Structural Analysis of Air Powered Car

Bridjesh Pappula[a], Geetha Narayanan Kannaiyan[b], Gowtham Naidu Siva Naga Sai[c], Pruthweeshwar Udutha[d], Ravichandra Vangala[e] and Jashwanth Nadendla[f]

[a] Department of Mechanical Engineering, MLR Institute of Technology, Hyderabad, India
[b] Department of Mathematics, Dayanand Sagar College of Engineering, Bengaluru, India
[c] Department of Mechanical Engineering, MLR Institute of Technology, Hyderabad, India
[d] Department of Mechanical Engineering, MLR Institute of Technology, Hyderabad, India
[e] Department of Mechanical Engineering, MLR Institute of Technology, Hyderabad, India
[f] Department of Mechanical Engineering, MLR Institute of Technology, Hyderabad, India

Abstract

Fossil fuels on engines had been successful until 30-40 years. But now they are one of the main leading causes to global warming and emissions of toxic gases such as CO2, SO2 etc. Compressed Air Vehicle (CAV) is an environmentally efficient engine that runs on compressed air. Air is used as a fuel by the compressed air engine. The CAV uses compressed air displacement to move an engine's pistons. The CAV is a pneumatic actuator that conducts effective operation by injecting compressed air. There is no ignition, because fuel and air mixture are not present. Developing a whole car to operate on pneumatic systems would appear to be a largely complex work and is an expensive one and in this paper an attempt is made to research the adaptation of the existing IC engines to operate on compressed air using a tadpole configuration and the possible advantages and drawbacks of the CAV system are derived.

Keywords 1

Compressed air vehicle, Engine, Pneumatic actuator

1. Introduction

In 1870 Polish engineer Louis Mekarski developed a Compressed Air Vehicle (CAV) in France. It was copyrighted in 1872 and tested in 1876 at Paris. Mekarski's engine's operational theory involves the use of energy contained in compressed air to improve hot water gas enthalpy as it travels through hot water. The Luxembourg-based MDI Group member and former Formula One engineer Guy Negre is working on a compressed air engine (CAE) has built an Air Vehicle. In 1998, he built a compressed air- 4-cylinder engine operating on air and fuel that is said to be zero emission vehicles. When operating at speeds of 35 mph and at higher speeds of 96 mph, it used compressed air to power the pistons, essentially in such engine compressed air [1] was heated by a fuel (bio-fuel, gasoline, or diesel) which allowed the air to expand before entering the turbine. The fuel consumption was found to be about 100 mpg. The next step in car development is low weight automobiles. Reducing the car's weight has several benefits as it improves the vehicle's total performance, can boost maneuverability [2], takes less fuel to stop and drive the engine. To come up with new solutions, the experiments are moving on around the world. Yet climate change is just one of the issues facing by mankind. Earth's temperature is on the rise and that effect triggers climate change [3]. Fossil fuels are commonly used as energy sources in different areas such as electric stations, internal and external combustion engines, as heat sources in processing industries, etc. But the supply is very small and fossil fuels consumption is growing at a faster pace due to their enormous use [4]. It is also important in this environment of energy shortage to establish sustainable technology for the usage of renewable energy sources, so that fossil fuels can be retained [5]. Smoke originating from the cars is one of the main causes of emissions. Therefore there will be an

WCES-2021: Workshop on Control and Embedded Systems, May 01, 2021, Chennai, India.
EMAIL: meetbridjesh@gmail.com (Bridjesh Pappula)
ORCID: 0000-0002-8964-4667 (Bridjesh Pappula)

easier method to keep the car going, therefore we can avoid any harm to the planet. Solar, electric, ambient air etc., are the alternate forms of energy available. Thanks to high energy capacity, low contamination, quick loading at low cost and long service life [6], compressed air is advantageous as compared to batteries. Wind is to the world like a shield. This forms of gaseous water, which renders stable and non-polluting source. It has the advantage of being squeezed to a very high pressure and keeping it maintained for a long time. This is inexpensive and is easily present in the environment [7]. And it can be used on cars as an alternate source. There is a lot of work going on this compressed air vehicle and experts are doing their hardest to boost this technology's efficacy [8]. It is observed that the vehicle's performance varies from 72% to 95%. But this can be called one of the favored solutions for operating the engine [9].

2. Literature Review

Andrew Papson et al., [10] analyzed the characterizes and future efficiency of CAVs in terms of fuel quality, driving range, carbon emissions and cost of fuel and explores their feasibility as a mobility alternative relative to gasoline and electric vehicles. The technical topics include compressed air energy density, thermodynamic expansion losses, pump-to-wheel and well-to-wheel CAV performance, and similarities with gasoline and electric vehicles. Results indicate that while these are a daring, innovative approach to today's transport problems, it is essentially unworkable and poorly correlates with gasoline and electric vehicles in both environmental and economic metrics.

Verma [11] proposed that, similar to batteries, compressed air is advantageous because of a lots of energy capacity, low contamination, quick loading at low cost and long operational life. With a range of 125 miles between fill-ups, the car was able to reach speeds of up to 68 mph, all for even less than $13,000. Sadly, the dates for the much-publicized arrival of the air car on both Indian and American markets have gone away without any news as to when the vehicle will finally enter the road.

Lukasz and Milewskia [12], demonstrated that compressed air powered cars are an alternative to hybrid vehicles and automobiles powered only by electricity from fuel cells or lithium-ion batteries. One aspect that many vehicles are outclassed by the compressed air automobile is its compact weight which translates quickly into energy needs. Other energy-saving solutions, on the other hand, are equipped with a heavy pack of batteries or fuel cells. In fact, these costly batteries have to be replaced at considerable expense every couple of years and with due consideration taken to environmentally safe disposal. A compressed air tank is adequate for the vehicle's whole lifespan, and is secure even in collisions. Electrical, electric and most compressed air cars work ultra-efficiently when stationary, reducing vibration, pollution and travel costs.

3. Working of air powered car

The idea behind the operation of the air powered engine is the capacity of the air to maintain concentrated energy, and to release the same after expansion. On compression, it maintains the pumping job as the compressed air capacity. That is where the compressed air is processed for future usage of the containers [13]. When this air is allowed to expand, the air pressure energy is transformed into kinetic energy and induces propulsion. This same concept is applied to engines. The solenoid valve is used to control the air supply of the piston on a daily basis, because the valve shuts down and opens electrically and without interruptions according to the predefined time of the valve [14]. As the forced air enters the piston through the inlet door, it generates pressure force on the piston during the first half of the rotation of the crankshaft, expands, and then moves out through the outlet during the second half of the rotation of the crankshaft. Owing to this impact power, the piston is reciprocating. The primary purpose of keeping fuel at such an elevated pressure is to insure that, sufficient volume of gas is accessible in the vehicle to enable it to run for a longer period of time before the tank has to be refilled [15].

4. Design of Chassis

Chassis is typically a three-dimensional arrangement with struts and braces (as in cars) that forms the body and distributes the weight equally in all directions. Three-dimensional truss, centered on the rigidity of the triangle, consisting of linear components subject only to stress or friction. Its simplest space structure is a tetrahedron with four joints and six members. The space frame is a rather solid, dense, versatile structural fabric that can be used horizontally or bent to a number of shapes [16]. The beauty of its open lattice work web of light weight tubular diagonals is surpassed only by its structural purity. The schematic of chassis is presented in Figure 1.

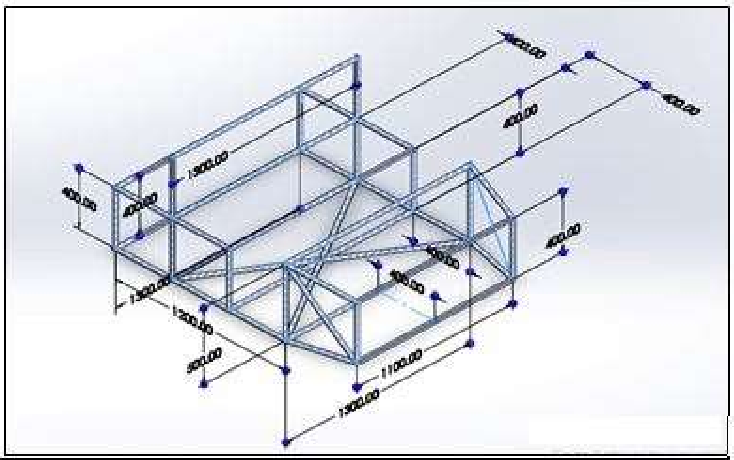

Figure 1: Schematic of chassis

5. Structural Analysis of Chassis

5.1. Material

The material used is AISI 4130 steel and the properties are presented in Table 1.

Table 1
Properties of AISI 4130

Materials properties	AISI - 4130
Carbon (%)	0.305
Density (g/cc)	7.85
Tensile yield strength(MPa)	460
Tensile ultimate strength (MPa)	560
Modulus of elasticity (GPa)	210
Poission’s ratio	0.29

5.2. Calculations

- Total weight of chassis and payloads (m) = 220 kg
- Velocity of vehicle = 6.94 m/s
- Think distance = velocity* (think time) = 6.94*0.15 = 1.041 m
- Brake distance =(v)2/(2*μ*g) = 3.068 m
- Total time for stopping the vehicle = (think distance + brake distance) / (v) = 0.6 s
- Accleration (a) = (v-u) / time = 6.85 m/s^2

- Total Force = m*a = 2501.52 N
- Force on each rod = 625.38 N

5.3. Front Impact

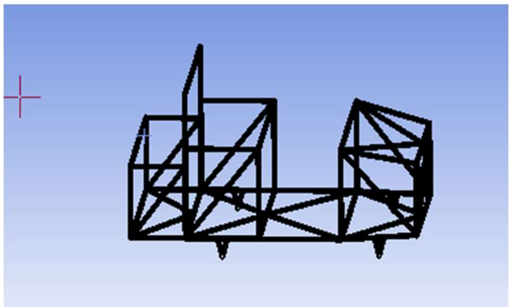

Figure 2: Meshing of chassis

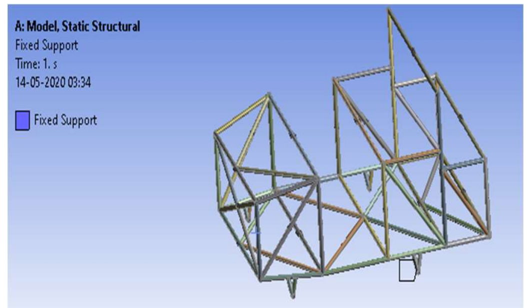

Figure 3: Supports on chassis

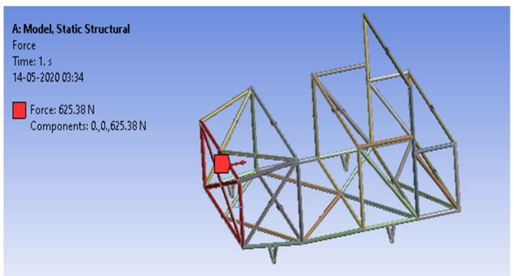

Figure 4: Schematic of load acting on chassis

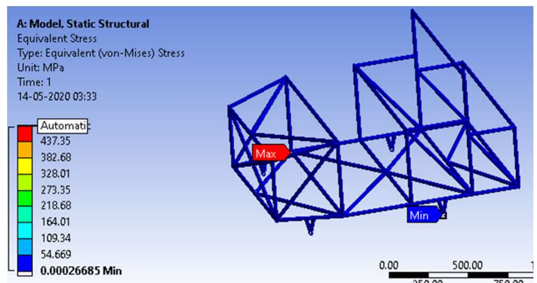

Figure 5: Schematic of values of stress

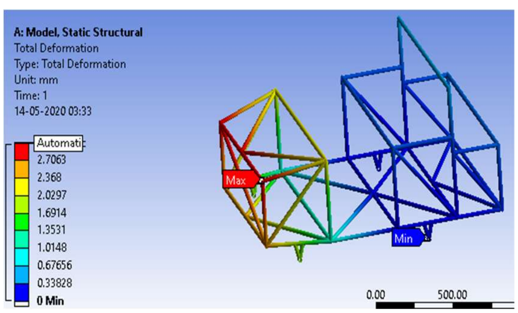

Figure 6: Schematic of deformation of chassis

5.4. Rear Impact

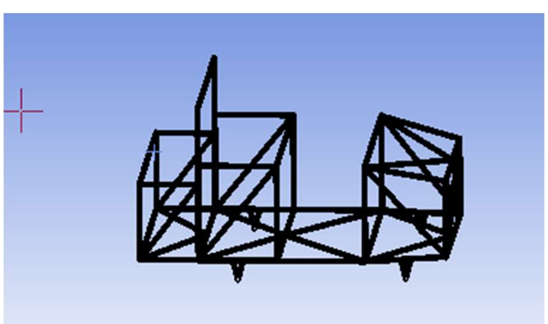

Figure 7: Schematic of Meshing on chassis

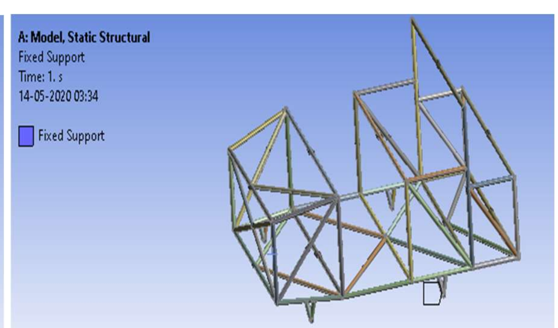

Figure 8: Schematic of loads imparted on chassis

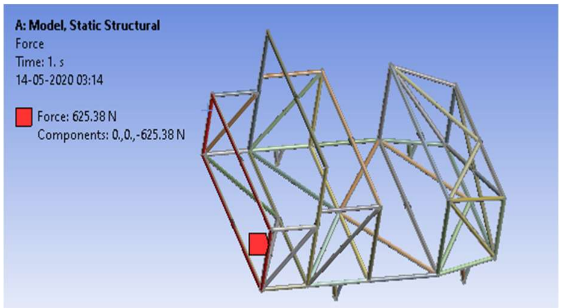

Figure 9: Schematic of application of load

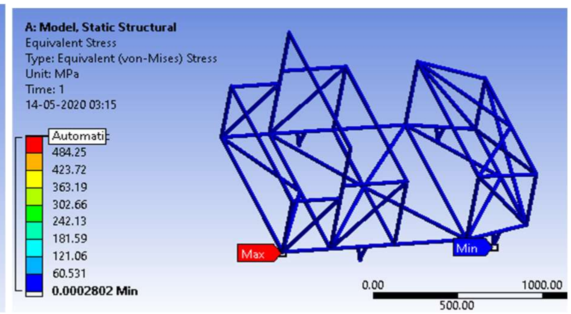

Figure 10: Schematic of stresses generated

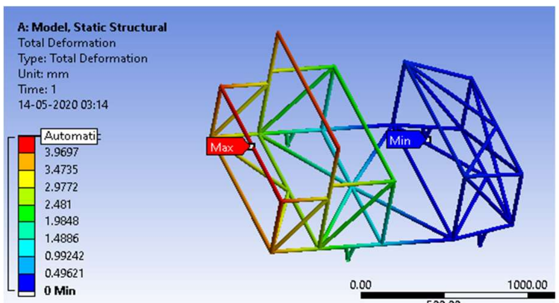

Figure 11: Schematic of total deformation during rear impact test

6. Results

The results of impact loading is presented in Table 2.

Table 2
Table title

Impact	Stress (MPa)	Total deformation (mm)
Front impact	492.02	3.04
Rear Impact	544.78	3.15

7. Conclusion

From this paper about analysis on chassis of a compressed air car is helpful to design a chassis for compressed air car and there is need for introducing light weight material for chassis with good material properties. The design can be optimized to reduce effect of stress and improve efficiency of CAVs.

8. References

[1] Rixon K L, Mohammed Shareef V, Prajith K S, Sarath K, Sreejith S, and Sreeraj P. "Fabrication of Compressed Air Bike." International Research Journal of Engineering and Technology, 3 (3), 2016.

[2] Gopi Chand Boosa, P Chandra Bhushan, and M. Dhanunjaya. ”Compressed air powered engine for the design and development of single cylinder engine.” International Research Journal of Engineering and Technology, 6 (9), 2019

[3] Rushikesh Lavhale, Darshan Datir, and Aniket Wagh. ”Application of Compressed Air Engine to Replace SI Engine: A Review.” International Research Journal of Engineering and Technology, 5 (5), 2935 – 2938, 2018.

[4] Felix Creutzig, Andrew Papson, Lee Schipper, and Daniel M Kammen. ”Economic and environmental evaluation of compressed-air cars.” Environmental Research Letters, 4 (4), 044011, 2009

[5] C. Naveenkumar, M.Akshai, Athul Mathew, R.Balakumaran, and S.Balaji. ”Design Fabrication and Simulation of Compressed Air Hybrid Vehicle.” International Research Journal of Engineering and Technology, 5(2), 182-188, 2018

[6] Scott B. Peterson, J.F. Whitacre, and Jay Apt. ”The economics of using plug-in hybrid electric vehicle battery packs for grid storage.” Journal of Power Sources, 195(8), 2377-2384, 2010.

[7] Bridjesh P, Vinayak J, Teja N, and Madhu S. ”Design of Chain Differential for a Race Car.” International Journal of ChemTech Research, 10(3), pp. 225-228, 2017

[8] N.Govind, S.Sanyasi Rao, and Manish kumar Behera. ”Design and Fabrication of Compressed Air Vehicle.” International Journal & Magazine of Engineering Technology Management and Research, 2(7), 2015

[9] B. Subramanyam, and P. Bridjesh. ”Design and Analysis of Student Formula Car Roll Cage.” Indian Journal of Science and Technology, 9(48), 2016. DOI: 10.17485/ijst/2016/v9i48/105996

[10] Papson, A, Creutzig, F, and Schipper, L. ”Compressed Air Vehicles: Drive-Cycle Analysis of Vehicle Performance Environmental Impacts and Economic Costs.” Transportation Research Record, 2191(1), 67–74, 2010.

[11] Verma, SS. ”Latest Developments of a Compressed Air Vehicle: A Status Report.” Global Journal of Researches in Engineering Automotive Engineering, 13(1), 1-10, 2013.

[12] Łukasz. S, and Jarosław. M. ”Dynamic analysis of compressed air energy storage in the car.” Journal of Power Technologies 91(1), 23–36, 2011.

[13] C.Y.Yuan, T. Zhang, A. Rangrajan, D. Dornfeld, B. Ziemba, and R. Whit beck. ”A decision based analysis of compressed air uses pattern in automotive manufacturing.” Journal of manufacturing system, 25(4), 293-300, 2006.

[14] Patnaik, S. ”Compressed Air Engine.” International Journal of Research in Mechanical Engineering and Technology, 5(2), 49-52, 2015.

[15] Abhishek Lal. ”Design and Dynamic Analysis of Single Stroke Compressed Air Engine.” International journal of renewable energy research, 3(2), 315-319, 2013.

[16] Subramanyam B, P. Bridjesh and Madhu S. ”Manufacturing of steering components for a race car.” International Journal of Mechanical Engineering and Technology, 8(6), pp. 207–211, 2017