Design and Development of a Hybrid Human Powered Vehicle

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

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CERTIFICATE

This is to certify that the thesis entitled ***" Design and Development of a Hybrid Human Powered Vehicle"*** *submitted by* ***Swarnim Shrishti (110ID0275) and Anand Amrit (110ID0598)****in partial fulfillment of the requirements for the award of the degree* ***BACHELOR OF TECHNOLOGY*** *in* ***INDUSTRIAL DESIGN*** *at* ***National Institute of Technology, Rourkela*** *is an original work carried out by them under my supervision and guidance.*

The matter embodied in the thesis has not been submitted to any other university/institute for award of any other degree.

Date:07/05/2014

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NOMENCLATURE

V = Speed of HPV (in km/hr).

R = Outer Radius of rear wheel (in m).

N = Cadence (in rpm).

Ω = Angular velocity (in rpm).

K = Ride rate (in N/mm).

K_{sp} = Spring Constant (in lbs/inch).

α = Angle between spring and chases (in degrees).

C_d = Drag Coefficient.

Abstract

In a world that is running out of fossil fuels, harvesting human kinetic energy will provide an immediate solution to various mechanical challenges and fuel limitations. Also harvesting renewable source of energy can also be a tool behind solving the problem. This project deals with developing a Human Powered Hybrid Vehicle that uses both human and solar energy to drive the vehicle.

The main objectives behind this project is to build a suitable mode of transportation which would utilize human energy in an efficient way to be used for driving the vehicle such as it runs faster than the present day human powered vehicles. For this purpose the human strength and weakness, the aerodynamic effect of the fairing, the effectiveness of the drive train etc. are taken into consideration. Structural and weight analysis were performed to select the right material for the frame so as to build a vehicle which would be very light weight but strong enough to sustain high loads exerted by the driver during a ride. Utmost priority has been given on the driver safety. With modern technology, steps were taken such that the vehicle doesn't move unless and until the seatbelt and the helmet is worn, thus increasing driver safety. About 450W are produced by elite cyclists in one hour journey and a healthy amateur can generate 200W in same time while pedaling. This energy is harvested to generate electricity on demand and to use it when needed to ensure minimum wastage. Measures have been taken to capture the solar energy and to make use of it for driving the vehicle. The main aim here is to fabricate a cost effective, easy to use and easy maintenance cum repairable vehicle with green personal mobility solution. Blue Streak is a technically enhanced improvisation of a bicycle that also provides better comfort and greater speeds as well as more cargo carrying facility. There are many designs of human powered vehicle but they have some problems related to human comfort, durability, more drag force etc., this calls for the development of design, solving some of the problems in existing designs. This project is based on making a hybrid human powered vehicle. Two prototypes of two different designs have been manufactured for this purpose.

Keywords: Human powered vehicle, Aerodynamic efficiency, Ergonomics, Computational fluid dynamics, Collision protection system.

Chapter 1

Introduction

Chapter 1: Introduction

The salient features of a human powered vehicle which is to be developed are:

The dimension of the vehicle will be around 2000mmX500mmX1000mm.

It will be a modified version of a bicycle which has three wheels, two in front and one in rear and has its centre of gravity lower near to ground and roll centre at the centre line of the vehicle to prevent rolling of the vehicle during turning.

The chassis of the vehicle will be completely made up of stainless steel tubes with primary parts of 42 mm outer diameter and 0.7mm thickness and secondary parts of 25mm diameter and 1.5 mm thickness. Less number of tubes is used to reduce the overall weight of the vehicle.

A hub motor will be fitted at the rear wheel which runs on 12V battery. Whenever the rider is exhausted pedaling of a vehicle, the hub motor can be turned on which can work till the battery is exhausted. The battery is charged when the rider pedals the vehicle.

A re-adjustable seating arrangement is used to accommodate rider at any height.

A CFD analysis on ANSYS will be done so that fluent fairing is given over the chassis to reduce air drag and thus increase the vehicle speed. Fairing material used will be thick transparent plastic with bamboo sticks as it is a skeleton which is overall a new innovation in the field of vehicle body cover and also has less manufacturing with easy availability.

A roll over protection system made up of stainless steel tubes will be used in a cockpit area to prevent human injury in case of rolling of the vehicle as shown in Fig.1.1

Sufficient area is provided in the vehicle for material transportation required.

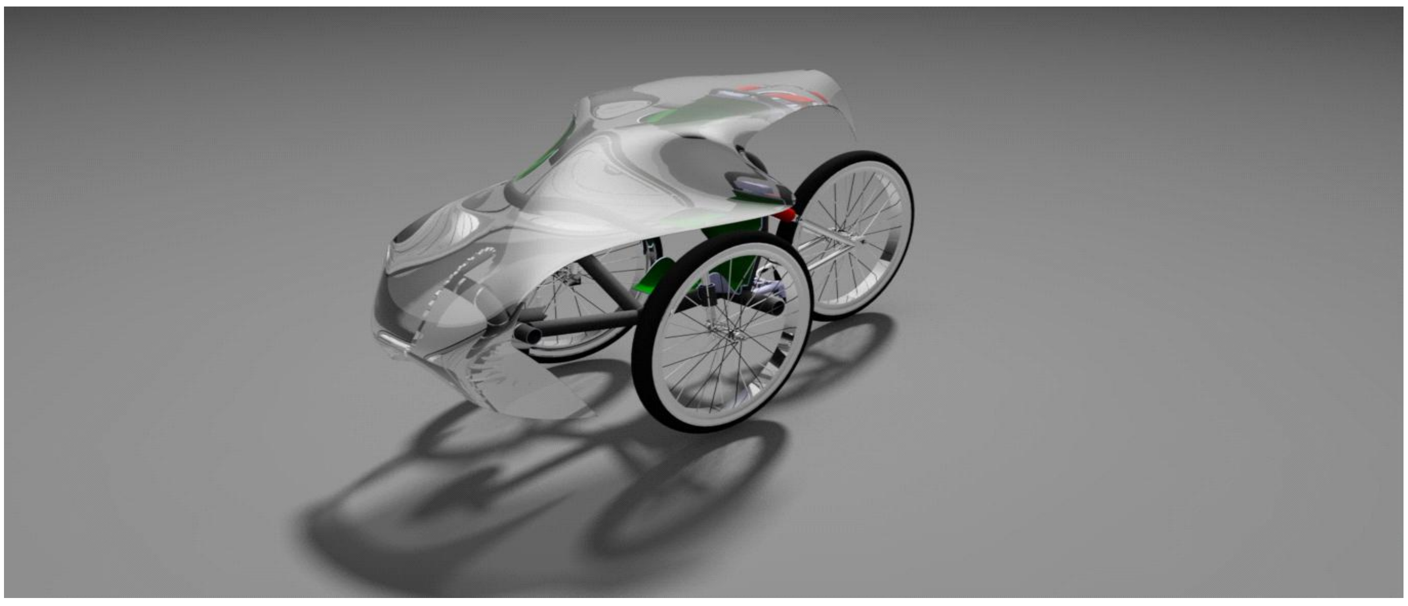

Figure 1.1 Concept Design

1.1 Problem Statement

To design a hybrid human powered vehicle which gives the rider optimum amount of comfort for riding over long distances also keeping in mind the durability of the vehicle.

1.2 Objectives

The major objectives and pertinent work plan to fulfill these can be broadly summarized as:

- To reduce the weight of the vehicle.
- To improve the aesthetics of the vehicle.
- To improve the durability of the vehicle.
- To develop an efficient energy storage system.
- To improve the aerodynamic efficiency.
- To develop a roll over protection system.

1.3 Innovation

Innovations are done to make the vehicle more efficient and user friendly than the conventional human powered vehicles. The major innovations are as follows:

- The leaning position of the vehicle makes it more comfortable.
- Storage of mechanical energy in the form of electrical energy.
- Unassisted start and stop.
- Aerodynamically efficient fairing.
- Ergonomically suitable vehicle due to less strain on human legs while pedaling in comparison to general bicycles.

1.4 Event Planner

Figure 1.2 shows the event planner of the project.

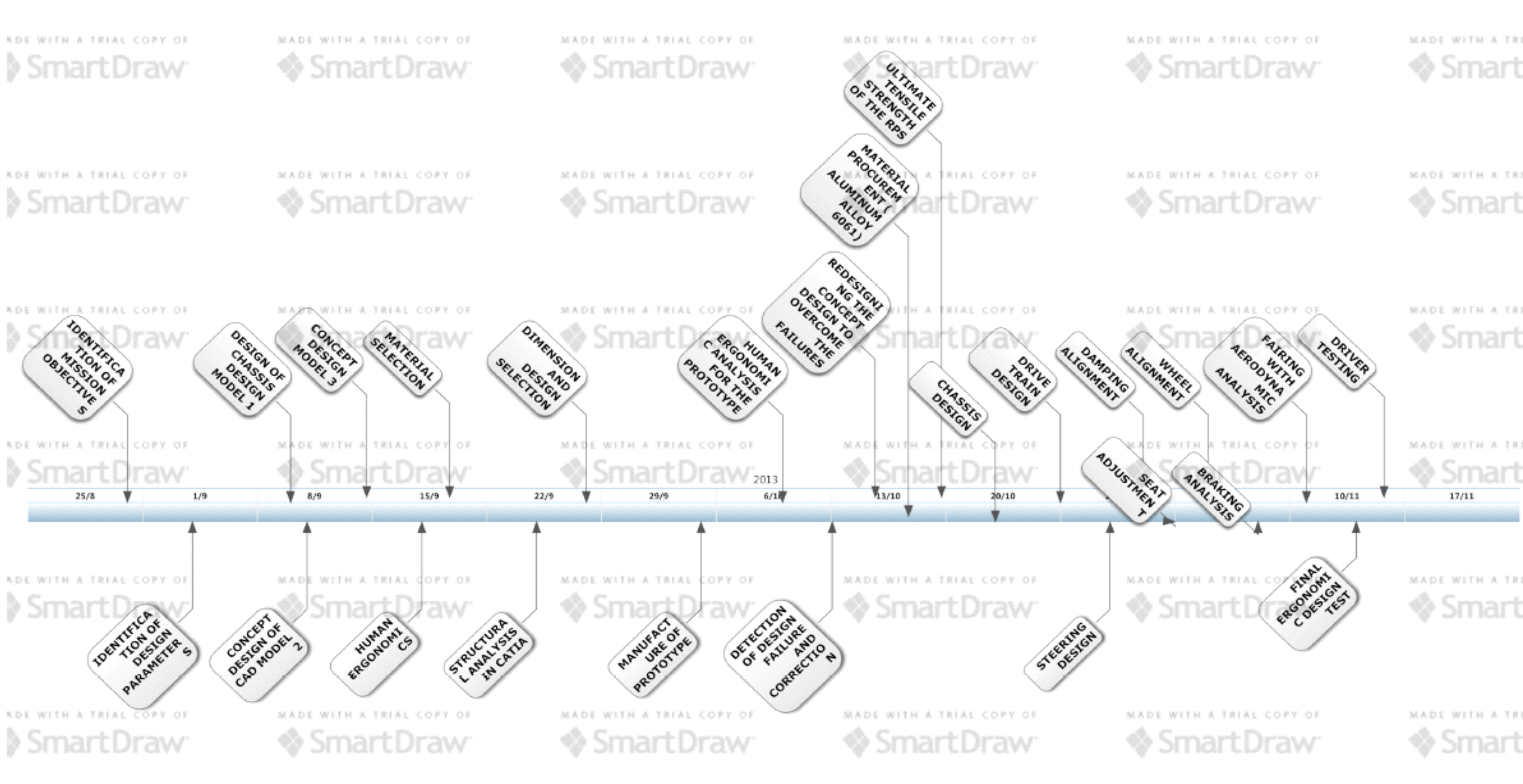

Figure 1.2 Event Planner

Chapter 2

Literature Review

Chapter 2: Literature Review

2.1 Ergonomics

Improving ergonomics means designing the user-interface to make it more compatible with the task and the user. This makes it easier to use and more resistant to errors that people are known to make. Changing the work environment to make it safer and more appropriate for the task. Changing the task to make it more compatible with user characteristics. [1]

2.2 Anthropometry

For design purposes, the criteria for deciding what constitutes a ‘population’ are functional and are related directly to the problem at hand. The word ‘anthropometry’ means measurement of the human body. It is derived from the Greek words ‘anthropos’ (man) and ‘metron’ (measure). The first step in designing is to specify the user population and then to design to accommodate as wide a range of users as possible –normally 90% of them. Well designed products acknowledge and allow for the inherent variability of the user population. [2]

2.2.1 Statistical treatment of anthropometric data

Designing for a person demands dimensional variations to be well fitted. When designing for mass use & for unknown individuals, one of the most relevant statistical interpretations & considerations is the percentile value of the collected data taken from a specific population group. [3]

2.2.2 Percentiles

Percentiles are the statistical values of a allotment of variables transferred into a hundred scale. These values of anthropometric data can be calculated from cumulative frequency graphs and arithmetically. [3]

Professor Debkumar Chakrabarti in his book “Indian Anthropometric Dimensions” has listed all anthropometric variables and some related Indian data.[4]

2.3 Previous Research

- Lucerne[5] (2009), printed a paper which considers the progress and the extend of human powered vehicle (HPV) equipment in order to clarify the intertwine of air force and also to indicate the possibilities that are natural in more competent bicycles. It urbanized and widespread previous work in this area by Kyle and by Beaujon, , amongst others, together with the studies and findings a mass of enthusiasts, riders and historians. It focused not only on the confinements imposed in cycle sports but also the ways in which broader social changes also link with the processes of novelty.

- Danny Too[6] (2003), considered a large number of human body factors that affect cycling conditions. These factors can often be categorized into three categories: (1) environmental factors, (2) intrinsic human body factors, and (3) extrinsic motorized factors. The interaction of different factors within a category can be complex, but need to be examined and understood if efficient human-powered vehicles are to be developed. The purpose of his paper is two-fold: (1) to observe the factors in each group, their relations, and how they affect presentation in human-powered vehicles, and (2) to provide a human machine performance replica for these factors.

- Too and Landwer[7] (2008), considered the boundaries of performance in human powered vehicles (HPV) which in order to be reached, developers of HPVs need to understand how the body interacts with the vehicle to increase propulsive forces, and how the vehicle interacts with the environment to decrease resistive forces. Their paper studied, contrasted and summarized the various research literature on both erect and recumbent cycling positions regarding how orderly changes in peripheral motorized variables (seat-tube-angle, seat-to-pedal distance, crank arm length) interact with interior human body factors (hip, knee, and ankle angles) to affect power creation and cycling performance.

- Julian Edgar[8] (2007), studied several spring material by contrasting their cut off, density and pressure forces. He found the lightest possible spring to be used. Steel coil springs last long and are compacted. Airbag spring is long way compact and is light weight.

- Benjamin Thomas Stein[9] considered an internal cycle ergo indicator that allows for viable and entertaining mountain bike cyclists to replicate uphill conditions with controlled and managed pedaling. While dealing with an uphill condition, with or without a climbing mechanism, the cyclist body may not be in the same position as while pedaling outdoors. This possible dissimilarity in body position may have training requirements. The purpose of this study was to know if the dissimilarity was due to human body factors or due to motorized factors.

Chapter 3

Methodology

3.1 Material Selection

After brainstorming frame geometries, the frame material was determined to balance the various properties of strength, weight, fabrication time, material cost and aerodynamic effects. The material considered were Stainless Steel AISI 304, Chromoly, Aluminium 6061-T6. The choice was determined using a decision matrix as documented in Table 3.1 and it was found that stainless steel was the best frame material to use.

Table 3.1 Material Selection

PROPERTIES	***STAINLESS STEEL AISI 304 (Annealed)***	***CHROMOLY***	***ALUMINIUM 6061-O***
Density (x1000 kg/m3)	7.9	7.8	2.7
Elastic Modulus (GPa)	200	205	69
Poisson's Ratio	0.26	0.28	0.33
Yield Strength (MPa)	207-552	380-1215	241-275
%Elongation	12-40	28.2	
Melting Point(^{0}C)	1400	1432	582
Brinell Hardness	201 HBW	197-375 HBW	95 HBW
Bulk Modulus (GPa)	130	-	67
UTS (MPa)	620	560-1310	310
Elongation at Break (%)	35	12-26	14
Strength to Weight Ratio (kNm/kg)	78	71-160	110
Shear Modulus (GPa)	100	-	34
Fatigue Strength Coefficient (MPa)	876	2294	383
Fatigue Ductility Coefficient	0.063	1.443	0.207
Fatigue Ductility Exponent, c	-0.3069	-.7255	-0.628
Fatigue Strength exponent, b	-0.1057	-0.1013	-0.053
Cyclic Strain Hardening Exponent, n'	0.3419	0.1375	0.089

3.2 FEM Analysis of Aluminium 6061 tubes and Stainless steel

Analysis was done on 2 Tubes of aluminum alloy 6061 and Stainless Steel to compare the load bearing capacity of the chosen aluminum 6061, each of 40mm diameter and 2mm thickness. Loads of 3000N was applied on both the tubes and deformation of 0.2mm was found on aluminum 6061 and 0.08mm was found on stainless steel tube as in Fig 3.1 and Fig 3.2. This shows stainless steel with the least deformation is the best frame material to be used.

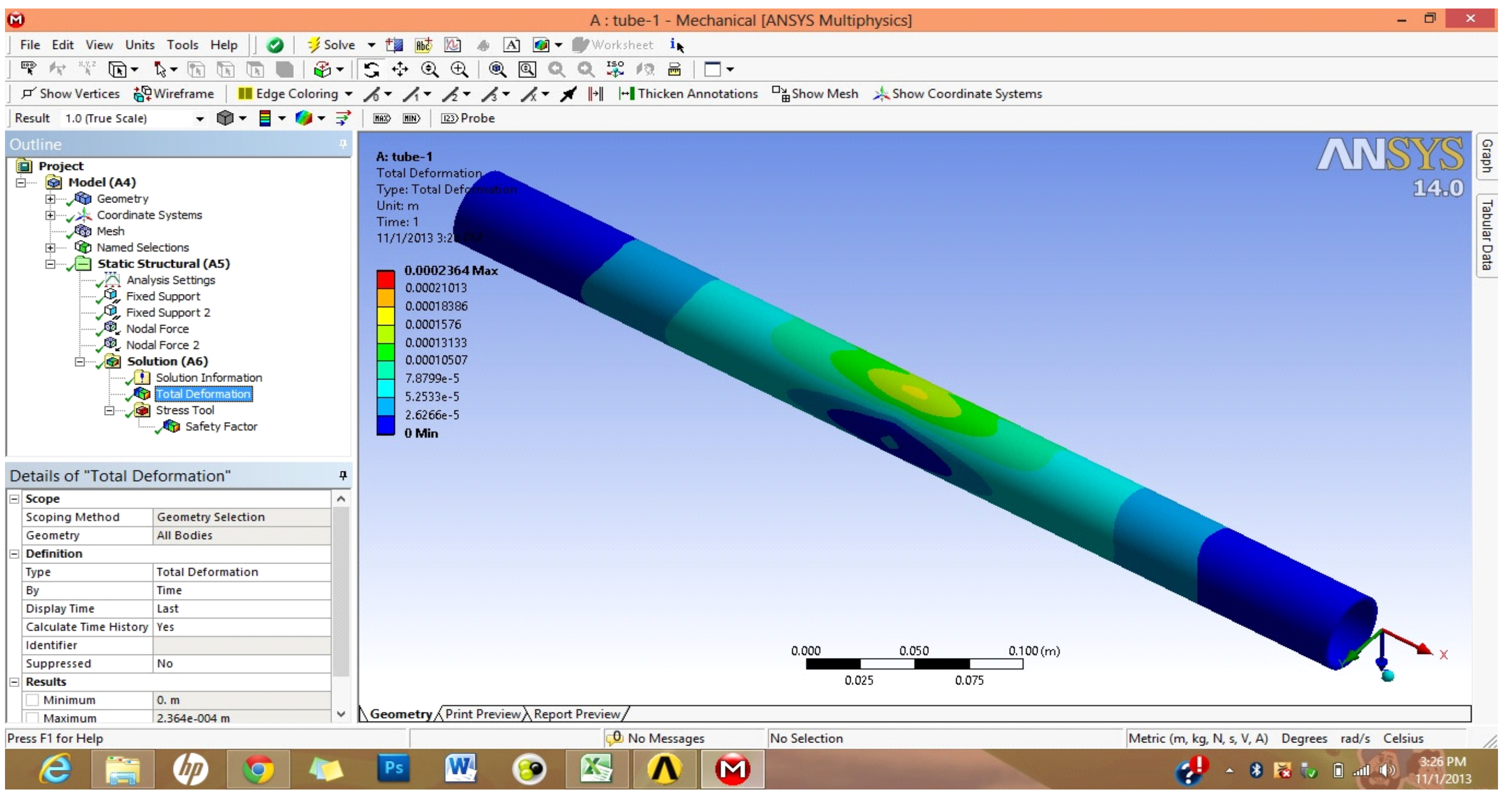

Figure 3.1 Aluminium 6061 tubes

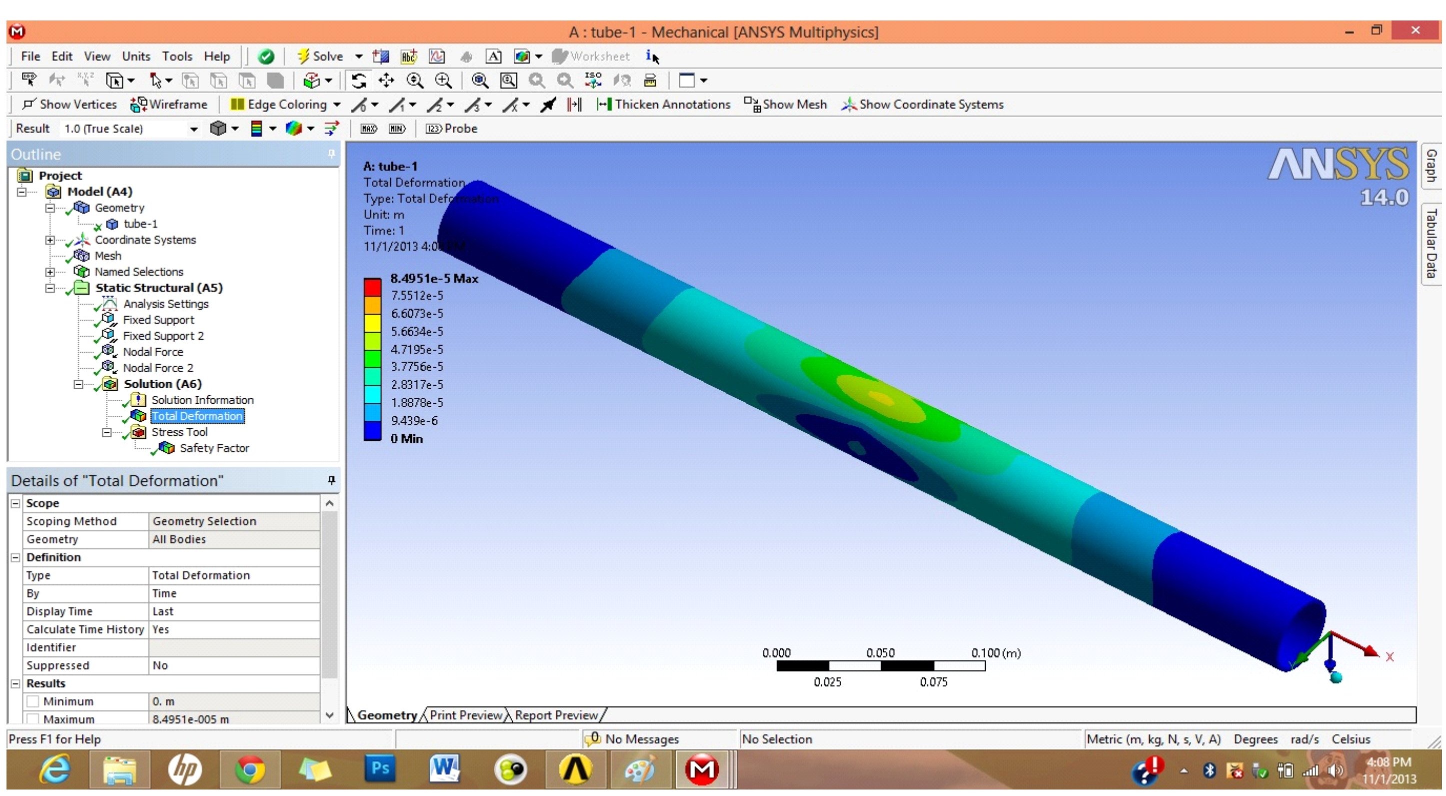

Figure 3.2 Stainless Steel

Chapter 4

Design

Chapter 4: Design

4.1 Frame Design

The frame was designed to place the rider in a position that would minimize frontal area as well as provide a shape to fit a body of upheaval for a laminar flow fairing. Three concept designs were created, varying the general position of the driver and thus a final frame setup was considered.

4.1.1 Concept 1

- In this concept, as shown in Fig 4.1 effort in pedaling is large due to excess height of pedal axle.
- As the rollover protection system is perpendicular to the chassis seating position, so that enough drag is produced which reduces driver efficiency.
- Ergonomically not suitable, as strain on human legs is more due to increased height of pedal axle.

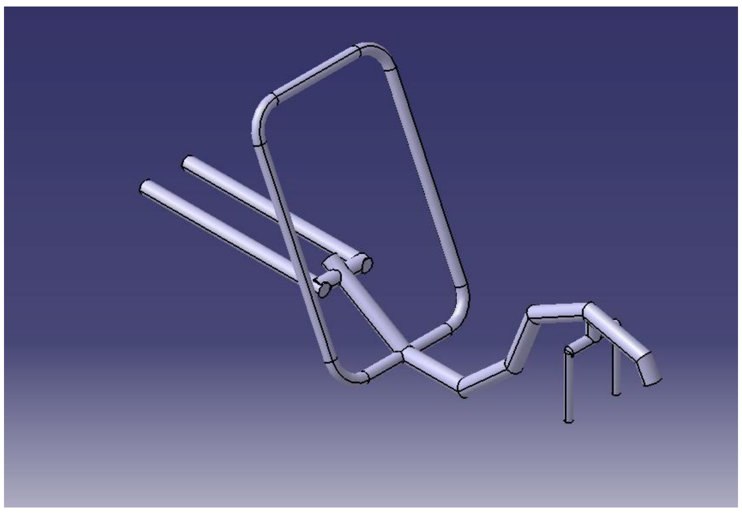

Figure 4.1 Concept 1

4.1.2 Concept 2

- Less effort in pedaling as compared to concept 1 due to decrease in pedal axle height.
- Air drag is more as compared to concept 1 due to increased surface area of body cover as shown in Fig 4.2.

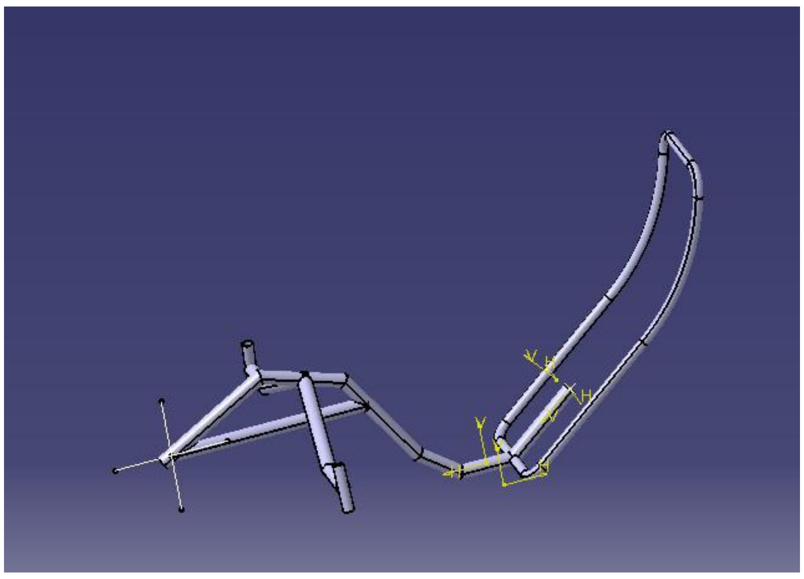

Figure 4.2 Concept 2

4.1.3 Structural Analysis of Concept 2

- Load analysis on concept design 2 was done to determine design parameters.
- Thickness of tube was taken as 7mm and material taken was aluminium alloy 6061.
- Load analysis was done by applying load varying from 1000N to 5000N.

Static load applied on chassis by an average human being =1000N (approximately)

Dynamic load applied on a vehicle by an average human being and by external forces from the road= 5000N (approximately).

- At 1000N, deformation produced is 0.5mm (max.)
- At 2000N, deformation produced is 0.9mm (max.).
- At 3500 N, deformation produced is 1.01mm (max)
- At 4500N, deformation produced is 2.3 mm(max).
- At 5000N, deformation produced is 2.55 mm(max).

Factor of safety at 5000N: 2(min).

However the load as much as 5000N is too large to be considered for a vehicle moving at 30-40 km/hr. and at such So the concept is over engineered and dimensional parameters should be changed.

4.1.4 Human Ergonomics on Concept 2

- Human ergonomics analysis was done to determine workspace of human limbs for average height of 5'7".
- Analysis resulted in collision.
- Analysis resulted in determination of dimensions of rollover protection system.
- Length and position of steering handle was determined by the workspace of hand limbs.
- Position of pedal axle and crank length was determined based on workspace of leg limb.

4.1.5 Concept 3 (Final Concept)

- Lesser effort in pedaling as compared to concept 2 due to decreased height of pedal axle.
- Reduction in air drag due to inclination given to RPS system with respect to chassis.
- Ergonomically suitable due to less strain on human legs during pedaling as in Fig 4.3.

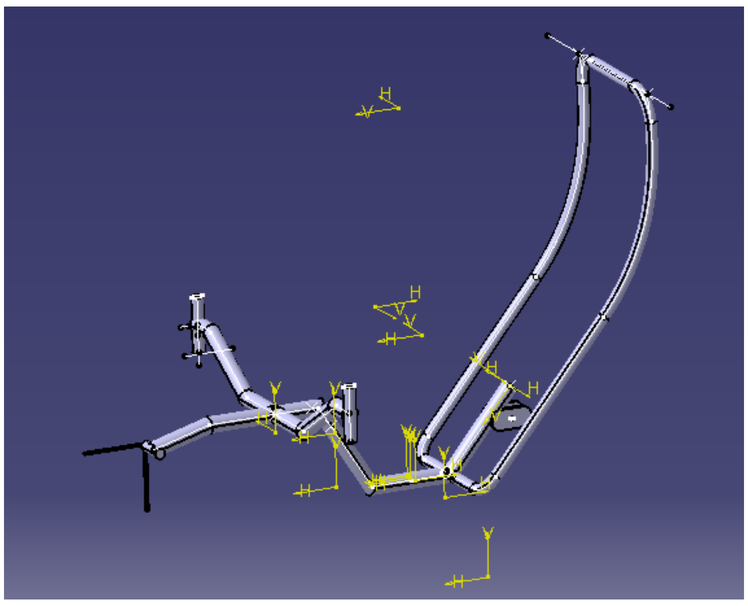

Figure 4.3 Concept 3

4.1.6 Human Ergonomics on Concept 3

A top-down design methodology was used to first locate the important components as shown in Fig 4.4(a),(b),(c). To aid in fitting a human rider, a manikin was used in Catia V5. By designing to largest rider, the smallest riders are guaranteed to fit inside the fairing.

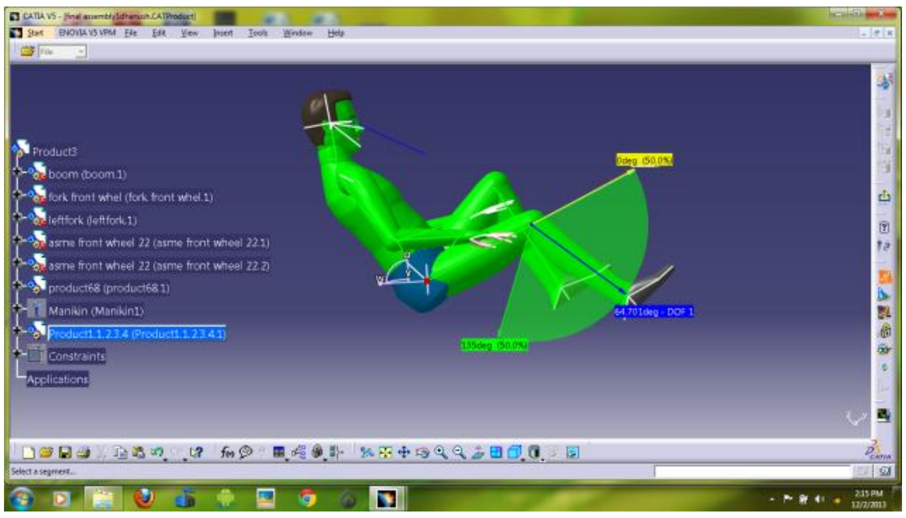

Fig. 4.4(a)

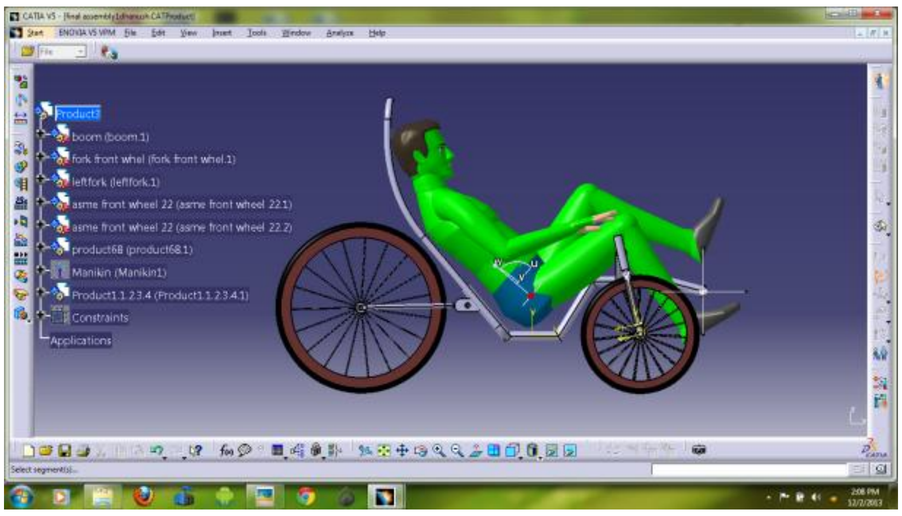

Fig.4.4(b)

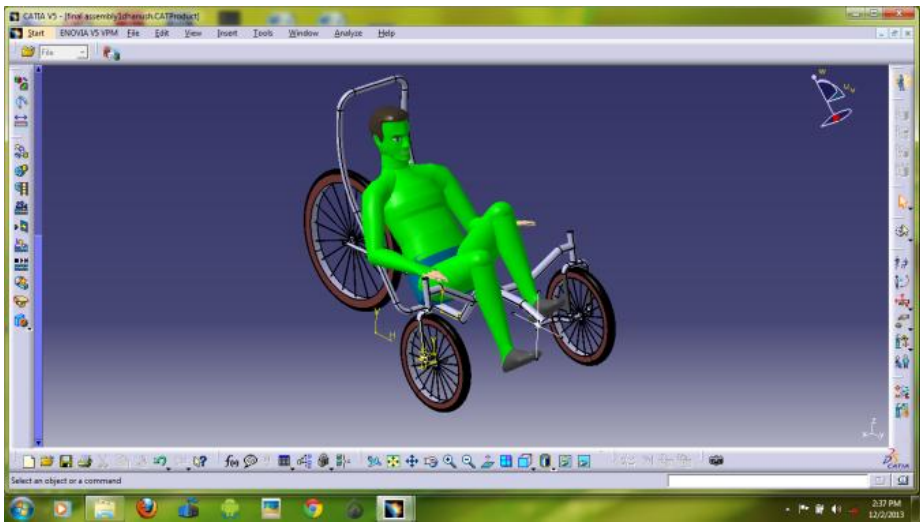

Fig.4.4(c)

Figure 4.4 Human ergonomics on concept 3

4.1.7 Rollover Protection System

It was crucial that we perform analysis in addition to testing in order to validate our concept. We used the composite analysis feature of ANSYS 14.0 to analyze our Rollover Protect under a top and side load, per specification of the 2014 ASME HPVC rules.

For the purposes of simulation, it was assumed that the cross-section of the roll bar is constant and the bar was treated as if it were perfectly connected to the roll bar. Material properties of stainless steel that we used are: Young’s Modulus of 69 GPa in the axial direction, a Poisson’s ratio of 0.33, and an Ultimate Tensile Strength in the axial direction of 310 MPa.

4.2 Fairing Design

The lowest drag shape around an object would ideally have no flow separation, and maintain flow for as long as possible before going turbulent. In order to maintain laminar flow for as long as possible, a favorable pressure gradient is created by constantly sloping the slides outward. Three concept designs of the fairing were generated for the frame as shown in Fig 4.5(a), 4.5(b) and 4.5(c).

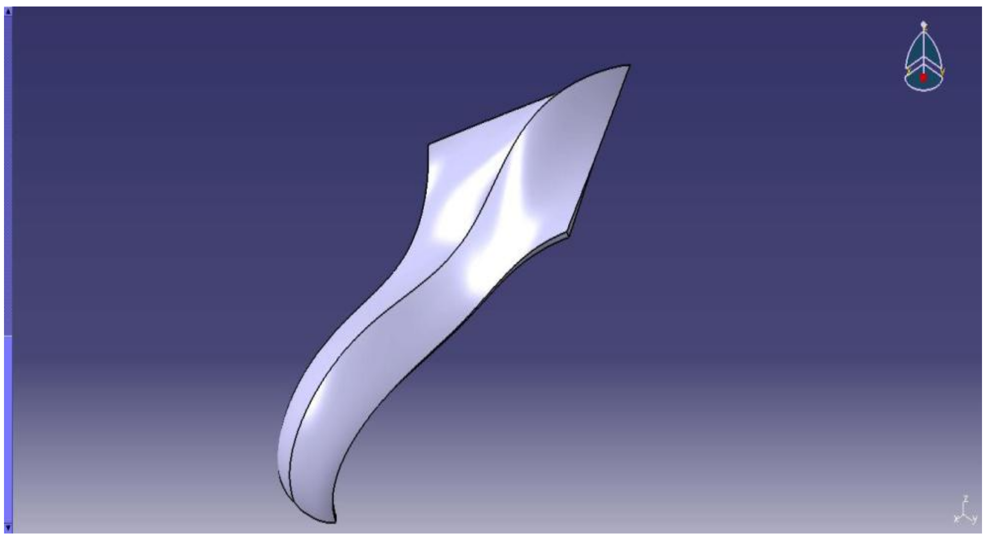

Fig. 4.5(a)

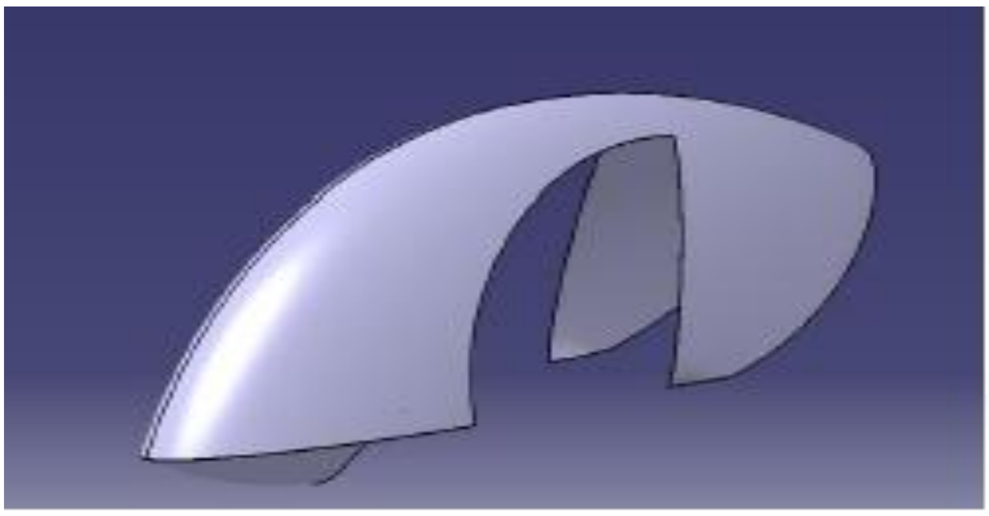

Fig.4.5(b)

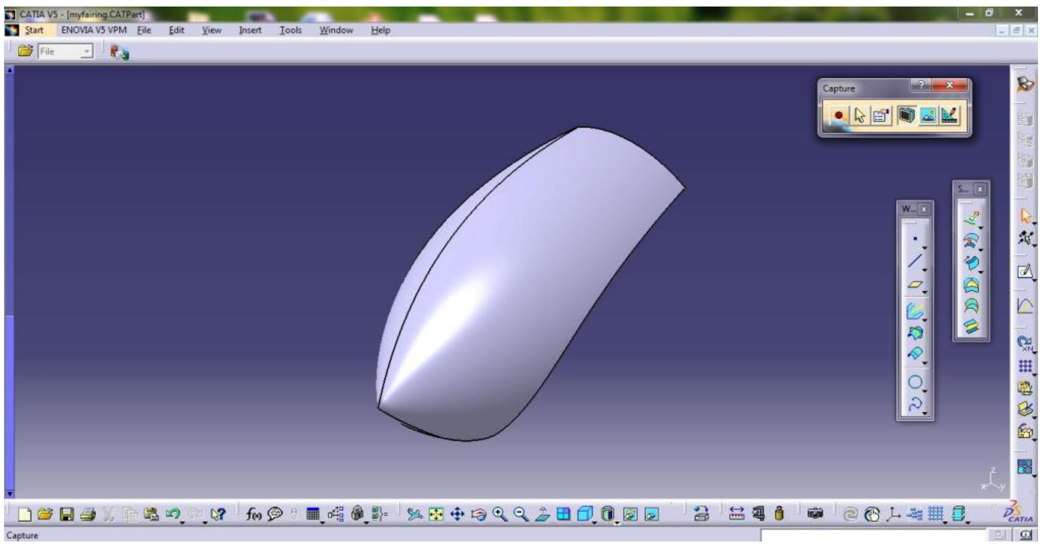

Fig.4.5(c)

Figure 4.5 Fairing

4.3 Computational Fluid Dynamics Analysis

We used a computational fluid dynamics (CFD) model to simulate the air flow around the fairing in order to minimize aerodynamic drag. ANSYS FLUENT was used to test both headwind and crosswind conditions. Tests were conducted near the vehicle's desired top speed of 73.0 km/h with crosswinds of 0 km/h on both the concept designs. CFD analysis of design 1 is shown in Fig 4.6. CFD analysis on design 2 is shown in Fig 4.7 and concept 3 is shown in Fig 4.8.

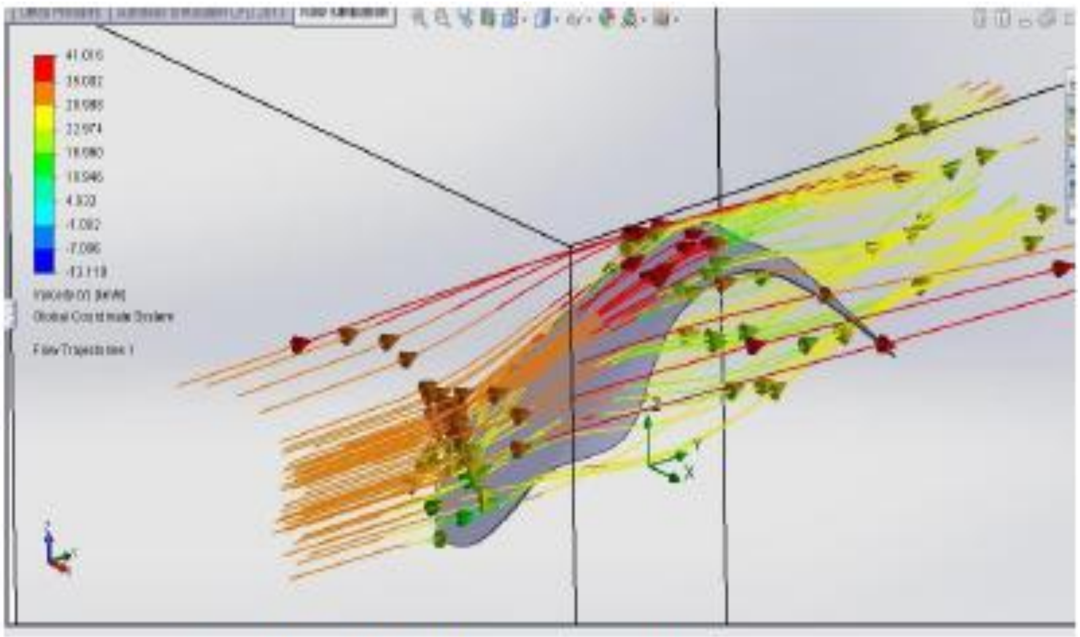

Figure 4.6 CFD Analysis on Design 1

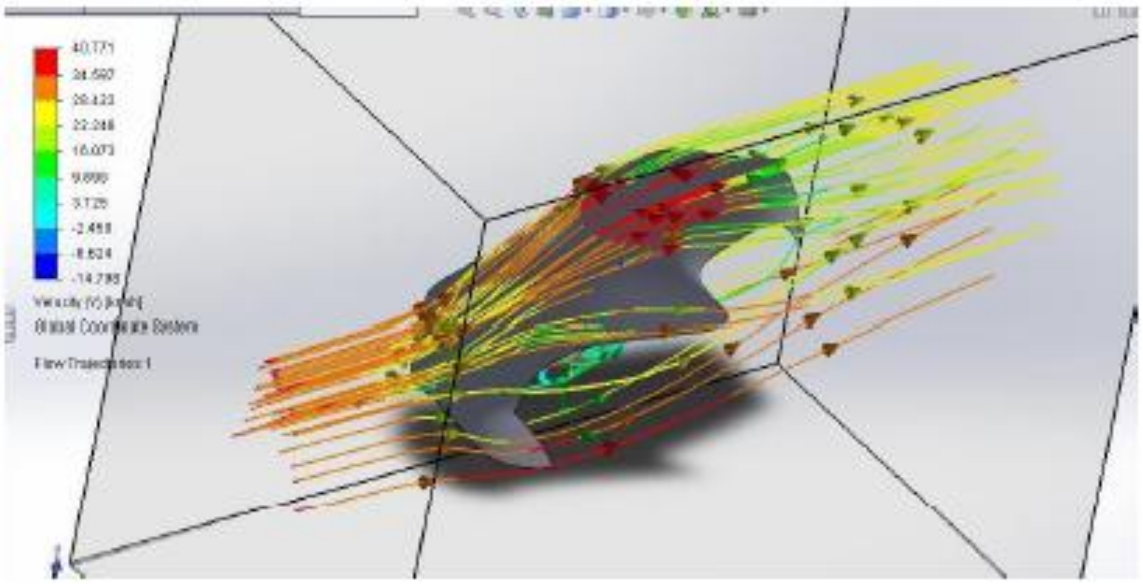

Figure 4.7 CFD Analysis on Design 2

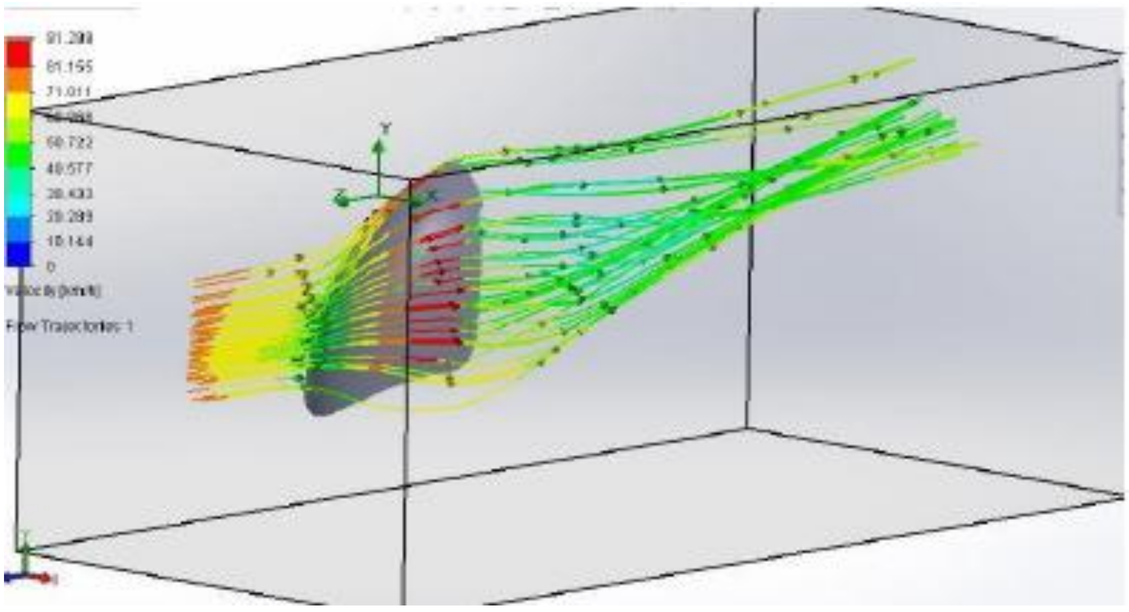

Figure 4.8 CFD Analysis on Design 3

- SOLIDWORKS Flow Simulation and Autodesk Falcon was used for CFD analysis of the fairing.
- The C_d value is the drag coefficient. This comparative quantity describes the "formal quality" of bodies, irrespective of their size.

- A number of factors influence the C_d value, including the vehicle shape. The lower this value, the more aerodynamically efficient the vehicle's design. So concept 3 was found to be best as can be seen from Table 4.1.
- A precise statement regarding the vehicle's aerodynamics can only be made once both the C_d value and the vehicle's frontal area (the projection of the vehicle's front outline onto a plane surface) are known.

Table 4.1 CFD Analysis

Concept Number	Cd Value	Surface Area (m^2)	Cd X Surface Area
1	0.6	4.12010638	2.472
2	0.66	3.00236556	1.982
3	0.009	2.98201202	0.027

4.4 Spring analysis

For our vehicle we used 1 bicycle suspensions having K_{sp} (spring constant) value of 850lbs/inch.

Total load of the vehicle with rider = 500N

Load on the rear wheel in static condition = 250N

Wheel travel allowed = 34.4 mm

Ride rate = 7.25 N/mm

$K = K_{sp} * (\text{motion ratio})^2 * \cos 2\alpha$

Where,

k= ride rate

α= angle between spring and chassis

Motion ratio is taken 1.

k (N/m)	m (kg)	k/m	sqrt	freq	rate (N/mm)	k	ksp	mr		cos^2(ra)	cos(ra)	ra(radian	ra(deg)
7250	25	290	17.0294	2.71081	7.25	7.25	14.5	0.1	0.145	50	7.07107	#NUM!	
						7.25	14.5	0.15	0.32625	22.2222	4.71405	#NUM!	
						7.25	14.5	0.2	0.58	12.5	3.53553	#NUM!	
						7.25	14.5	0.25	0.90625	8	2.82843	#NUM!	#NUM!
						7.25	14.5	0.3	1.305	5.55556	2.35702	#NUM!	#NUM!
						7.25	14.5	0.35	1.77625	4.08163	2.02031	#NUM!	#NUM!
						7.25	14.5	0.4	2.32	3.125	1.76777	#NUM!	#NUM!
						7.25	14.5	0.45	2.93625	2.46914	1.57135	#NUM!	#NUM!
						7.25	14.5	0.5	3.625	2	1.41421	#NUM!	#NUM!
						7.25	14.5	0.55	4.38625	1.65289	1.28565	#NUM!	#NUM!
						7.25	14.5	0.6	5.22	1.38889	1.17851	#NUM!	#NUM!
						7.25	14.5	0.65	6.12625	1.18343	1.08786	#NUM!	#NUM!
						7.25	14.5	0.7	7.105	1.02041	1.01015	#NUM!	#NUM!
						7.25	14.5	0.75	8.15625	0.88889	0.94281	0.33984	19.4712
						7.25	14.5	0.8	9.28	0.78125	0.88388	0.48669	27.8856
						7.25	14.5	0.85	10.4763	0.69204	0.83189	0.58829	33.7066
						7.25	14.5	0.9	11.745	0.61728	0.78567	0.66701	38.2169
						7.25	14.5	0.95	13.0863	0.55402	0.74432	0.73128	41.899
						7.25	14.5	1	14.5	0.5	0.70711	0.7854	45

figure 2.6(a)

Figure 4.9 Spring Analysis

Chapter 5

Drive Train Analysis and Innovision

5.1 Drive Train

The drive train is one of the most important aspects of reliability for a Human Powered Vehicle. A well designed drive train will make the HPV more efficient and user friendly as well as decrease excessive mechanical losses improvise speed and increase the reliability of the HPV.

In our HPV we have introduced rear wheel drive system over front wheel and internal gear hub. The advantages of rear wheel drive are that it does not allow torque steer with the pedal stroke and it leaves plenty of space for the gearing system assembly. The cassette and derailleur can be placed at the rear wheel well out of the way of rider's feet. Additionally it is light weight and is much less expensive. On the contrary they have longer drive chain and require more chain tensioners which we have overcome in our design by optimizing the dimensional accuracy. As per our design which includes two wheels at the front, the front wheel drive systems have their share of drawbacks. In the above case, to improvise the steady state condition while taking a sharp turn we need to use a differential which will increase the weight of the vehicle as well as hamper our economic viability. Lastly, though the internal gear hubs are more effective while shifting of the gear but are less efficient than a cassette- derailleur system due to multiple planetary gear connection which causes more friction and high energy losses. Hence looking forward towards the advantages of a rear cassette derailleur system over front wheel and internal gear hubs we opt for the rear wheel drive train. Further analysis was done to determine the best combination of crank chain ring and cassette that will be the best for our top speed goal and also for rider comfort.

5.2 Determining the Velocity of HPV

For a given cadence, gear ratio and the outer radius of the rear wheel we determine the value of the speed of the HPV as:

V (km/hr.) = R (m) * GEAR RATIO * CADANCE (rpm) * 2π/60 * 18/5

Let the front sprocket is rotated by the driver at a cadence (N rpm). So the rear sprocket rotates at a cadence of (N* GEAR RATIO).

The velocity of rear wheel of radius R for this rpm is given by

V= ω*R = N*GEAR RATIO*2π/60*R*3600/1000 (km/hr.).

According to ISO 5775 designation for wheels our team has selected the size of rear wheel as 28 inch * 11/8 inch * 9/8 inch. We have used 30 speed shimano gears in our drive train which involves 50T, 39T and 30T at the front sprocket and the combination of 25,23,21,19,17,15,14,13,12,11 at the rear sprocket.

The velocity calculation for different gear combination and cadence are shown in Table 5.1, 5.2, 5.3.

Table 5.1 Calculation of speed for different values of cadence with respect to 50T chain ring

50T CHAIN RING						
	CADENCE(RPM)					
REAR COG	120	110	100	90	80	70
25	32.15	29.47	26.8	24.11	21.43	18.75
23	34.95	32.04	29.12	26.21	23.3	20.4
21	38.28	35.09	31.91	28.71	25.52	22.33
19	42.31	38.78	35.26	31.73	28.2	24.68
17	47.29	43.35	39.4	35.46	31.52	27.58
15	53.61	49.13	44.66	40.19	35.73	31.26
14	57.42	52.64	47.85	43.06	38.28	33.49
13	61.84	56.68	51.53	46.38	41.22	36.07
12	66.98	61.41	55.83	50.24	44.66	39.08
11	73.08	66.99	60.91	54.82	48.72	42.63

Table 5.2 Calculation of speed for different values of cadence with respect to 39T chain ring

39T CHAIN RING						
	CADENCE(RPM)					
REAR COG	120	110	100	90	80	70
25	25.08	22.99	20.9	18.81	16.72	14.63
23	27.26	24.99	22.72	20.44	18.17	15.91
21	29.86	27.37	24.88	22.39	19.91	17.41
19	33.01	30.25	27.51	24.75	22.01	19.25
17	36.88	33.81	30.74	27.66	24.59	21.51
15	41.82	38.32	34.83	31.35	27.87	24.38
14	44.79	41.06	37.33	33.59	29.86	26.13
13	48.23	44.22	40.19	36.17	32.15	28.14
12	52.25	47.91	43.54	39.19	34.84	30.48
11	57.02	52.25	47.51	42.75	38.02	33.25

Table 5.3 Calculation of speed for different values of cadence with respect to 30T chain ring

30T CHAIN RING						
	CADENCE(RPM)					
REAR COG	120	110	100	90	80	70
25	19.29	17.68	16.07	14.47	12.86	11.25
23	20.97	19.22	17.47	15.73	13.98	12.23
21	22.97	21.05	19.14	17.23	15.31	13.39
19	25.38	23.27	21.15	19.04	16.93	14.81
17	28.37	26.01	23.64	21.28	18.92	16.55
15	32.15	29.47	26.79	24.12	21.44	18.75
14	34.45	31.58	28.71	25.84	22.97	20.09
13	37.12	34.02	30.92	27.83	24.74	21.64
12	40.19	36.84	33.49	30.15	26.79	23.45
11	43.85	40.19	36.54	32.88	29.23	25.58

Thus we have finally achieved a theoretical top speed of 73.08km/hr. with the combination of 50T-11T for a cadence of 120 rpm with the wheel size of 0.7112m as diameter.

5.3 Innovations

5.3.1 Collision protection system

Objective: To prevent the vehicle from colliding with any passerby or other vehicle.

Need: Sometimes the vehicle may go out of control and hit any nearby person or vehicle leading to casualties. Such a system would prevent it from happening.

Description: When any obstacle (of bigger size like another vehicle or passerby comes at a near immediacy to the vehicle the system automatically applies brakes of its own. It consists of a high torque motor which is connected to the brake machine via a brake wire and an ultrasonic distance sensor. Whenever a vehicle comes near the vehicle, the ultrasonic sensor detects the object proximity and sends the relevant data to the microprocessor which in turn makes the motor to rotate and pulls the brake wire. Thus the brake gets applied.

Fig 5.1 shows a schematic diagram of such a system.

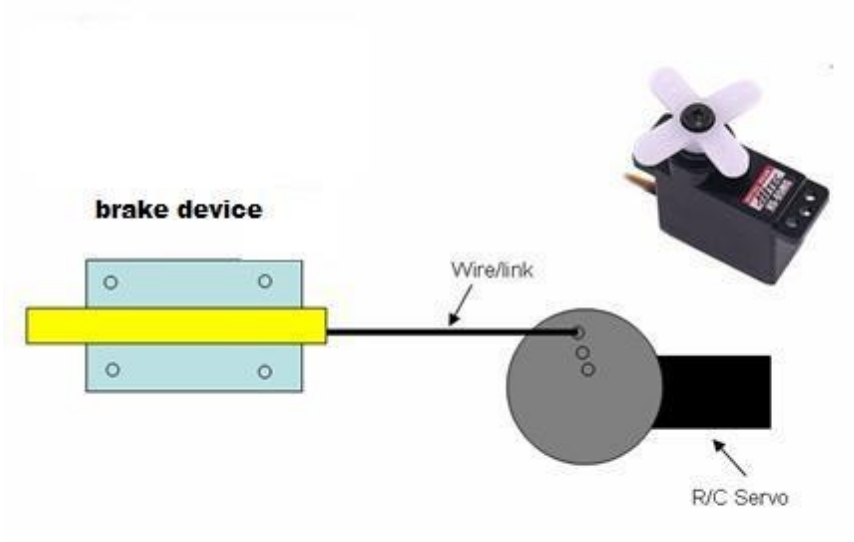

Figure 5.1 Collision Protection System

5.3.2 Energy saving system

Objective: To save energy using regenerative braking system

Need: During braking a large amount of energy gets wasted in the form of friction. If we could save that energy then we can use it for other purposes.

Description: Considering energy capture devices, we drew inspiration from bicycle lamps, which used dynamos to capture energy. Two armatures were constructed to act as high power dynamos which could produce 12v electric current each. This system straddles the rear and the front wheel clamping down on rim with a rubberized wheel. When the rubberized wheel comes in contact with the rim, it spins the shaft connected to the electric motor, generating an electric current. The energy extracted by this method causes the vehicle to slow. This energy is then stored in a 12v battery. Both the dynamos in the front and in the rear are connected in parallel.

Chapter 6

Results and Discussion

6.1 Results of Concept Design

We tested two load conditions, a 2722N top load at 12° from vertical and a 1361N side load. The results are shown in Figure 6.1(a), 6.1(b) and Figure 6.2(a), 6.2(b). Analysis shows top loading results in 16.31mm deformation and side loading results in 1.4mm deflection. This model predicts that we are well below the yield strength of aluminum 6061-T6. Top model Top the model does predict that we are above the maximum allowable deformation under the side load condition, while the model predicts a large factor of safety, it does not account for secondary failure modes like abrasion of the rollover protection system or buckling of the surface. For these reasons, we will build in rib reinforcements around the rider and in places where we expect high stress. Our main conclusion from these results is that there is enough strength inherent in the material of our RPS, provided that we can prevent buckling and protect against abrasion.

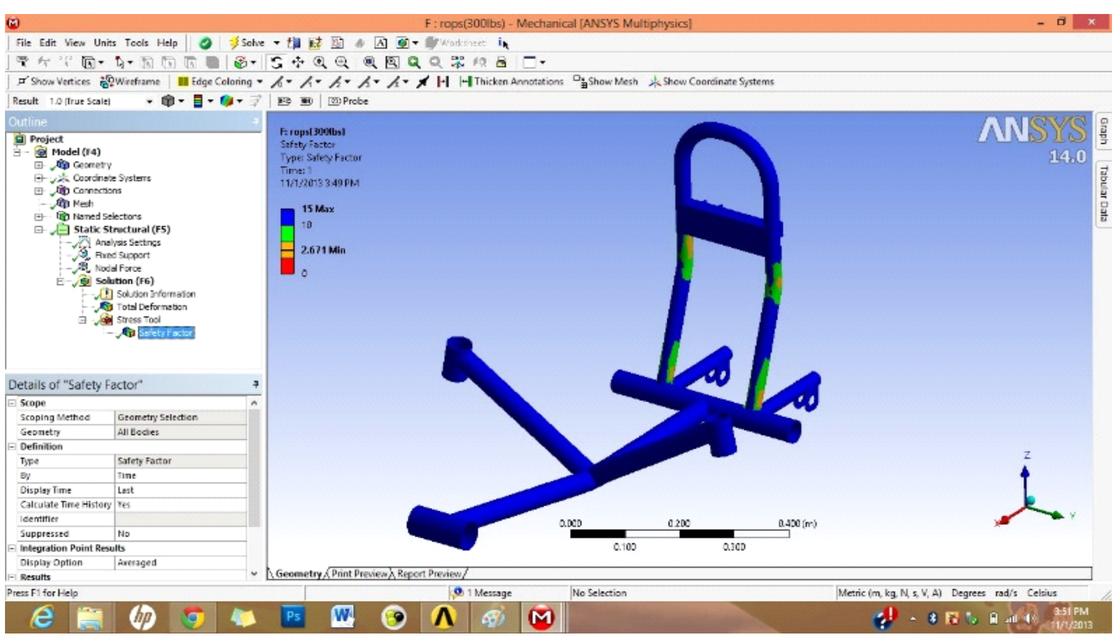

Fig 6.1(a)

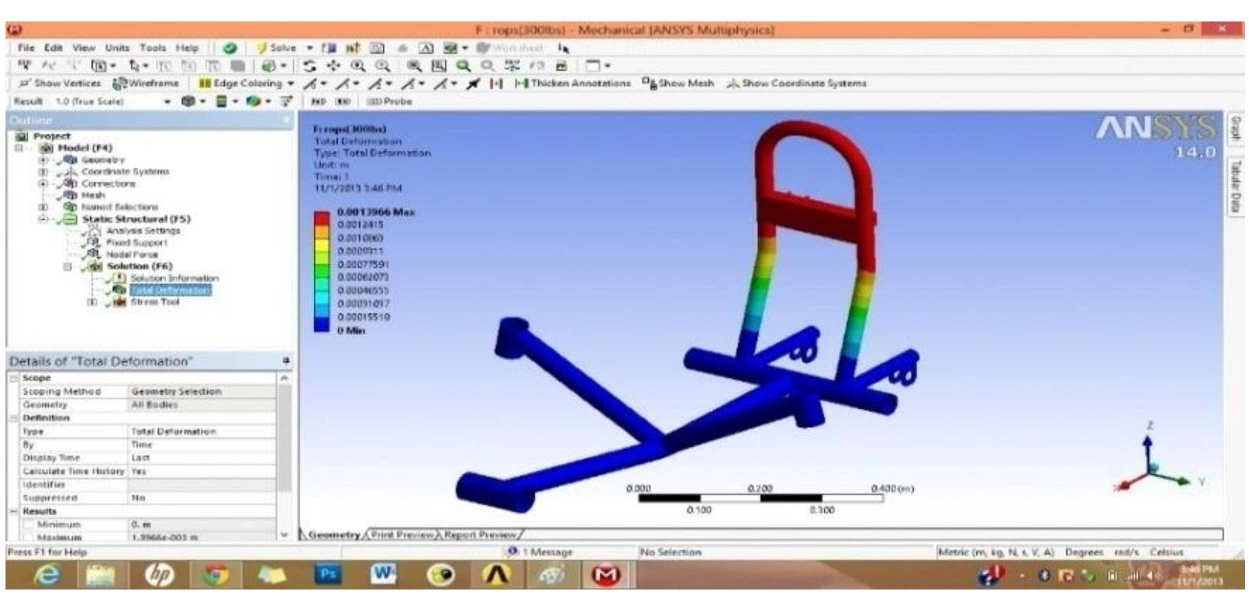

Fig 6.1(b)

Figure 6.1 300 lb side impact(FOS Analysis)

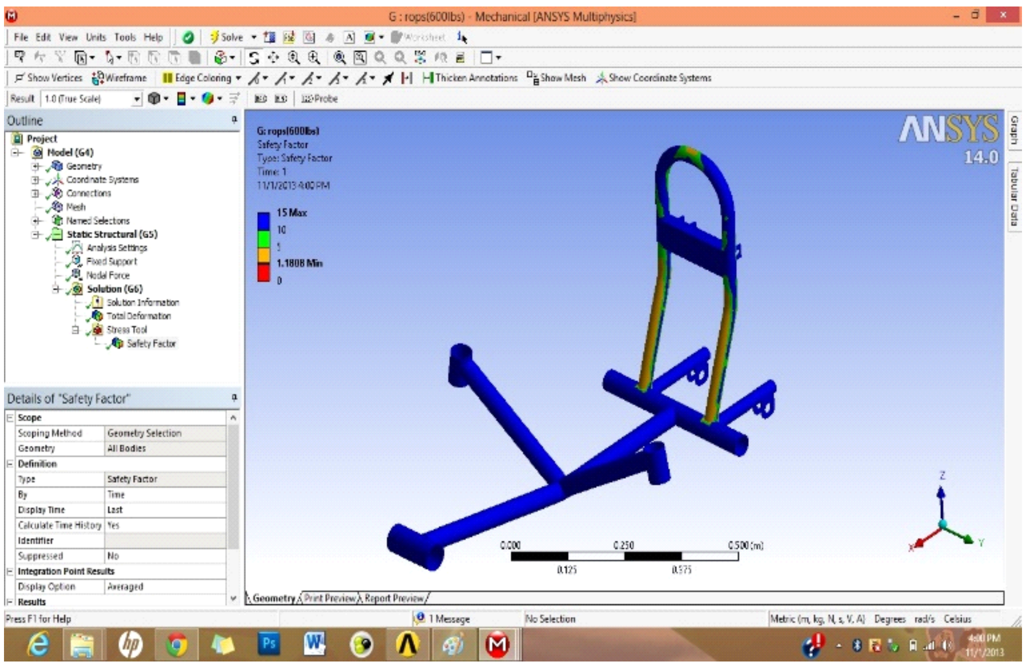

Fig 6.2(a)

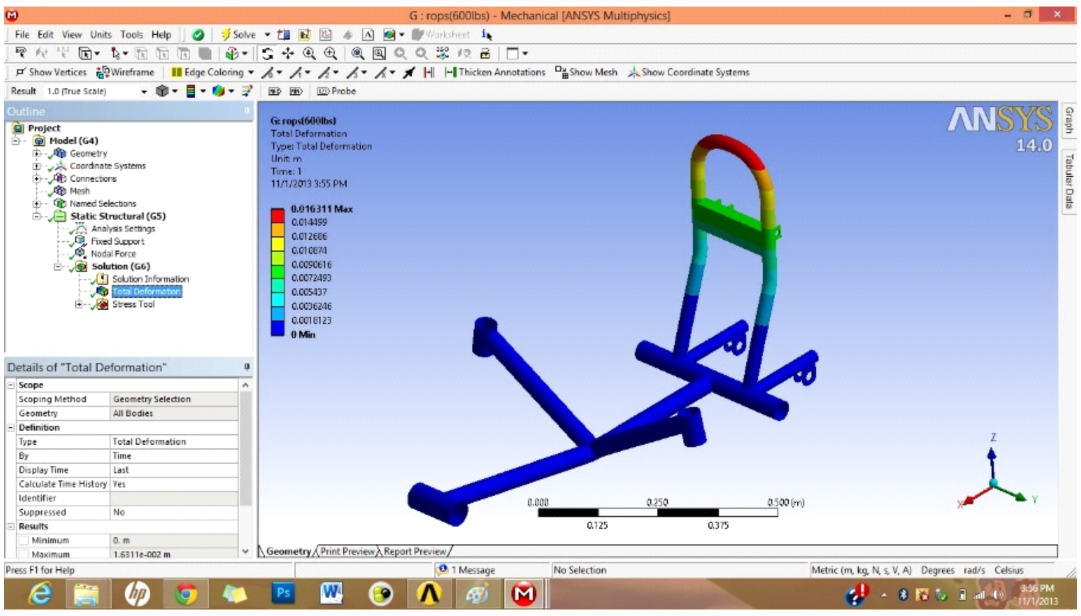

Fig 6.2(b)

Figure 6.2 600 lb top impact (FOS Analysis)

6.2 Final Result and Design

Top force as less as 0.014N and downward force as high as 1.1N was found. So Design 3 was finalized to be used in our vehicle. The above analysis shows concept design 3 to be a better design with drag. Based on above analysis we reached on a final design as shown in the figure 6.3(a), 6.3(b), 6.3(c).

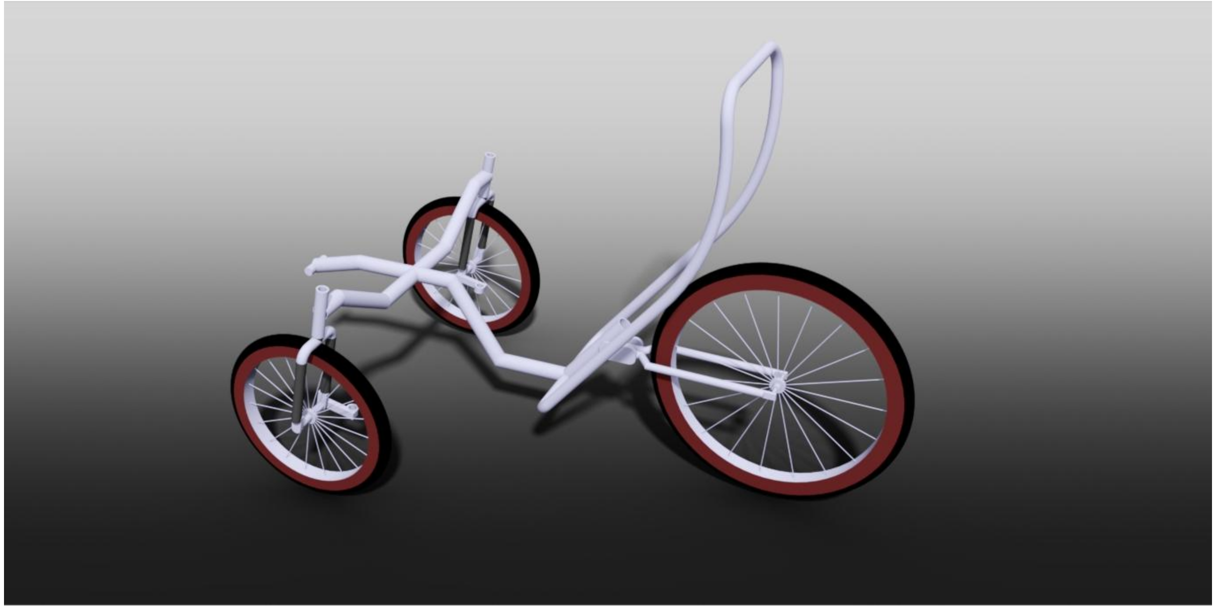

Fig 6.3(a)

Fig 6.3(b)

Fig 6.3(c)

Figure 6.3 Final Design

6.3 Discussion

- ANSYS and SOLIDWORKS SimulationXpress was used for FEM analysis.
- SOLIDWORKS Flow Simulation and Autodesk Falcon was used for CFD analysis of the fairing.
- CATIA and SOLIDWORKS were used for solid and surface modeling.
- Determination of the dimensions of the frame was a big challenge which was solved after numerous analyses.
- The flow structure of the fairing was also determined after many CFD and drag analysis.
- While ergonomic analysis, we faced a problem due to unavailability of Indian manikins in the software. Hence, we created manikins according to Indian data and dimensions of our drivers.

Chapter 7

Conclusions

Chapter 7: Conclusions

7.1 Product

We manufactured the product of the final design using stainless steel as shown in figure 7.1.

Figure 7.1 Manufactured Vehicle

- Our final design is an efficient and agile vehicle that could safely and effectively be used for everyday transportation.
- It is highly efficient as compared to upright bicycles requiring very less power to overcome air drag at the same speed.
- Small frontal profile and streamlined body allow it to travel at very fast speed as compared to the normal bicycles.
- This style of fairing increases the appeal and attractiveness to touring in a tricycle. Sufficient protection is provided to the rider with an integrated roll over protection system.
- Combined efficiency, safety and utility make it well suited to capture a large market segment in sustainable transportation.

7.2 Further scope

Functional Design

- Other improvement is to make use of all types of sensations and incident energy being received by the vehicle during run. We can make use of the central energy produced by repelling motion of a permanent magnet inside of coils to produce induced electromotive force. All the produced energy can be used to charge a mobile which becomes a necessity sometimes. And our one idea is to use the small fraction of rotational energy from the shaft of the vehicle to run a switch pump.
- We recommend more work so that the vehicle can be converted to a fusion vehicle completely, which means the source of energy can be from both human power and also from other renewable sources of energy like solar energy or wind energy. We have also conducted experiments with solar energy and has found 1 hr of charging in the sun can provide 15- 20 minutes of ride without any pedaling.
- The crossbreed vehicle typically achieves greater fuel saving and lower emissions than usual inner ignition engine vehicles, resulting in fewer emissions being generated.

Aesthetics and Ergonomics

- The vehicle has been designed in such a way that it could attract attention. Though the frame could consist of straight and curve lines in a fashioned way to make it more appealing.
- The carrier can be given a slight curve structure so as to add to the aesthetics of the vehicle. The carrier also serves as the support for the rollover protection system.
- The fairing was designed to give a half bullet shape making it an addition on to the aesthetics of the vehicle. The further improvement in the design of fairing can be made to make it look aesthetically sound while minimizing the air drag.
- A further improvement in the ergonomics of the vehicle can be done by adjusting the position of the pedals so that the rider can ride for a long time without any strain in legs.

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