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Design & Development of Combined Human and Electric Powered Vehicle

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Abstract- *In the present day's energy markets are conquered by a significant raise in energy demand due to the strong economic growth in the developing countries especially in China and India. At the same instant the developing countries as well as developed countries are also suffering from the problems related to lack of fossil fuels and the pollution generated from the use of the fossil fuels. So we have basically two problems related to fossil fuels. There are various causes to generate carbon dioxide, carbon monoxide, NOx, SOx type of harmful gases in the atmosphere like burning of coals in thermal power plants, transportation sectors, small and large scale manufacturing industries etc. Here we concerned about the transportation sector which is a major cause of producing air pollutants gases. The pollution produces by the vehicles is a big problem. And another huge problem related to the transportation is decrement in the reserve fossil fuels. Here we have need of some alternative system or any kind of technology which is not depends on the fossil fuels and also not produces air pollutants. Combined human and electric powered vehicle could be a good example of such kind of alternative solution and we can use it in future for small distance transportation. This paper consist all the necessary data, which is important to fabricate this vehicle.*

Key words- *Fossil fuels, Human power, Electric power, Analysis, AISI 4130, Transportation, Technology.*

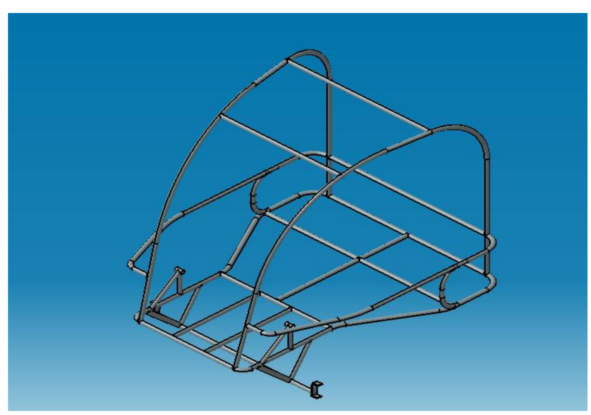
I. INTRODUCTION TO COMBINED HUMAN AND ELECTRIC POWERED VEHICLE

Combined human and electric powered vehicle is the vehicle which is driven by human muscular power as well as electric power. We can say it uses the combination of both human power source and electric power source. This is a three wheeled vehicle, driven by maximum two members with side by side seating arrangement, it can also made with tandem type seating arrangement. The vehicle is equipped with a BLDC 400 Watt electric motor, 2 sealed lead acid battery (each of 24 Volts) and belt drive used for electric power transmission, beside this two manual pedaling system also provided for the human power transmission based on the principal of bicycle. Whenever we want we can change the mode of drive. The tadpole type configuration is used for this vehicle in which two wheels are mounted in front side and one wheel in back side of the vehicle. The vehicle has a drag link type steering system handled by one driver (Right hand side). Disc brakes with sliding calipers in direct connection are provided in all the three wheels for proper and effective braking. For the transmission of power chain drive with derailleur and belt drives have used.

II. DESIGN METHODOLOGY

2.1 Design and CAD model preparation of roll cage

The roll cage design has prepared on the design software CATIA with the standard diameter and thickness cross sectional pipe available in the market. We choose the cross section as per the maximum static load applied on the frame and considering factor of safety also. We prepared the CAD Model first with three different circular pipe cross sections like 1 in. diameter 1mm thick, 1 in. 2mm thick, 1.25 in. 2mm thick (These are the standard specimen available in the market) and analyze it on ANSYS software, the best result found in 1 in. diameter 2 mm thick cross sectional pipe as per our requirement.



CAD model

2.2 Material and their properties:

The roll cage of the vehicle has prepared by SAE (Society of Automotive Engineers) steel grade AISI 4130 steel. It is an alloy steel containing Chromium and Molybdenum as their alloying element, referred as Chromoly steel or chrome-moly steel. Chromoly steel has magnificent strength to weight ratio and considerably higher strength and hardness as compare to Mild Steel , Aluminium alloy and other grades of steel.

Actual prototype

Composition of AISI 4130(Chromoly alloy steel):

Alloying composition (by weight)

SAE grade	% Cr	% Mo	% C *	% Mn	% P (max)	% S (max)	% Si
4130	0.80–1.10	0.15–0.25	0.28–0.33	0.40–0.60	0.035	0.040	0.15–0.35

Mechanical properties:

Material	Condition	Tensile strength [psi (MPa)]	Yield strength [psi (MPa)]	Elongation in 2" [%]	Hardness (Rockwell)
4130	Cold drawn—normalized[2]	85,000–110,000 psi (590–760 MPa)	70,000–85,000 psi (480–590 MPa)	20–30	B 90–96

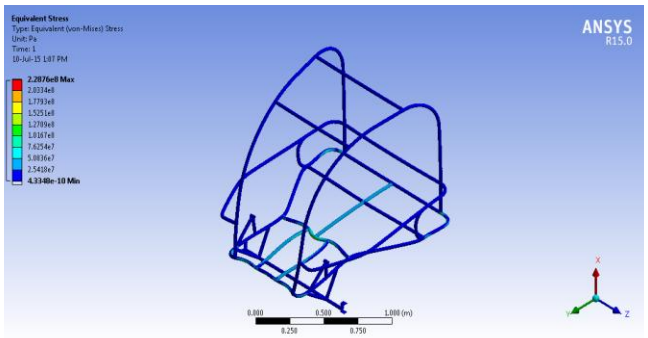
2.3 CAE and finite element analysis of roll cage:

Computer aided engineering is the usage of various computer software tools to solve the engineering analysis problems, it include the Finite Element Analysis (FEA), Multibody Dynamics (MBD) and Computational Fluid Dynamics (CFD) etc. After preparing the CAD model the analysis done on the FEA software ANSYS 15.0 with different conditions. The ANSYS workstation system is a substantial scale multi reason limited component program which may be utilized for illuminating a few classes of designing examination.

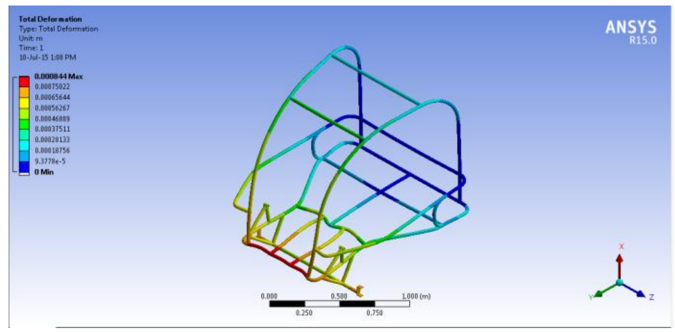
We have done structural analysis on the different conditions, these conditions are as follows:

1. Front impact analysis
2. Rear impact analysis
3. Rollover impact analysis
4. Side impact analysis

Front Impact Analysis:



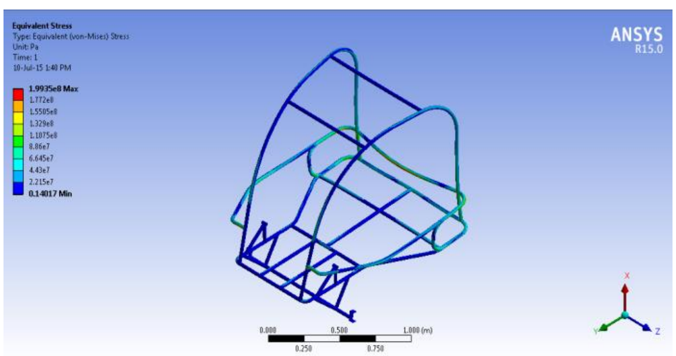
Maximum Stress

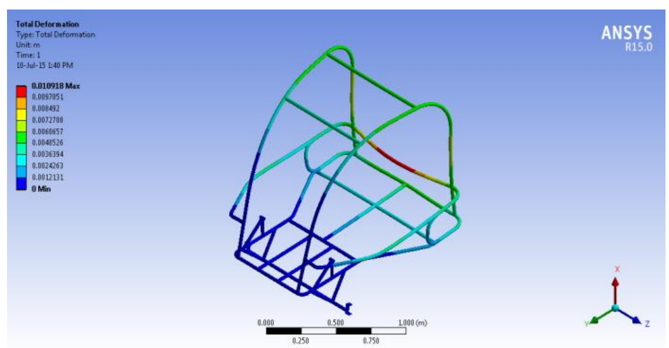


Maximum Deformation

Model type	Full model (Coordinate generated)
Loading	14000 N (@ 6G)
Maximum stress developed	230 MPa (Analysis is done for the load of 14000 N)
Maximum Displacement	0.805 mm
Factor of safety	Ultimate stress / Working stress = 480/ 230 = 2.1 (Design is safe)

Rear impact Analysis:

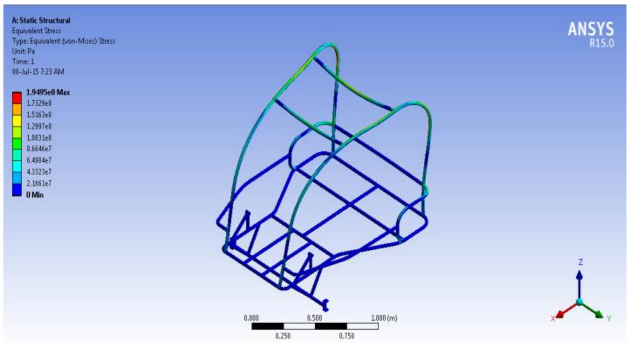


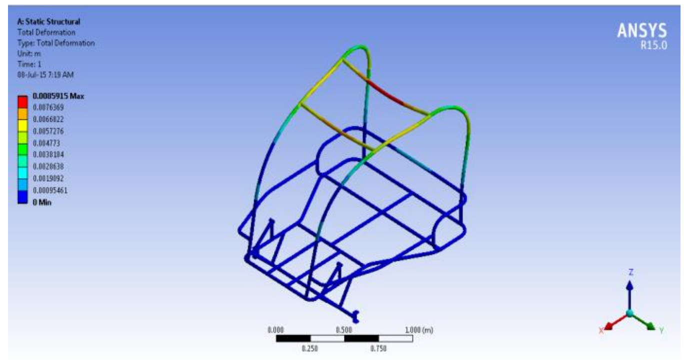


Model type	Full model (Coordinate generated)
Loading	7000 N (@ 4G)
Maximum stress developed	199 MPa (Analysis is done for the load of 7000 N)
Maximum Displacement	10 mm

Factor of safety	Ultimate stress / Working stress = 480/ 199 = 2.41 (Design is safe)

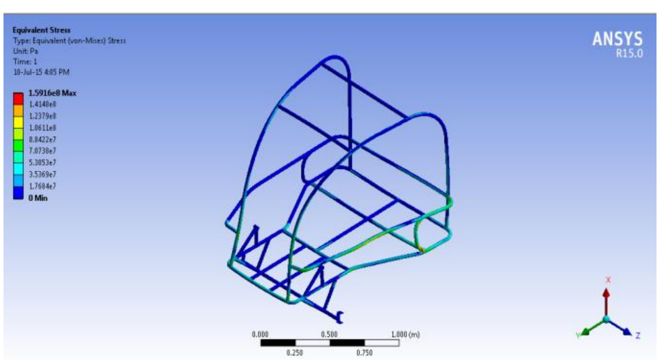
Rollover Impact Analysis:

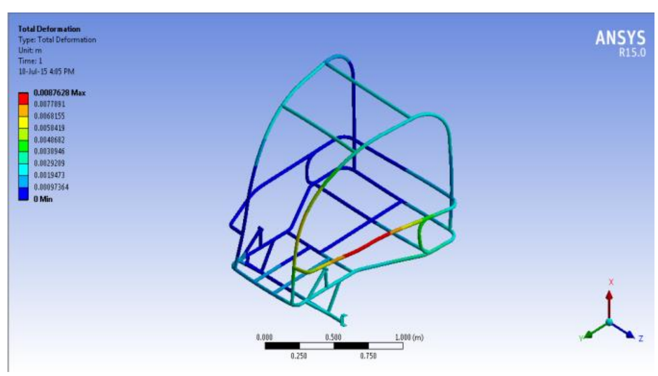




Model type	Full model (Coordinate generated)
Loading	5000 N (@ 4G)
Maximum stress developed	194 MPa (Analysis is done for the load of 5000 N)
Maximum Displacement	1 mm
Factor of safety	Ultimate stress / Working stress = 480/ 194 = 2.47 (Design is safe)

Side Impact Analysis:





Model type	Full model (Coordinate generated)
Loading	5000 N (@ 4G)

Maximum stress developed	198 MPa (Analysis is done for the load of 5000 N)
Maximum Displacement	8 mm
Factor of safety	Ultimate stress / Working stress = 480/ 198 = 2.42 (Design is safe)

2.4 Design of steering system:

The Ackerman steering mechanism is used to calculate the steer angle of inner and outer wheel. We all know that Ackerman steering uses turning pair which has greater life as compare to Davis mechanism.

Ackerman steering calculations

CotØo – CotØi = w/l

Øo – steering angle of outer wheel

Øi – steering angle of inner wheel

w - track length

l - wheel base

Taking outer wheel angle 31^0

Cot 31^0-Cot Øi = 1200/1565

1.6 - CotØi = .77

Øi = 48.33^0

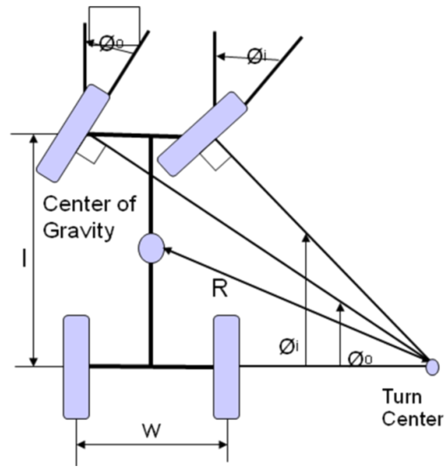
cotØ = (cot Øo + cot Øi)/2

Ø = 38.1070

Turning Radius R = $(a^2+l*cot2Ø)^{1/2}$

Where "a" is distance between cg and rear wheel.

R = 2064 mm



2.5 Design of transmission system:

<u>Drive Train:</u> Chain Drive for manual power

Belt Drive for electric (motor) power

The motor chosen is BLDC motor of 400 watt and 48 Volt

Battery used for the supply of power is 48 V 35 Ah lead acid sealed battery.

<u>Drive Train Calculation:</u>

<u>Chain Drive:</u>

Velocity Ratio= 44/18=2.444

Number of chain links:

K= (T1 + T2) + 2x/p + $[(T1 - T2)/2\pi]^2$ p/x

Where T1 and T2 are no. of teeth on both sprockets, x is the center distance and p is the pitch of the chain

K= 175 links

Angular velocity of the wheel= 41.92 rad/s

Angular velocity of common shaft= 65.21 rad/s

Design Power = rated power * service factor = 1KW *1.25*1.5 = 1.875KW

Type of Chain:

ISO No. 088, Pitch 12.7mm, Roller Diameter 8.51mm, Width between Inner Plates 7.75mm

Breaking Load: 17800N

Pitch Line Velocity: $\pi D_1N_1/60 = \pi *0.07363718/60 = 2.4009$ m/s

Load on Chain = 1.875KW/2.4009m/s = 780.1N

Factor of Safety = 22.81

Min Allowable F.S. = 8.55

Chain is safe

Belt Drive:
Length of V Belt = π (d1+d2)/2 + 2x + $(d1 - d2)^2/4x$
Where d1 and d2 are Diameter of pulleys and x is the center distance
L = 1594m
From Design Data Book the required belt is **A 1651/65 IS: 2494**

2.6 Design of braking system:

Braking system is a very important system in any vehicle without effective braking the vehicle is uncompleted and very risky for drive. So for effective braking we used disc brakes in all the three wheels in the vehicle.
Retarding Force:
BF = Ma
Where:
BF = total braking force (N)
M = total vehicle mass (kg)
a = deceleration (m/s2)
Calculation:
BF = 230*(-7.37)
BF=1695 N
Stopping Distance calculation:
To reduce the k.E. to zero
Workfriction = $-\mu mgd = -mv^2$
So the stopping distance will be
D = $v^2/2\mu g$, where v is in m/sec.
D = 8.332/(2*.8*9.81)= 4.41 m
Braking Torque:
T= Retarding force for wheels*static laden radius of tire / speed ratio between wheel and brake
T=1695.5*10*25.4/103=430.67Nm
Efficiency:
ηbr=Retarding force/Mg
ηbr=4.41/9.81*100= 76%

III. TECHNICAL SPECIFICATION OF THE VEHICLE

The general technical specifications of the entire vehicle are shown in below given table, which is necessary to give a general overview of the vehicle.

S. no.	Performance	Value
1	Maximum speed	46 km/hr
2	Overall weight	303 kg
3	Suspension	Hydraulic suspension
4	Turning radius	2 m
5	Braking force	113 N
6	Stopping distance	7 m
7	Braking efficiency	75 %
8	Ground clearance	8 in.
9	Wheel track	47 in.
10	Wheel base	61 in.

Technical specification of the vehicle

IV. CONCLUSION

At present scenario we all are going through the problems related to the pollution from the combustion of fossil fuels and shortage of fossil fuels, both are related to each other and a very serious issue also. So we need to find some alternatives to takeover these problems and a hybrid vehicle which is driven by the human and electric power could be a very good option for small distance transportation in urban areas for future aspects. It is totally an eco friendly vehicle. It provides a comfortable ride with safety.

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