escapes from outlet valve. This is the principle working of compressed air engine.

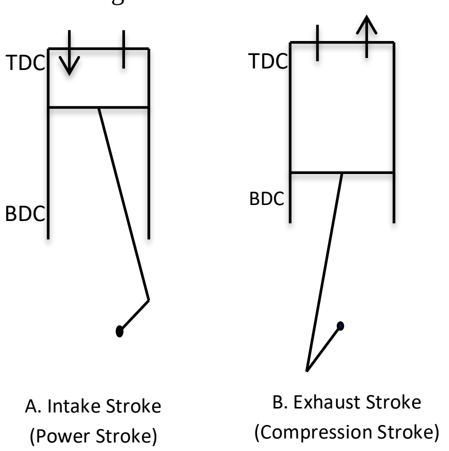

Fig. 1. Working principle of compressed air engine

An existing engine can be used as compressed air engine by some modifications. To design the car, some parameters need to be assumed or fixed for which the car will be designed like torque or speed etc. The paper aimed to design the car for high speed which would be for one person only. It is a rear engine rear wheel drive. The design of an engine, steering system, frame, axle and transmission system is discussed.

2. Problem definition

Recently, due to civilization, the frequency of automobiles has been increasing enormously and transport sector utilizes a huge quantity of fuels like petrol, diesel, natural gas etc. many environmental problems such as global warming, ozone layer depletion etc. are emerging due to the combustion of fossil fuels. From the survey result by the government of India, —"Ministry of Petroleum & Natural Gas" it is found that, 70% of diesel & 99.6% of petrol consumed by the transport sector [1]. So, to reduce such problems it is essential to find some alternative fuel. Compressed air will be better replacement for conventional fuels. Air has the property to get compressed to very high pressure and retain it for a long period of time. Air is cheap and can be found everywhere in the atmosphere. So, it can be used as an alternative fuel for the automobiles. So, the utilization of conventional fuel will be minimized.

3. Literature Review

Lots of exploration & evolution related to the design of an air engine & the car is been going on. Many research papers related to the development of air engine and car have been published. Many more modifications and development has been done to improve the performance of compressed air vehicle. Attempts have been made to use existing engines as a compressed air engine.

Vishwajeet Singh has modified a 4 stroke engine into 2 stroke to convert it into a compressed air engine by modifying the camshaft, speed ratio, inlet valve, inlet and outlet valve springs [2].

Rohamane R. V., et al has also converted 4 stroke engine into 2 stroke engine but they had used Hero Honda Pvt. Ltd. engine and got 1650 rpm at a 4-3 bar and 1600 rpm at 3-2 bar [3].

Bharat R. Singh, J.P. Yadav has made the prototype of compressed air engine. He has used horizontal single cylinder low-speed engine at 10-17 bar by operating various solenoid valves. The mechanical efficiency obtained about 20% [4]. There are many comparative studies had also done.

Ruchil Patel has compared 4 stroke engine and a compressed air engine. The difference was the camshaft of compressed air engine has 2 lobes on cam profile instead of 1 [5].

Hemant Kumar Nayak, et al has compared fuel vehicle, compressed air vehicle, and battery electrical vehicle. For fuel vehicle, fuel weight and volume is less, greenhouse gas emission is high. For compressed air engine, fuel weight is high; there is no greenhouse gas emission. It can also be hybrid with other types of vehicle. For battery electric vehicle, it does not emit harmful gases, requires more space to store batteries, its maintenance cost is high [6].

4. Design

4.1. Design of Engine

Some parameters are considered for which engine is to be design are listed below.

Table 1. Considered Parameters for engine

Sr. No.	Parameters	Specifications
1	Car velocity	30 kmph
2	Gear reduction ratio	3
3	Radius of Wheel	0.15 m
4	Number of cylinder	1
5	Transmission Efficiency	80%
6	Mechanical Efficiency	80%
7	Gradient Angle	2.3°

4.1.1. To find various parameters required to propel a vehicle

The vehicle is subjected to air resistance (AR), rolling resistance (RR), gradient resistance (act while grade climbing) (GR) and inertia resistance (IR). Considering the car is traveling with constant velocity on gradient, the forces acting are AR, RR & GR. To find the power required to propel the vehicle, wheel diameter and speed of vehicle is decided.

$$Air\ Resistance(AR) = \frac{1}{2} \times \rho \times A_f \times C_d \times \left[\frac{v}{3.6}\right]^2 \qquad (1)$$

Where,
Car velocity(v) = 30 kmph
Radius of Wheel (r_w) = 0.15 m
Air density (ρ) =1.202 kg/mm^2
Car Frontal area(A_f) = 3.2 m^2
Coefficient of aerodynamic resistance(C_d) = 0.5

$$AR = 66.78\ \text{N}$$

$$Rolling\ Resistance(RR) = f_r \times mg \qquad (2)$$

Where,
Coefficient of rolling resistance(f_r) = 0.02
Car Mass(m) = 300 Kg
Acceleration due to gravity(g) = 9.81 m/s^2

$$\text{RR} = 58.86\ \text{N}$$

$$Gradient\ Resistance(GR) = w \sin\theta \qquad (3)$$

Where,
Gradient Angle (θ) = 2.3°
Weight of vehicle (w) = mg

$$GR = 118.37\ \text{N}$$

$$Total\ Resistance\ Force\ (F) = AR + RR + GR \qquad (4)$$

$$= 244.01\ \text{N}$$

$$Engine\ Requied\ Power\ (P_e) = \frac{F \times v}{\eta_t} \qquad (5)$$

Where,
Transmission efficiency (η_t) = 0.8

$$\therefore P_e = 2.5407\ \text{KW}$$

$$Engine\ Speed\ (N_e) = \frac{v \times i_t}{0.377 \times r_w} \qquad (6)$$

Where,
Gear reduction ratio (i_t) = 3

$$\text{N}_\text{e} = 1591.51\ \text{rpm}$$

$$Engine\ Torque\ Required\ (T_e) = \frac{P_e \times 10^3 \times 60}{2\pi N_e} \quad (7)$$

$$T_e = 15.24 \text{ Nm}$$

$$Torque\ at\ wheel\ (T_w) = \frac{9550 \times i_t \times \eta_t \times P_e}{N_e} \quad (8)$$

= 36.59 Nm

$$Power\ at\ wheel(P_w) = \frac{\eta_t \times N_e \times T_e}{9550} \quad (9)$$

= 2.03 KW

$$Car\ Tractive\ Effort\ = \frac{9550 \times i_t \times \eta_t \times P_e}{N_e r_w} \quad (10)$$

= 243.93 N

Since there are two strokes and according to the above calculations selecting Suzuki TS185 engine. Also, the small size engine will also occupy less space.

The Engine specifications are given below:

Table 2. Engine specifications

Sr. No.	Parameters	Specifications
1	Engine type	Air cooled
2	Number of cylinders	1
3	Displacement	183 cc
4	Bore x Stroke	64x57 mm
5	Maximum Power	18 HP @6000rpm
6	Top speed	138.4 kmph

4.1.2 To Find mean effective pressure required

$$P_e = \frac{pLANK}{60 \times 10^3} \quad (11)$$

Where,
Engine power (P_e) = 2.5407 KW
Bore diameter (d) = 0.064 m
Stroke length (L) = 0.057 m
Speed of engine (N_e)= 1591.51 rpm
Cross sectional area of cylinder (A) =3.22×10^{-3} m^2
Number of rotations required to complete one power cycle (K) = 1

$$\therefore\ p = 5.2187\ bar$$

The above pressure is the minimum pressure required within the engine cylinder to move the vehicle with a constant speed. Hence, considering cylinder 6 bar as mean effective pressure inside the engine cylinder.

$$\therefore\ p = 6\ bar$$

4.1.3 To find the engine torque

$$p = \frac{2\pi KT}{V_d} \quad (12)$$

$$Volume\ of\ Cylinder\ (V_d)\ =\ 1.83 \times 10^{-4}\ m^3$$

$$\therefore Engine\ Torque\ (T) = 17.47\ Nm$$

This torque is greater than required torque therefore selected engine can give the required output.

4.1.4 To Find Brake Effective Torque

Brake Power

$$Mechanical\ Efficiency\ (\eta_{mech}) = \frac{Brake\ Power}{Indicated\ Power}$$

$$= \frac{Brake\ mean\ effective\ pressure\ (p_b)}{Indicated\ mean\ effective\ pressure\ (p)} \quad (13)$$

$$\therefore\ Brake\ Power(P_b) = 2.0326\ kW$$

Brake mean effective pressure (p_b) = 4.8 bar

Friction Mean Effective Pressure (p_f)

$$\boldsymbol{p_f = p - p_b} \quad (\mathbf{14})$$

$$\boldsymbol{p_f = 1.2\ bar}$$

Frictional Torque

$$Frictional\ Torque\ (T_f) = \frac{\eta_{mech} V_d p_f}{2\pi K} \quad (15)$$

$$= 2.796\ Nm$$

Also, $T_f = T - T_b$ (16)

$$\therefore Brake\ Effective\ Torque\ (T_b) = 14.674\ Nm$$

4.1.5. To find volumetric capacity of engine cylinder per second

$$\boldsymbol{Volumetric\ capacity\ of\ engine\ cylinder\ per\ second\ (V_s) = \frac{LAN_eK}{60}} \quad (\mathbf{17})$$

Where,
Length of stroke (L) = 0.057 m
Engine Speed (N_e)= 1591.51rpm

$$\boldsymbol{V_s = 0.0049 \frac{m^3}{s}}$$

4.1.6. To calculate distance covered

Selecting, the air tank of 50 liters Capacity

$$\boldsymbol{Volume\ of\ cylinder\ (V_d) = 1.83 \times 10^{-4}\ m^3}$$

= 0.183 liter

Therefore number of rotations done in 50 liter of tank will be

$$\frac{\mathbf{50}}{\mathbf{0.183}} = \mathbf{273.22\ rotations}$$

Since, no. of crank rotation = no. of wheel rotation
Distance covered by the vehicle in one rotation of wheel will be equal to

$$\boldsymbol{Circumference\ of\ the\ wheel\ = 2\pi r} \qquad (\mathbf{18})$$

Where,
Radius of wheel(r) = 0.15 m

= 0.9425 m

With 50 liters vehicle will travel through the distance of,

273.22 × 0.9425 = 257.51 m.

4.2. Design of steering system

Selecting the Ackermann steering mechanism due to following reasons:

- It avoids slipping of tires around the curves.
- Simple geometry
- It is based on Pure rolling
- It occupies less space

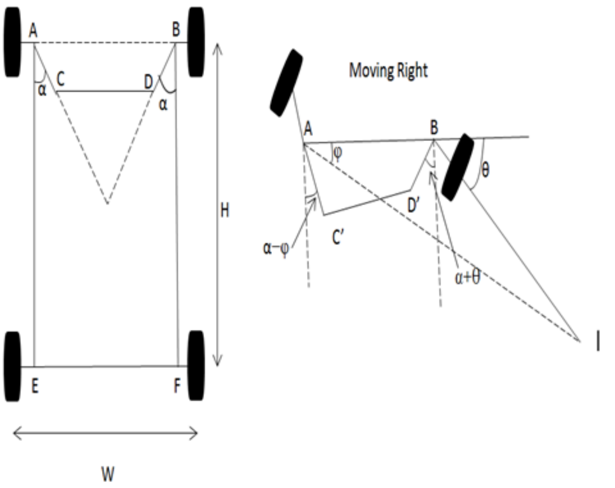

Fig. 2. Ackermann Steering

The condition for perfect steering is given by

$$\cot\varphi - \cot\theta = \frac{W}{H} \qquad (19)$$

Where,
Wheelbase of vehicle (H) = 1000mm
Track width of vehicle (W) = 800mm
Inner lock angle (θ) = 40°
Outer lock angle (φ) = 26.66°

$$Ackermann\ angle\ (\alpha) = tan^{-1}\left(\frac{0.5W}{H}\right) \qquad (20)$$

= 21.80°

$$Turning\ Radius\ (R) = \frac{W}{2} + \frac{H}{\sin\gamma} \qquad (21)$$

= 2219.96 mm = 2.219 m

$$Average\ steer\ angle\ (\gamma) = \left(\frac{\theta+\varphi}{2}\right) \qquad (22)$$

=33.33°

$$Ackermann\ percentage = \left(\frac{\theta-\varphi}{\alpha}\right) \times 100 \qquad (23)$$

= 61.19 %

Steering ratio = 10:1

$$\text{Vertical load on tires} = \frac{2500}{4} \qquad (24)$$

= 625 N

Maximum steering effort

$$= \frac{vertical\ load\ on\ tyres}{steering\ ratio} \qquad (25)$$

= 62.5N

4.3. Design of transmission system

Transmission system used to transmit the power generated at the engine to the wheels. There are 3 types of drives used for transmission systems viz. gear drive, belt drive, chain drive. Since gear drive is most efficient than other drives but the cost is high and also can only be used for small distance transmission. Chain drive is a positive drive, it is easily available in the market and the efficiency is almost similar to the gear drive. Therefore, chain and sprocket are designed for transmission of power from the engine to wheels.

4.3.1. Number of teeth

Rated Power = 2.5407 kW
N_1 = 1591.51 rpm

$$\boldsymbol{Z_1 = \frac{2F_0}{(sin\alpha)^2}} \qquad (\mathbf{26})$$

$$\boldsymbol{Z_1 = 17.097 \sim 18}$$

Considering *i* = 3,

$$\boldsymbol{i = \frac{N_1}{N_2} = \frac{Z_2}{Z_1}} \qquad (\mathbf{27})$$

$$\boldsymbol{\therefore Z_2 = i \times Z_1 = 54}$$

$$\boldsymbol{N_2 = \frac{N_1}{i} = 530.503\ rpm}$$

$$\boldsymbol{Design\ Power\ = Rated\ Power \times Service\ Factor} \qquad (\mathbf{28})$$

$$\boldsymbol{Service\ Factor\ (k_s) = k_1 k_2 k_3} \qquad (\mathbf{29})$$

k_1 = 1.5

k_2 = 1.5

k_3 = 1

$$\boldsymbol{k_s = 2.25}$$

∴Design power = 2.5407×2.25 = 5.7166 kW

Now, selecting 08B roller chain, from table given in [11]

For 08B simple roller chain

Chain pitch (P) = 12.70 mm
Selecting, ISO chain no = 10B
Roller diameter (d_1) = 8.51mm
Braking load ($\boldsymbol{W_b}$) = 17.8×10^3 N
Width (b_1) = 7.75mm

$$\boldsymbol{PCD\ of\ pinion\ (d_1)\ = Pcosec\left[\frac{180}{Z_1}\right]} \quad (30)$$

= 73.14 mm~ 74mm

$$\boldsymbol{PCD\ of\ Gear\ (d_2)\ = Pcosec\left[\frac{180}{Z_2}\right]} \quad (31)$$

= 218.42 mm~ 220mm

$$\boldsymbol{Pitch\ line\ velocity\ of\ pinion\ (V_1) = \frac{\pi\ d_1 N_1}{60}} \quad (32)$$

= 6.1665 m/s

$$\boldsymbol{Load\ on\ chain\ (W) = \frac{Rated\ Power}{Pitch\ line\ velocity}} \quad (33)$$

W = 0.4121 kN

$$\boldsymbol{Center\ Distance\ = 40\ \times P} \quad (34)$$

= 381 mm

In order to reduce the initial sag in the chain, the value of center distance is reduced by 2 to 5 mm

Therefore, corrected center distance (a) = 381－4

= 378mm

$$\boldsymbol{No\ of\ links\ (L_n) = \left(\frac{2a}{p}\right) + \frac{Z1+Z2}{2} + \left[\frac{Z2-Z1}{2\pi}\right]^2\left(\frac{P}{a}\right)} \quad (35)$$

= 96.63 ~ 98 links

$$\boldsymbol{Length\ of\ chain\ (L)\ = k\ \times P} \quad (36)$$

= 1.2246 m

4.4. Design of Frame

For designing the frame, it is important to select the proper material. Every material has different properties. The Material should sustain in high bending, torsional and shear stresses and also be light in weight. Therefore some of the materials that can be used for frame are listed below:

Table 3. Materials for frame

Sr. No.	Material	Density (g/cc)	Ultimate Tensile Strength (MPa)	Yield Tensile Strength (MPa)	Modulus of Elasticity (GPa)	Cost (Rs/kg)
1	AISI 1018	7.87	440	370	205	150
2	AISI 1020	7.87	394.72	294.7	200	100
3	AISI 1030	7.85	525	440	190-210	100
4	AISI 4130	7.85	560	460	190-210	360

Therefore from the above table selecting AISI 1018. The frame has to sustain in bending, shear and, torsional stresses. Since the square section has good strength. Therefore, selecting the hollow square cross-section rod for constructing frame. Following calculation is to check the permissibility of the selected parameters.

Table 4. Considered Parameters for frame

Sr. No.	Parameters	Specifications
1	Load on frame	2452.5 N
2	FOS	3
3	Material	AISI 1018
4	Permissible Bending stress	$123.33\text{x}10^6$ N/m^2
5	Permissible shear Stress	$60.67\text{x}10^6$ N/m^2
6	Length of frame	1.5 m
7	Square Cross section	Diameter (D) = 0.032m Thickness (t) = 0.003m

4.4.1. Checking under shear stresses

First shear force diagram & bending moment diagram has to be drawn by considering a beam having similar length as frame with the considered load acting uniformly over the length of the beam.

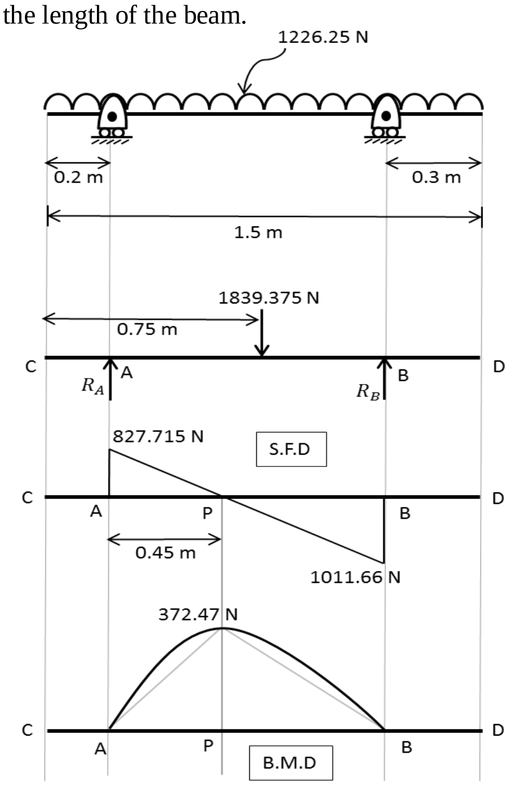

Fig. 3. SFD & BMD of frame

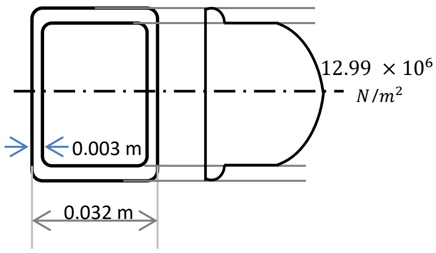

Fig. 4. Shear stress through the cross section

From Shear force diagram, the maximum shear force is found to be 1011.66N.

$$Shear\ Stress\ (\tau) = \frac{VAy}{Ib} \qquad (37)$$

Where,
Shear force (V) = 1011.66 N
Cross sectional area (A) × Max. Distance (y) = A_1y_1 - A_2y_2 = 1.89 × 10^{-6} m^3
Area Moment of Inertia (I) = 4.93×10^{-8} m^4
Thickness at center (b) = 0.006

$$\therefore\ \tau = 12.99\ \times 10^6\ N/m^2$$

Since, $\tau_{induced} < \tau_{permissible}$
∴ The Design is Safe.

4.4.2. Checking under bending stresses

From the bending moment diagram, the maximum bending moment is found to be 372.47 Nm.

$$\sigma = \frac{My}{I} \qquad (38)$$

Where,
Bending moment (M) = 372.47 Nm
Maximum distance from neutral axis (y) = 0.012m
Area Moment of Inertia (I) = 4.93×10^{-8} m^4

$$\therefore\ \sigma = 120.88\ \times 10^6\ N/m^2$$

Since, $\sigma_{induced} < \sigma_{permissible}$
∴ The Design is Safe.

4.4.2. Slope and deflection in chassis

$$Deflection(y) = \frac{-5wl^4}{384EI} \qquad (39)$$

Where,

$$Load\ on\ half\ side\ of\ the\ chassis(w) = \frac{2452.5}{2}$$

= 1226.25 N

Modulus of Elasticity (E) = 205 GPa
Length of chassis (l) = 1.5 m

$$\therefore y = -0.0079\ m$$

$$Slope\ (\theta) = \frac{-wl^3}{24EI} \qquad (40)$$

= - 0.0171 rad

4.5. Design of rear axle:

Since it has to withstand bending stresses and transmit the power without failure selecting AISI 4130 for axle.

Table 5. Considered Parameters for axle

Sr. No.	Parameters	Specifications
1	Load on axle	1226.25 N
2	FOS	3
3	Material	AISI 4130
4	Permissible Bending stress	153.33x10^6 N/m^2
5	Permissible shear Stress	76.67x10^6 N/m^2

4.5.1. To calculate axle diameter

Axles have circular cross sections. Hollow sections possesses high strength than solid sections. Since there area increase which resist deformation.

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{R} \qquad (41)$$

Where,
Engine torque to be transmit (T) = 15024 Nm
Polar Moment of inertia (J)
Poisson's ratio (G) = 80 GPa
Length of the axle (L) = 0.8m
Slope while deformation (θ) = 1° = 0.01745 rad
Shear stress (**τ**)
Radius of gyration (R)

$$\therefore \frac{G\theta}{L} = 1.745 \times 10^9$$

Considering, $\frac{d_2}{d_1} = 0.8$

$$J = \frac{\pi}{32} \times \left({d_1}^4 - {d_2}^4\right) = 0.01963{d_1}^4$$

$$\therefore d_1 = 0.026\ m$$

$$d_2 = 0.021\ m$$

For safety considering, d_1 = 0.03 m & d_2 = 0.024m

4.5.2. Checking under shear stresses

First shear force diagram & bending moment diagram has to be drawn by considering a beam having similar length as axle with the considered load acting uniformly over the length of the beam.

From Shear force diagram, the maximum shear force is found to be 490.48N.

$$Shear\ Stress\ (\tau) = \frac{VAy}{Ib} \quad (42)$$

Where,
Shear force (V) = 490.48N
Cross sectional area (A) × Max. Distance (y) = A_1y_1 - A_2y_2 = 2.19× 10^{-6} m^3
Area Moment of Inertia (I) = 2.3475×10^{-8} m^4
Thickness at center (b) = 0.006

$$\therefore\ \tau = 7.63 \times 10^6\ N/m^2$$

Since, $\tau_{induced} < \tau_{permissible}$
∴ The Design is Safe.

4.5.3. Checking under bending stresses

From the bending moment diagram, the maximum bending moment is found to be 196.19 Nm.

$$\sigma = \frac{My}{I} \quad (43)$$

Where,
Bending moment (M) = 196.19 Nm
Maximum distance from neutral axis (y) = 0.015m
Area Moment of Inertia (I) = 2.3475×10^{-8} m^4

$$\therefore\ \sigma = 125.36\ \times 10^6\ N/m^2$$

Since, $\sigma_{induced} < \sigma_{permissible}$
∴ The Design is Safe.

4.5.4. Slope and deflection in frame

$$Deflection(y) = \frac{-5wl^4}{384EI} \quad (44)$$

Where,
Load on half side of the rear axle(w) $= \frac{2452.5}{2}$

= 1226.25 N
Modulus of Elasticity (E) = 210 GPa
Length of chassis (l) = 0.8 m

$$\therefore y = -1.33 \times 10^{-5}\ m$$

$$Slope(\theta) = \frac{-wl^3}{24EI} \quad (45)$$

$$\therefore \theta = -5.31 \times 10^{-5}\ rad$$

Since rear axle will be subjected to higher forces than front axle. Therefore, the same dimensions can also be used for front axle.

Results

Corresponding to the design vehicle can be manufactured effectively. The design help to conform the actual model will work properly. The calculated parameters are listed below.

Table 6. Calculated Parameters

Sr. No.	Components	Parameters	Specifications
1	Engine	Power Required at engine	2.5407 KW
		Torque at engine	15.24 Nm
		Speed of engine	1591.51 rpm
		Mean effective pressure	6 bar
		Model	Suzuki TS18
		Volumetric capacity of engine cylinder per second	0.0049 m^3/s
		Distance covered in 50 liters	257.51 m
2	Steering System	Inner lock angle	40°
		Outer lock angle	26.66°
		Ackermann angle	21.80°
		Turning Radius	2.219 m
		Average steer angle	33.33°
		Maximum steering effort	62.5N
3	Transmission System	Drive type	Chain drive
		Chain	8B simple roller chain
		Length of chain	1.2246 m
		No. of teeth on pinion	18
		No. of teeth on gear	54
		Pitch circle diameter	0.074 m
		Pitch circle diameter	0.220 m
		Pitch line velocity	6.1665 m/s
		Center distance between 2 sprockets	0.378 m
4	Frame	Material	AISI 1018
		Square Cross section	Diameter (D) = 0.03m Thickness (t) = 0.002m
		Deflection	0.006517 m
		Slope	1.39 rad
5	Rear Axle	Material	AISI 4130
		Circular Cross section	Diameter (D) = 0.03m Thickness (t) = 0.003m
		Deflection	0.0000133m
		Slope	0.0000531 rad

Conclusion

This calculations help to finalize the different components of air powered vehicle. This is the basic design procedure of a simple air-powered vehicle. Since only air is used, the vehicle does not emit any hazardous gases. To compress the air it needs electricity which is affordable than conventional fuels. Though there are many researches have been done. It needs some development in this technology. So as to manufacture an air car on market scale.

References

[1] Press information bureau, Government of India, Ministry of Petroleum and Natural Gas, 28-January-2014

[2] Vishwajeet Singh, "Compressed Air Engine", *International Journal of Scientific and Research Publications*, 7(7), 403-412, 2017

[3] Rohamare R V., Tambe Kiran B., Dethe Bharat Y. & Dhanwate Krushna D.,"Conversion of 4-Stroke Single Cylinder Petrol Engine into Compressed Air Engine", *International Journal of Informative & Futuristic Research (IJIFR)*, 2(2), 426-431, 2014

[4] Bharat R. Singh, JP Yadav," Study And Fabrication of Compressed Air Engine", *S-JPSET*, 2(1), 1-8, 2011

[5] Ruchil A. Patel, "A Study On Compressed Air Engine Technology: A Review", *International Journal of Advanced Technology In Engineering and Science*, 03(01), 192- 196, 2015

[6] Hemant Kumar Nayak, Devanshu Goswami & VinayHablani, "Technical Review on Study of Compressed Air Vehicle (CAV)", *International Journal of Automobile Engineering Research & Development (IJAUERD)*, 3(1), 81-90, 2013

[7] Mr. Birajdar M. D., Prof. Mule J. Y., "Design Modification of Ladder Chassis Frame" *International Journal of Science, Engineering and Technology Research*, 4(10), 3443-3439, October 2015

[8] Anjul Chauhan, Lalit Naagar, Sparsh Chawla, "Design And Analysis of Go-kart", *International Journal of Aerospace and Mechanical Engineering*, 3(5), 29-37, September 2016

[9] V B Bhandari, *Design of Machine Elements*, McGrew Hill Education (India) Private Limited, New Delhi, fourth edition, 2017

[10] R.S.Khurmi, J.K.Gupta, *A Textbook of Machine Design*, Eurasia Publishing House (PVT.) LTD., New Delhi, Fourteenth Edition

[11] "Car Performance Formulas" Available: http://www.thecartech.com/subjects/auto_eng/car_performance_formulas.htm [Accessed: 24 Jan 2019]