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Design, Analysis and Fabrication of 3-Wheeled Hybrid Vehicle Run by Human Effort and Electric Motor.

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Abstract

The use of energy acquired from fossil fuels to propel automobiles has always had its negative effects on the environment. Research on substitutes for fossil fuels has existed for a few decades now. This paper emphasizes on a 2 seater vehicle which is powered by human effort and by an electric motor, which can be employed both individually as well as simultaneously. The simulation and analysis of this vehicle has been carried out in ***Solidworks*** *and* ***Ansys*** *softwares.*

Index-Terms

Human pedaling, electric motor, Solidworks 2011 modeling, Soldworks simulation, ANSYS 11.

1)Introduction

It is for certain, is that we have to reduce our carbon emissions and our dependence on fossil fuels, so it is essential than we develop alternative ways of getting ourselves from A to B. It is becoming very clear that as far as personal mobility is concerned, electric propulsion is the way forward, for following reasons:

1) Its efficiency is far greater than all other forms of propulsion currently in use.

2) It offers the possibility of charging EVs from renewable energies.

3) Wherever the electricity comes from, it produces zero emission at the tailpipe.

4) EVs offer great performance.

A human powered vehicle with an added advantage of an electric motor can reduce the disadvantages of the electric vehicles and also prove beneficial for the human being in terms of exercise and physical fitness. Research is being conducted worldwide in this area and some companies have come up with 4-wheeled hybrid vehicles which run on electric motor and gasoline engines. But this vehicle is different than those vehicles because of the following factors.

1) It is powered by electric motor and human effort.

2) It has no requirement for a fossil fuel powered engine to substitute for the motor at times when battery is down.

The technical aspect of this paper deals with the design of the major components of such vehicle for e.g., chassis, and it emphasizes more on the structural analysis under static and dynamic conditions and later adds the fabrication methods for the same. Our mission is to provide an affordable, better and eco-friendly way of transport to the people.

2)Design-Procedure

In real time environment the frame a vehicle should be able to bear the weight of the drivers and the weight of the freight which sums up to 300 Kilograms, but this weight increases up to 3 times in case of a shock load that occurs when the vehicle falls in a ditch or passes over a speed bump when the vehicle is travelling at speeds more than 20 KMPH [1][3].

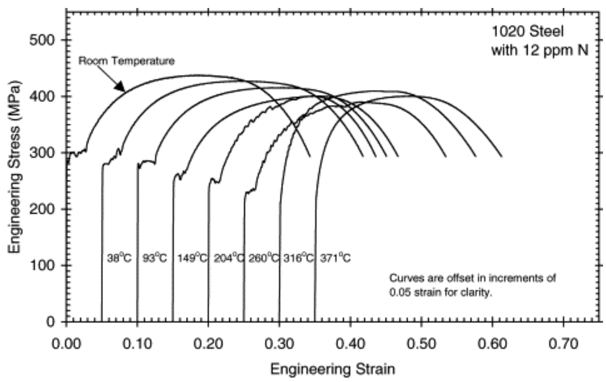
The frame of the vehicle was designed to bear these loads but still have the least weight possible. The material used in such a frame has to be such that it does not increase the weight while providing strength to the vehicle. Considering factors like tensile strength, easy availability, recyclability, and cost AISI 1020 Carbon steel (cold rolled-seamless) is best for the pipe.[5]

There were two possibilities for the cross-section of the frame's members one being square pipe and other being a circular pipe. To reduce the number of weldments and ease of bending give an advantage to the use of pipe for the frame, hence pipes are a better option for a vehicle of this sort; the models were made using Solidworks 2011 software.

Table 1) Properties of Pipe material

PHYSICAL DATA	Value
Density (kg / cu.m)	7861
Specific Gravity	7.86
Modulus of Elasticity (GPa)	200
Tensile Strength (MPa)	420
Poisson's Ratio	0.3
Yield Strength (MPa)	205
Carbon percentage	0.17-0.23%

Figure 1) Stress-strain curve at different temperatures



The frame is totally made of pipe of 1 inch diameter and 2 inch thickness, hence no requirement for any raw material other than the pipe. Its design provides an ergonomic seating position which reduces the human effort while pedaling the vehicle. The weight of the roll cage is 35KiloGrams.

3)Stress Analysis of the frame

The model of this frame was developed in Ansys 11 software and a stress analysis with the following loading conditions was done:

1) **Static condition loading-** A load of 3000 N (taking g= 10 m/s^2) acting on the frame [1][2].

2) **Dynamic condition loading-** a shock load of 9000 N acting on the frame [3].

The frame initially was considered without the two stiffeners that joined the front arch to the seats of the frame.

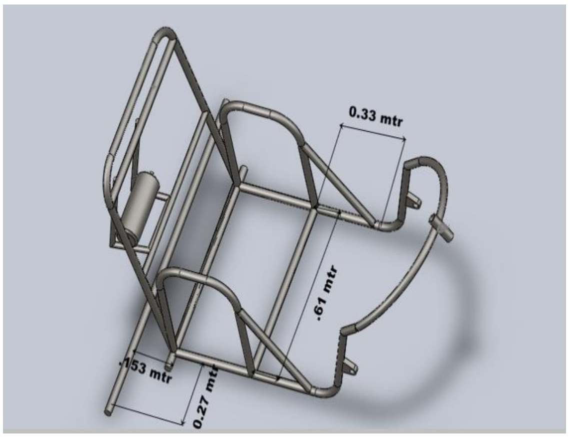


Figure 2) Selected Design of the frame

In Ansys the model was created and not imported to reduce any problems arising with the meshing of the model. Six nodes were identified to apply the loads. The meshed model is as follows. In this model maximum deflections occurred in the pipe bend that bridges the front arch and the seating sections of the frame.

Hence two stiffeners were added as a counter measure, also the edges of seats were curved to reduce stress concentration and facilitate ease of fabrication. Figure 4 shows the results.

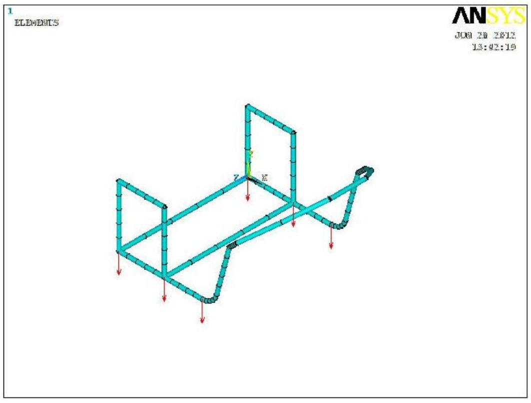


Figure 3) Meshed model without stiffeners.

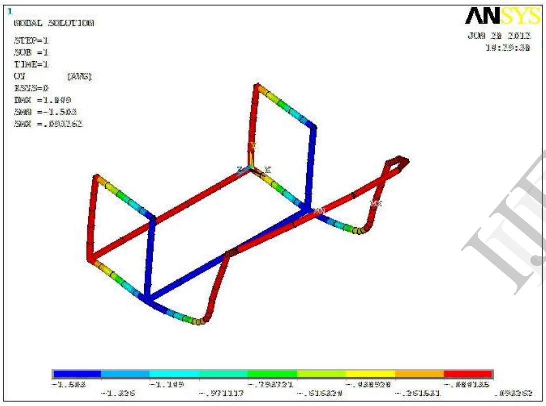


Figure 4) Deflection (without stiffener

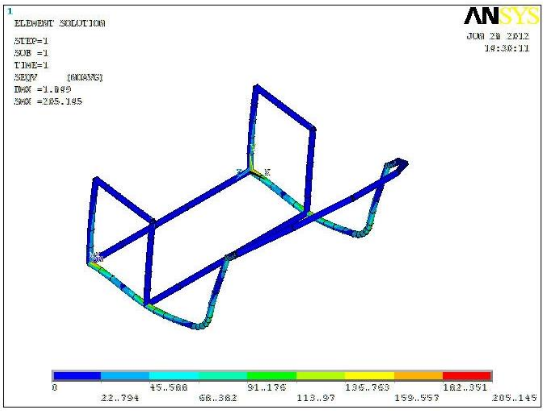


Figure 5) Von-Mises stress without stiffeners.

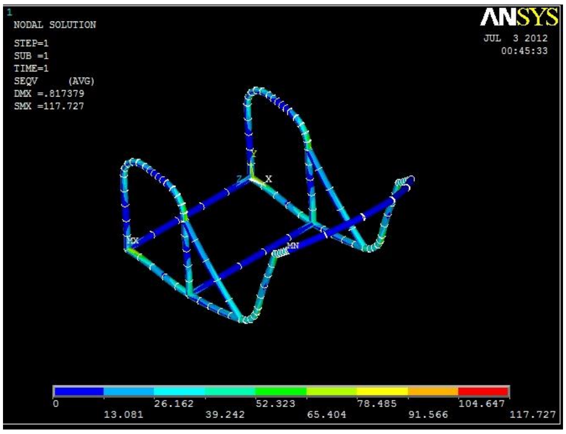


Figure 6) Von-Mises stress with Stiffeners.

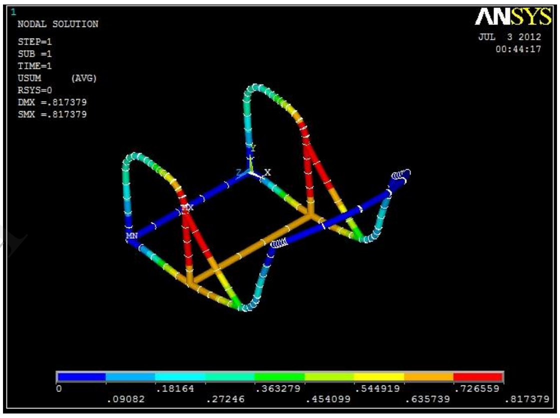


Figure 7) Deflection with stiffeners

Table 2) Results of Analysis

Load= 9000N	**Def mm Min**	**Def mm Max**	**Von-Mises Stress in MPa (Min)**	**Von-Mises Stress in MPa (Max)**
Without stiffener	**0**	**1.6**	**20**	**205**
With stiffener	**0**	**0.8**	**13**	**117**

4)Assumption and relatedCalculations

The following assumptions were made while designing the vehicle
1) Maximum Speed = 45 kmph.

2)Force applied by rider on pedal =300N[6].

3) The starting torque by 1 person is 50 Nm.

Stopping distance:

Assumed as 10 m.

Energy of the vehicle, **E=½mv² =0.5×300×12.5²= 23.4 Kilo Joules**

Braking force

$$v^2 - u^2 = 2(a)(s)$$

$$45^2(5/18)^2 = 2(a)\ 10$$

$$\mathbf{a=7.8m/s^2}$$

Force = m.a = 300*7.8 = 2340 N [7]

Since such great force is required for stopping the vehicle we have provided the vehicle with three brakes with each brake for each wheel.

5)Electric Drive

The electric motor must be capable of producing enough torque to propel the vehicle from stationary position with maximum load. Hence under such conditions a Permanent Magnet Direct Current (PMDC) motor is a feasible solution.[8] They are frequently the best solution to motion control and power transmission applications where compact size, wide operating speed range, ability to adapt to range of power sources or the safety considerations of low volt age are important. Their ability to produce high torque at low speed makes them suitable substitutes for gear motors in many applications[8]. Because of their linear speed-torque curve, they particularly suit adjustable speed and servo control applications where the motor will operate at less than 5000 rpm. Inside these motors, permanent magnets bonded to a flux-re-turn ring replace the stator field windings found in shunt motors. A wound armature and mechanical brush commutation system complete the motor. The permanent magnets supply the surrounding field flux, eliminating the need for external field current. The permanent magnets supply the surrounding field flux, eliminating the need for external field current. This design yields a smaller, lighter, and energy efficient motor.

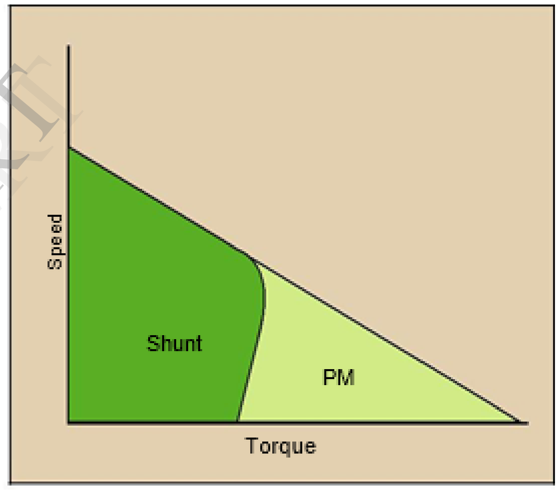


Figure 8) Torque Vs Speed Characteristics of PMDC motor.

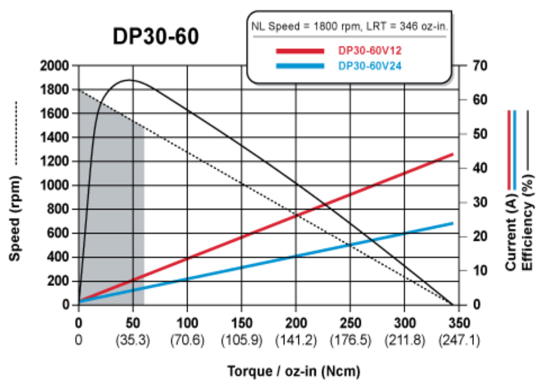


Table 3. Minimum maneuver entrance speed resulting in one wheel lift — Effect of number of occupants.

	Slowly increasing steer						NHTSA J-turn			Road edge recovery		
			Range of linear acc. (m/s^2)									
TWV model	Max. steer angle (deg)	Entrance speed (m/s)	Lower limit	Upper limit	Mid point	Angle at mid point acc. (deg)	Max steer angle (deg)	Time to rise (s)	wheel lift-off (m/s)	Entrance speed at steer angle (deg)	Max Time to rise (s)	Entrance speed at wheel lift-off (m/s)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
0-passenger	1·82	13·23	0·36	2·25	1·31	1·03	8·25	1·23	6·83	6·70	1·38	7·61
1-passenger	1·82	13·04	0·35	2·24	1·30	0·97	7·62	1·13	6·88	6·19	1·27	7·64
2-passenger	1·82	12·97	0·45	2·25	1·35	0·97	7·62	1·13	6·78	6·19	1·27	7·51
3-passenger	1·82	12·95	0·49	2·25	1·37	0·92	7·56	1·12	6·73	6·13	1·27	7·46

Max:- maximum; acc:- acceleration

According to the Torque-Speed Characteristics of PMDC motor a motor of the following specifications suits best for the requirements

1) Speed – 1440 RPM
2) Power-35Amp-hr – 48Amp-hr
3) **AngularVelocity (ω)=(2πN/60)**

   2×3.14×(1440)/60= 150.79rad/sec

6)Fabrication

The fabrication of the vehicle is a simple but time taking process. The basic frame has 9 pipe bends and 12 weldments and requires approximately 7.5 metres of pipe. After addition of other parts like seats and tyres the vehicles weighed 80 Kilograms. The fasteners used were of metric grade M8.8. Electric arc welding was used to do the welding. Shoe brakes were used for both the rear wheels to provide ample breaking force. The seats were placed at a height of 30 inches from the ground to increase stability by lowering the centre of gravity. The front arch was reinforced with an additional similar arch to safeguard the driver in case of front collision and roll-cage was provided to protect the driver in case of a roll over. The vehicle was 86” in length and 46” in width with a turn radius of 2.5 metres.

7)Conclusion

The vehicle was tested in Punjab University Institute of Engineering and Technology under various conditions. It proved to be an appreciable design. In the braking test it stopped within 3 metres after application of brakes. It was able to climb a gradient of 3 degrees up to a distance of 11metres solely powered by the electric drive within 12 seconds. The vehicle was tested for endurance and it covered 19 laps of 1.5 Kilometre each in 90 minutes without breaks. Hence this vehicle could be a great substitute for petrol or diesel vehicles.

8)References

[1] Vehicle Chassis Analysis: Load Cases & Boundary Conditions For Stress Analysis by Ashutosh Dubey and Vivek Dwivedi

[2] "AUTOMOBILE FRAME STRESSES," SAE Technical Paper 210051, 1921, doi:10.4271/210051.

[3] Suh, K., Lee, Y., and Yoon, H., "Dynamic Stress Analysis of a Vehicle Frame by Flexible Multibody Dynamics Simulation," SAE Technical Paper 2001-01-0032, 2001, doi:10.4271/2001-01-0032.

[4] Fundamentals of motor vehicle technology by V.A.W Hiller & Peter Coombes.

[5] A textbook of Machine design by R.S Khurmi.

[6] Jim.M Papadopoulos, Pot – Doctoral research project “FORCES IN BICYCLE PEDALING” Department of Theoretical and Applied Mechanica , Cornell University.

[7] “The Physics of Braking Systems” by James Walker , Journal of SCR Motorsports.

[8] “Applying PMDC motors” by Ronald Bullock, A book for “Power Transmissions design” by Bison Gear & Engineering Corp pp 33-36.