A PROJECT REPORT

ON

"DESIGN AND FABRICATION OF ELLIPTICAL BICYCLE FOR COST OPTIMIZATION"

Submitted by

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In partial fulfillment for the award of the Degree

Of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

UNDER THE GUIDANCE

Of

Prof. SAAD SHAIKH

DEPARTMENT OF MECHANICAL ENGINEERING

ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL,

NAVI MUMBAI – 410206

UNIVERSITY OF MUMBAI

ACADEMIC YEAR 2015-2016

ANJUMAN-I-ISLAM

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CERTIFICATE

This is to certify that the project entitled

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by them under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University Of Mumbai**, is approved.

Project guide	**Internal Examinar**	**External Examiner**
(Prof. Saad Shaikh)	(Prof.______)	

Head of Department	**Principal**
(Prof. Zakir Ansari)	(Dr._______)

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APPROVAL OF DISSERTATION

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(Internal Examiner) **(External Examiner)**

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Date: ___________

ACKNOWLEDGEMENT

After the completion of this work, we would like to give our sincere thanks to all those who helped us to reach our goal. It's a great pleasure and moment of immense satisfaction for us to express my profound gratitude to our guide **Prof. SAAD SHAIKH** whose constant encouragement enabled us to work enthusiastically. His perpetual motivation, patience and excellent expertise in discussion during progress of the project work have benefited us to an extent, which is beyond expression.

We would also like to give our sincere thanks to **Prof. ZAKIR ANSARI** , Head Of Department, and **Prof. RIZWAN SHAIKH**, Project co-ordinator from Department of Mechanical Engineering, Kalsekar Technical Campus, New Panvel, for their guidance, encouragement and support during our project.

I take this opportunity to give sincere thanks to **Mr. PRAVIN MORE** , Manager/Owner in "*R. P. Motors"*, for all the help rendered during the course of this work and their support, motivation, guidance and appreciation.

I am thankful to **Dr. ABDUL RAZZAK HONNUTAGI** , Kalsekar Technical Campus New Panvel, for providing an outstanding academic environment, also for providing the adequate facilities.

Last but not the least I would also like to thank all the staffs of Kalsekar Technical Campus (Mechanical Engineering Department) for their valuable guidance with their interest and valuable suggestions brightened us.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

EllipiMove is a tool used in training by fitness enthusiasts and athletes to improve their performance with an innovative engineering concept that combines the motion of running, bicycling and elliptical machine. Elliptical cycling is for people who want to get physically fit, achieve their fitness goal and recover from hip and knee injuries. Its unique mechanism encourages maximum people to use this bike. Our aim is to design the elliptical bicycle in an optimized manner by reducing it's weight and cost in a such a way that it has low impact, high performance, exciting outdoor workouts and has an significant role in human welfare.

1. Introduction

The ElliptiMove is an elliptical bicycle. By modifying the elliptical trainer motion and combining it with the functionality of a bicycle, the ElliptiMove bicycle delivers a high-performance workout experience that closely mimics running outdoors while eliminating the impact. It provides the most comfortable, fun and efficient way to get out and stay active.

ElliptiGO co-founder and former Ironman tri-athlete Bryan Pate was inspired to create the world's first elliptical bicycle after injuries plagued him to the point where he could no longer run for fitness. Although he was an experienced cyclist, Pate chose instead to use the elliptical trainer to stay fit because it was more comfortable than sitting on a bike. Unsatisfied with the experience of working out in a gym, however, Pate had a vision of creating a product that would allow him to have both the outdoor "running experience" and the low-impact workout of the elliptical machine. In 2005, Bryan partnered with ElliptiGO co-founder Brent Teal, a mechanical engineer and ultra-marathoner, to design and develop the world's first elliptical bicycle. Five prototypes and thousands of test miles later, the ElliptiGO was born.

The ElliptiMove is perfect for anyone who wants to get a great cardiovascular workout outdoors without damaging their body. It is particularly well-suited for runners who want to enjoy a running-like experience while giving their knees and joints a break from the wear and tear caused by running. The ElliptiMove is also ideal for cyclists who want to get the experience of cycling without the discomfort caused by sitting on a conventional bike seat or riding in a hunched-over position.

The ElliptiMove is easy to ride and more stable than it looks. Riding an ElliptiMove requires the same amount of balance as is required to ride a traditional bike or scooter. Like anything new and different, it takes some getting used to, but we've found that most people get comfortable within 5 minutes of riding it.

ElliptiMove is very different from a traditional bicycle. Traditional bicycles usually have a big seat with a back rest whereas the ElliptiMove has no seat at all. The traditional bicycle rider pedals with the legs parallel to the ground while the ElliptiMove rider's legs are perpendicular to the ground standing up and pedaling and rider stands for the whole time. The traditional bicycle rider's visibility is usually limited because they are lower to the ground making it, both harder to see them and herder for them to see around obstacles like cars, busses, trucks etc. In contrast, the elliptical rider's visibility is unusually good because their line of sight is elevated.

Cruising speed on an ElliptiMove is around 24 kmph, but a really strong rider can reach speeds in excess of 40 kmph on level ground. The ElliptiMove climbs, descends, accelerates and maneuvers similarly to a bicycle, so anywhere you can take a road bike, you can take an ElliptiMove, including up and down steep hills and along twisty sections of road. The ElliptiMove shares many of the most desirable benefits of an indoor elliptical trainer, including a low-impact workout, a natural pedaling motion, a weight-bearing position, and the ability to deliver a high-intensity exercise experience, with one major difference – it can be used outdoors.

Because ElliptiMove is designed to be aerodynamically efficient, road bicycles have uncomfortable ergonomics. The ElliptiMove is designed to emulate the natural running movement, so the rider stands upright in a very comfortable position and propels the ElliptiGO using a very comfortable motion. Moreover, the most complained-about element of road biking is the seat, which causes significant pain and numbness for a majority of riders and has proven links to erectile dysfunction and other urological ailments. By enabling a seatless cycling experience, the ElliptiGO solves one of the most important and challenging problems facing the road bicycling industry.

2. Problem Definition

Most of the people use fitness equipments for workouts and to stay fit, however as the fitness equipments are placed in closed/ confined spaces, unfortunately the user ends up working out in an artificial environment and misses the opportunity to explore the nature. Another problem associated with fitness equipments is, the person using the fitness equipment has to perform a single exercise and is committed to that workout until it gets completed. So the aim of our project is to develop an elliptical bicycle or a fitness tool in minimum cost, which allows the user to work out as well as carry out his chores, commute from one place to another and can be used for general recreation.

3. Project Plan

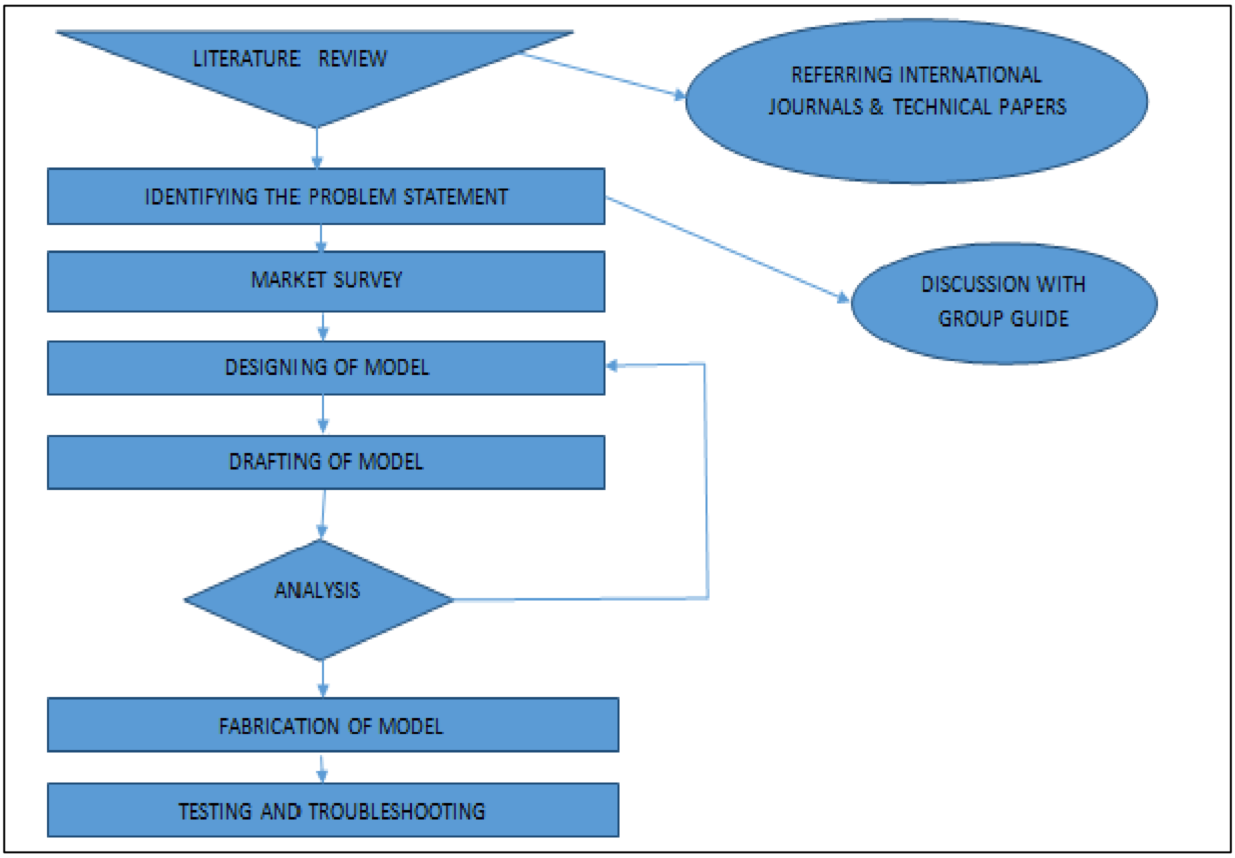


Fig 3.1:- Project Plan

The above figure shows the project plan and the complete flow of our work and the stages in which we went through while working on our project. The project plan includes literature survey, market survey, designing, drafting analysis and fabrication of the model.

4. Project Schedule

	Task Name	Durat...	Start	Finish	Predece...	% Complete
1	Tilte selection	8d	08/24/15	09/01/15	Completed	100%
2	Literature Survey	8d	09/07/15	09/15/15	Completed	100%
3	Market survey	8d	09/16/15	09/24/15	Completed	100%
4	Gym review	8d	10/08/15	10/16/15	Completed	100%
5	Designing of Model	19d	10/26/15	11/16/15	Completed	100%
6	Drafting of Model	10d	11/17/15	11/27/15	Completed	100%
7	Selection of Material	11d	01/01/16	01/13/16	Completed	100%
8	Analysis of Material	20d	01/14/16	02/05/16	Completed	100%
9	Fabrication of Model (P-1)	20d	02/06/16	02/29/16	Completed	100%
10	Fabrication of Model(P-2)	29d	02/27/16	03/31/16	Completed	100%
11	Model testing	5d	04/01/16	04/06/16	Completed	100%
12	Trouble shooting	5d	04/07/16	04/12/16	Completed	100%

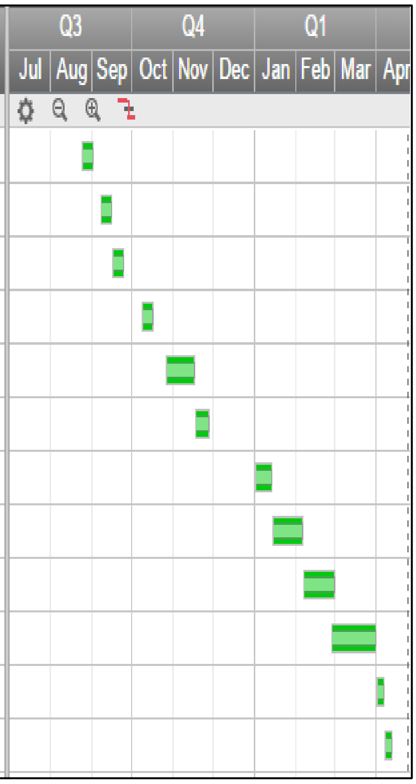


Fig 4.1:- ElliptiMove Project Schedule.

The above figure depicts the schedule of our project in which the maximum time is allotted to designing and fabrication of the model and minimum time is allotted to the market survey and testing of the fabricated model.

5. Literature Review

[1] A Bi-cycle frame should have low weight, high lateral stiffness and moderate vertical stiffness. Because of chain load, frame lateral deformation during pedaling is bigger when the rider pushes on right pedal (a pro rider may apply a force up to two times his weight). Most of the bicycles built today utilize heat treated steel or aluminum or titanium alloy tubing to minimize their weight. The tubes are then welded together to create the desired fork or frame geometry. It is Notable part in whole racing cycle system which is subjected to static and dynamic loads.

Historically, the most common material for the tubes of a bicycle frame has been steel. Steel frames can be very inexpensive carbon steel to highly specialize using high performance alloys. Frames can also be made from aluminum alloys, titanium, carbon fiber, and even bamboo and cardboard. Occasionally, diamond (shaped) frames have been formed from sections other than tubes. These include I-beams and monocoque.

We will also obtain the knowledge how to make a finite element model in Hyper mesh by going through literature papers. The conditions required for applying various Constraints and how the loads are applied is briefed about in the technical papers referred. By using composite materials we can reduce the cost of cycle. Reverse engineer and extract dimension of frame Make a 2D model of Chassis, Designing the chassis using CATIA V5R19. Get the exact parameters of the material used. Meshing the CAD model, Apply the Boundary conditions, Solve for the solution of meshed model using ANSYS ’15.

[2] By closely examining the finishing times of professional cyclists and tri-athletes over the past few years in several events such as the Tour de France, the Giro D’Italia and the Ironman World Championship, it has been recognized that small performance gains, on the order of roughly 3%, have highly significant relevance. For the professional cyclists, such time gains can

mean the difference between standing on the podium or not after many days of competition in a grand Tour event. For professional and amateur tri-athletes who face strong competition to secure very limited slots at qualifying events, these small differences determine whether they will be able to compete at the World Championship event – a highly coveted goal in this athletic community.

In recent years, as manufacturers of racing bicycles and bicycle components have turned to wind tunnel testing to optimize component design3, the athletes themselves are now able to purchase time in wind tunnels to refine and perfect their riding positions. Comprehensive reviews by Burke4 and Lukes cite many efforts which validate the conventional wisdom that the main contributors to overall drag are the rider, the frame including fork and aero bars, and the wheels. Greenwell et.al.6 have concluded that the drag contribution from the wheels is on the order of 10% to 15% of the total drag, and that with improvements in wheel design, an overall reduction in drag on the order of 2% to 3% is possible.

In the works published by Kyle and Burke11 and Kyle is was observed that a very significant reduction in drag was measured for rotating wheels when compared to stationary ones. Although the experimental work of Fackrell and Harvey was applied to study the aerodynamic forces on much wider automobile tires, it is worth noting that they also observed a reduction in drag and side forces when comparing rotating and stationary wheels.

[3] Since their invention in 1817, bicycles have proven to be a healthy and environmentally friendly mode of transportation for both enthusiasts and commuters alike. Although the bicycle has remained ubiquitous over time, the world has changed dramatically. Today, US roadways are dominated by automobiles, aggressive, modes of human transport. Unfortunately, bikers are considered second-class citizens as they attempt to share roadways with motorists. In fact, this has been the situation for most of the lifetime of the bicycle. In 1896, the automobile accident ever to occur in the U.S. took place in New York City between an automobile and a bicycle, and proved fatal for the cyclist.

According to a more recent report (2007) in the U.S., over 700 bicyclists die annually in accidents with automobiles, while there are over 44,000 annually reported cases of injuries due to bicycle-automobile accidents. A key limiting factor for modern-day bikers is roadway safety.

This is primarily due to the inherent unbalanced burden of risk that is placed on a biker during cyclist-motorist encounters. As will become evident in Section 2, existing laws and approaches towards biker safety (e.g., bike paths) are inadequate..

[4] With the improvement of living standards, the design orientation of bicycles has moved from its past significant role in the transportation field to its potential in today's leisure sports. Accordingly, customized design has become a trend in the development of bicycles in recent years. The comfort of riding a bike is an important factor that should given serious consideration when developing a bicycle. For example, Hsiao and Chou (2005) incorporated the degree of riding comfort into the design and development of an electric motorcycle, and also aimed at improving the comfort of riding on bicycle products by importing the design concept of “fitting an object to the human body”.

Among numerous studies on riding, de Vey Mestdagh (1998) suggested that riding posture could be optimized by changing the height of the saddle. Peveler et al. (2007) pointed out that injuries caused in bicycle sports are mostly related to incorrect adjustment of the saddle height, handlebar and/or pedals. In addition, Laios and Giannatsis (2010) proposed an appropriate design method related to bicycle size that considered bicycle design in accordance with human body dimensions, and further examined assessment results ergonomically to re-design a series of bicycles for children aged between 7 and 14.

[5] Spoked bicycle wheels are efficient, highly evolved, structural systems. A useful analogy for a bicycle wheel supporting vertical loads is that of a circular beam on a pre-stressed elastic foundation, fixed at the center and loaded radially at the circumference. To apply this analogy, the system of interlacing spokes can be modeled as a disk of uniform stiffness per length of circumference. Spokes of varying lengths may be laced into wheels of fixed dimensions, by modifying the interlacing geometry of the spokes.

The connection of the spoke to the hub is accomplished via a cold-worked right angle elbow in the spoke and a flanging of the spoke material. Most spoke failures occur at this fatigue critical detail. Upon the failure of one spoke, ensuing unbalanced lateral forces on the rim result in large lateral deformations of the rim, which may precipitate lateral buckling of the wheel, or failure of other spokes. A loose spoke can interfere with the smooth operation of the chain, which may result in a lost race, a collision, or an injury.

Variations in radial stiffness due to the spoke pattern, calculated using the theory of circular beams on elastic foundations, agree with those using a three-dimensional elastic frame analysis. While the spoke lacing pattern influences the over-all stiffness of the wheel, the strains in spokes at the loading point on the rim are not as sensitive to the spoke pattern. Static tests on three identical rear wheels, with different spoke lengths, also show that spoke strains are not strongly affected by the spoke pattern. Strain time-histories collected during road tests also show only small differences between the wheel types.

[6] It is possible to build a bicycle frame with very little equipment. I have done it myself. It took me a lot longer than it would if I had a few more items of quality equipment, and it was awkward and took lots of concentration. Deciding on the right amount of equipment is up to the individual frame builder. It will depend on how he/she wishes to make frames, the space available to house the equipment and the finances at their disposal. As can be seen in my case studies, frame builders can be successful using several different “philosophies” with regard to equipment. Take Richard Sachs for example: he is one of the most well-known and successful frame builders in the world, yet he doesn’t have a milling machine or a lathe. In fact, his workshop is noticeably devoid of equipment apart from a frame jig, a couple of benches, a vice and some hand tools.

Frame-building equipment can be very expensive, and this can be a big obstacle when trying to start a frame building business. Resourcefulness is a good trait to have when starting out as a frame builder. Any equipment or fixture that can be made or improvised will save money. Small jigs and tools can be constructed using basic metalwork and brazing skills, and this can become an interesting challenge.

[7] What are the best materials to use in bicycle frames—steel? Aluminum? Carbon fiber? Magnesium? Titanium? The answer lies in the physical properties of these materials—their characteristics and how they behave under certain conditions. The designer chooses the material that best suits the intended use of the bike (road or off road), and the expected cost (titanium and carbon fiber are especially expensive). Listed below are some of the properties bike designers look at when they build a bicycle.

Density- Density is how much a material weighs for a given volume. Titanium is about one-half the density of steel, and aluminum is about one-third the density of steel.

Stiffness- The measurement for stiffness is called the modulus of elasticity; it is the degree to which a material that undergoes stress can deform, and then recover and return to its original shape after the stress ceases. The bigger the number, the stiffer the material. A steel bicycle tube is generally stiffer than a titanium or aluminum tube, although tube diameter and wall thickness also affect stiffness.

Elongation- Elongation is a measure of how far a material will stretch before it breaks. It is very sensitive to the type of alloy used and how the metal is processed. The smaller the elongation number, which is expressed as a percentage, the more brittle the bicycle frame. Elongation numbers for titanium bicycle tubes are highest—from 20% to 30%; for steel tubes, from about 10% to 15%; and for aluminum, from 6% to 12%.

Tensile Strength- Tensile strength is a measure of the greatest longitudinal stress a substance can bear without tearing apart; it is expressed as a ratio of maximum load to cross-sectional area. The tensile strength of a bicycle tube varies with the type of alloy used and how the tube is made. The tensile strength of a typical titanium alloy bicycle tube ranges from approximately 700 to 910 mega Pascal's (MPa); of a steel tube, from 630 to 1190 MPa; and of an aluminum tube, from 210 to 350 MPa.

Fatigue Strength- Fatigue strength is a measure of the stress at which a material fails after a number of cycles. Steel and titanium alloys have a specific fatigue strength below which a load (force) may be applied an infinite number of times without causing the metal to bend or break. Aluminum alloys will, however, fail after enough load cycles even with a very small load. This is why aluminum tubes are generally much thicker than steel or titanium tubes.

Toughness- Toughness is the ability of a metal to absorb energy and deform before fracturing (breaking). A tough metal is more ductile (pliable) and deforms rather than breaks. A very important requirement of bicycle tubes is their ability to flex. Toughness is, however, a complex property to measure and analyze.

[8] Fatigue is a prominent failure mechanism for mountain bike frames, and can lead to serious accidents, costly recalls, and poor product image for bicycle frame manufacturers. The team collaborated with a local bike company, in the process of developing a new 6061-T6 aluminum mountain bike, to investigate the fatigue behavior of the new frame and optimize the material/heat treatment and frame design.

The fatigue testing was done in-house using a test rig specifically built for this project according to the ASTM standard F2711-08 for horizontal loading. A solid model of the frame was created and a finite element analysis (FEA) was conducted using the ASTM standard as a guide, with appropriate mechanical properties for various sections of the bike and the joining welds.

The FEA model enabled the team to predict fatigue failure locations and cycles to failure, and was further validated using the experimental fatigue testing results obtained from the prototype frames. On the physical frames tested, thorough fractographic examinations were conducted to identify the fatigue crack initiation locations and crack propagation mechanisms using optical and scanning electron microscopy. To complete the project, systematic studies were performed to optimize the frame's design, materials and heat treatment for improved fatigue resistance.

[9] As far back as 1986, Peterson and Londry (1986) used FEA to fine-tube the design of the Trek 2000 aluminum frame using two other existing designs (one steel, one aluminum) as performance benchmarks for mass, strength and stiffness characteristics. Their model used beam elements to represent the tubular frame structure (excluding forks) with restraints at the rear axle and head tube, and loads applied in a range of load cases at the seat tube, head tube, brake bridge, and bottom bracket (BB). While this study did not include an analysis of varied geometry, the analysis of varied load cases provided a rich insight into various generic performance characteristics, for example that energy losses in the vertical direction could be increased with little negative effect on hill climbing performance (i.e. an out of saddle load case) and that the down tube was always the greatest strain energy absorber, storing between 38-49% of the total (followed by the seat tube, storing between 19-25%).

While this study did not consider variations in geometric parameters, it has laid down important groundwork for the use of FEA to support the design and development of frames. Reynolds Technology Ltd (2011a) as producers of tubes for bicycles (and other industries) have produced a similar beam element FE model called eReynolds that they have made available to bicycle designers and frame builders. While eReynolds is capable of modeling more complex tube geometries than the model created by Peterson and Londry (including tube diameters, oval and round butt profiles, wall thicknesses), frame geometries and standard Reynolds materials (Reynolds, 2011b), it limits the load case to that specified in BS EN 14766 (British Standards, 2005b).

[10] Developments have recently been made in analysis of bicycle self stability. Applicability of benchmarked linearized dynamics equations to a variation of modern bicycle designs is investigated. Results gained through experimentation on an instrumented bicycle with variable geometry are compared to predicted results. Precise three dimensional modeling is used to calculate bicycle mass properties, for use in dynamics equations. Strong correlations between experimental and predicted results are found over large variations in bicycle geometry.

[11] Bicycles have been the subject of much research throughout their development. This thesis studies self stability of bicycles, which until recently had not been completely captured and verified mathematically. The work of Meijaard et al (2006), which produced a benchmarked set of dynamics equations, is the definitive resource for stability analysis. While qualitative analysis of bicycle dynamics has been undertaken since as early as 1869, with Rankine introducing counter steer, most papers did not contain explanation for the ability of a bicycle to remain upright uncontrolled.

[12] In 1896 Sharp discussed stability without steering input, but explained that it was due to rider lean inputs, inducing steer through gyroscopic precession of the front wheel. A significant paper dispelling some stability myths was that of Jones, published in 1970. Through a series of attempts at building an "unrideable bicycle" he dispelled the common belief that a bicycles stability is due entirely to gyroscopic precession of the front wheel. He also demonstrated instability of a bicycle with negative trail. Jones' paper lacked mathematical theory to support his findings.

6. Gym Survey

Sr no.	Name of the gym	Address/location of gym	Name of trainee	Review
1.	WOW-Work Out World	Santacruz east	Anjali	I had lost my 5kg weight by doing this exercise.
2.	WOW-Work Out World	Santacruz east	Ruby	I usually prefer for my stamina and weight control.
3.	Raymonds	Kalina	Santosh	Good exercise for thighs and lower body.
4.	Raymonds	Kalina	Rahul	Helps in weight loss.
5.	Spencers	Santacruz east	Ajay	Very effective in increasing stamina.
6.	Spencers	Santacruz east	Rafiq	Blood circulation improves.
7.	Body garage	Kurla west	Tamim	It increases my stamina.
8.	Body garage	Kurla west	Thomas	Very effective & helpful for high strengthening.
9.	Get Fit (The Health Zone)	Vikhroli west	Vinay.D.Singh	Would be nice to have moving machine cardio.
10.	Get Fit (The Health Zone)	Vikhroli west	Bhushan Pandloskar	Feel good if would be a moving machine & be act as a generator and generate energy.
11.	Get Fit (The Health Zone)	Vikhroli west	Siddhesh.T.Arote	Moving machine cardio is a superb idea.

12.	Get Fit (The Health Zone)	Vikhroli west	Manish Pawar	Interested in a moving cardio machine. I would love to ride it.
13.	Get Fit (The Health Zone)	Vikhroli west	Sanjay Patil	Moving cardio is good idea.
14.	Get Fit (The Health Zone)	Vikhroli west	Sumita Veema	Idea of open space cardio is really good, unique.
15.	Get Fit (The Health Zone)	Vikhroli west	Goodwin Fortado	Great idea
16.	Fitness India (Yes I Can Do It)	Ghatkopar west	Haresh Arjun Parab	Elliptigo cycle concept is very good
17.	Fitness India (Yes I Can Do It)	Ghatkopar west	Pradip Panchal	The concept is nice
18.	Fitness India (Yes I Can Do It)	Ghatkopar west	Shailesh Madresha	Made it easy & less complex
19.	Fitness India (Yes I Can Do It)	Ghatkopar west	Pujesh Jain	Profitable
20.	Fitness India (Yes I Can Do It)	Ghatkopar west	Ritesh Rane	Profitable and nice.
21.	Fitness India (Yes I Can Do It)	Ghatkopar west	Dr Rahul.V.R	Great project/instrument would be profitable
22.	Fitness India (Yes I Can Do It)	Ghatkopar west	Snehal.S.Navtea	Best for lower body preparation & good project. Will take this.
23.	Fitness India (Yes I Can Do It)	Ghatkopar west	Rahul Sharma	Best for cardiac & weight loss gain stamina.
24.	Fitness India (Yes I Can Do It)	Ghatkopar west	Shehnaaz.N.Khan	Good, its very good. We required such type of cycle which helps us in both way. Marketing cum gym.
25.	Fitness India (Yes I Can Do It)	Ghatkopar west	Shaheen.M.Mulla (9820722641)	It will be a very good idea. (interested in buying)

26.	Fitness India (Yes I Can Do It)	Ghatkopar west	Shown Raju Bagwan	It is a very good idea
27.	Fit & Fine	Vikhroli west	Zahur Shaikh	It is very good idea.
28.	Fit & Fine	Vikhroli west	Asmara Khan	It will be very effective for gyming outside the gym.
29.	Fit & Fine	Vikhroli west	Arshi yusuf	It might be a costly affair.

Table 6.1:- Gym Survey.

As this concept and bicycle design is not available in India we carried out a thorough survey in number of gymnasiums and fitness centers to get the comments, views and advices of various trainees and trainers present in the gym. The comments, views and advices of the trainees and trainers are mentioned in the above table.

7. Market Survey

Sr. no	Shop name/Dealer	Rate per kg	3 mm			4 mm			5 mm		
			1 inch	1.5 inch	2 inch	1 inch	1.5 inch	2 inch	1 inch	1.5 inch	2 inch
1.	Hindustan steels	41.75	595	680	808	850	978	1105	1233	1360	1488
2.	National steel co.	41.25	617	702	829	872	999	1127	1254	1382	1509
3.	Noor trading co.	42.50	581	664	789	830	955	1079	1203	1328	1453
4.	Prime steel	41.50	602	685	810	851	976	1099	1225	1348	1474
5.	S.M steel pvt ltd	43	602	688	817	860	989	1118	1247	1376	1505
6.	Ramco	42	580	880	1240	700	980	1360	820	1100	1480
7.	Swasti metals	43.25	606	692	821	865	995	1125	1255	1384	1514
8.	Delta steel traders	43.75	627	713	843	886	1016	1146	1275	1405	1535
9.	Durga steels	43.50	609	696	826	870	1000	1131	1261	1392	1522
10.	**KAZI TRADERS**	**41**	**574**	**656**	**779**	**820**	**943**	**1066**	**1189**	**1312**	**1435**
11.	Hardik steel traders	42.25	577	693	819	861	987	1118	1239	1365	1431
12.	Bombay metal & steel traders	42.75	599	684	813	855	984	1116	1237	1368	1496

Table 7.1:- Market survey

In the above table the market survey of various shops and retailers of pipes from which the material for our project was to be acquired is mentioned in a thorough manner, and the retailer providing the material in cheapest cost was chosen and is highlighted in the table.

8. Objective of the Project

- To design and fabricate an elliptical bicycle for cost optimization as compared to actual ElliptiGO, conventional bicycles and other fitness equipments.
- To design and fabricate an elliptical bicycle for weight optimization as compared to actual ElliptiGO, conventional bicycles and other fitness equipments.
- To provide the rider a workout experience while eliminating the impact on the joints of the human body caused during running, bicycling or working on an elliptical trainer in the gym, with the use of ElliptiMove.
- To provide comfortable and better ergonomics to the rider as compared to conventional cycle in order to eliminate the pain caused by constant cycling, with the use of ElliptiMove.
- Developing a fitness tool with the feasibility to explore the nature. To allow the rider to enjoy the outdoors and benefit from the utility of using an ElliptiMove to travel from one place to another for purposes of commuting, running errands, and general recreation.

9. Methodology

9.1. Material Selection:-

As per the material survey the best suited material is mild steel (MS). The mentioned material was chosen as the material for bicycle frame due to its low density, compatible yield strength, easy of fabrication, cost and ease of availability. This material was chosen for designing the frame by comparing its results with different materials as alloy steel, EN8 etc.

Optional Materials:-

1. Al-6061-magnesium and Silicon Major Alloying Element-density 2.70g/cm^3.

2. Al-7005-Zinc-density-2.78g/cm^3 depending on the temper, may be slightly stronger.

9.2. Designing of the Model:-

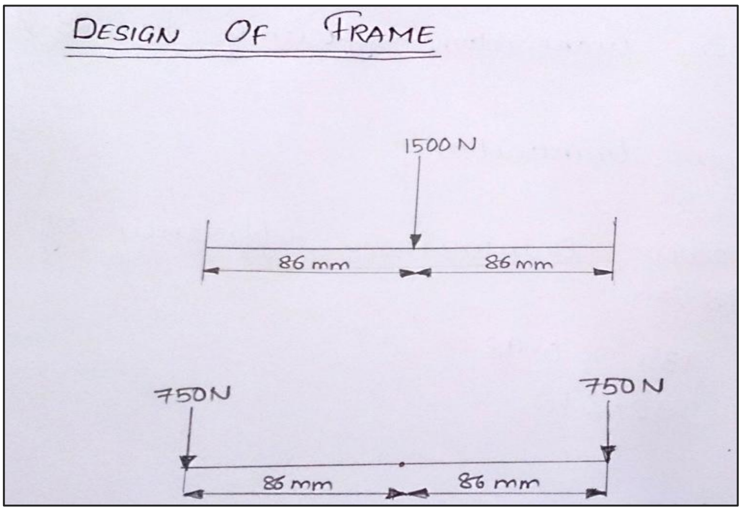


Fig 9.2.1:- Design of Frame

The above figure shows the distribution of the load applied on the frame which is assumed to be 1500 N. Further this load was distributed into two equal loads of 750 N.

The calculation for the torque required on the sprocket is as follows:-

{where, F= 750 N and r= 86mm}

$$T = F \times \mathrm{r}$$

$$T = 750 \times 86$$

$$\therefore \boldsymbol{T = 64500\ N.mm}$$

The calculations of the power transmitted by the sprocket in which the speed is assumed to be 20 rpm due to the fact that a human being cannot propel faster than 20 rpm is as follows:-

{where, T=64500N.mm, N=20rpm}

$$P = T\omega$$

$$P = T \times \frac{2\pi N}{60}$$

$$P = 64500 \times \frac{2\pi \times 20}{60}$$

$$\therefore \boldsymbol{P = 135\ W}$$

Since the power transmission efficiency of the Chain is 98%, the power transmitted by the sprocket changes as follows:-

$$\therefore P = 135 \times 0.98$$

$$\therefore \boldsymbol{P = 132.2\ W}$$

Design of Chain:-

Chain selected using this method will have a minimum life expectancy with proper installation and lubrication of 15000 hours.

The calculations for determining the length of chain as per the assumed data as follows:-

$$L = \frac{(Z_1 + Z_2)}{2} + \frac{2C}{p} + \frac{(Z_1 - Z_2)^2}{4\pi^2 C}$$

Where,

Z_1= Number of teeth on drive sprocket (i.e. Z_1= 13),

Z_2= Number of teeth on driven sprocket (i.e. Z_2= 57),

f_1= Application factor (i.e. f_1=1),

f_2= Tooth factor (i.e. f_2=1),

p= Chain pitch (i.e. p= 0.5),

C= Center distance between drive and driven sprocket (i.e. C=13inch),

$$\therefore L = \frac{19 + 57}{2} + \frac{2 \times 13}{0.5} + \frac{(57 - 19)^2}{4\pi^2 \times 13}$$

$$\therefore \boldsymbol{L = 94\ pitches}$$

The Chain length as per the calculations was found to be 94 links.

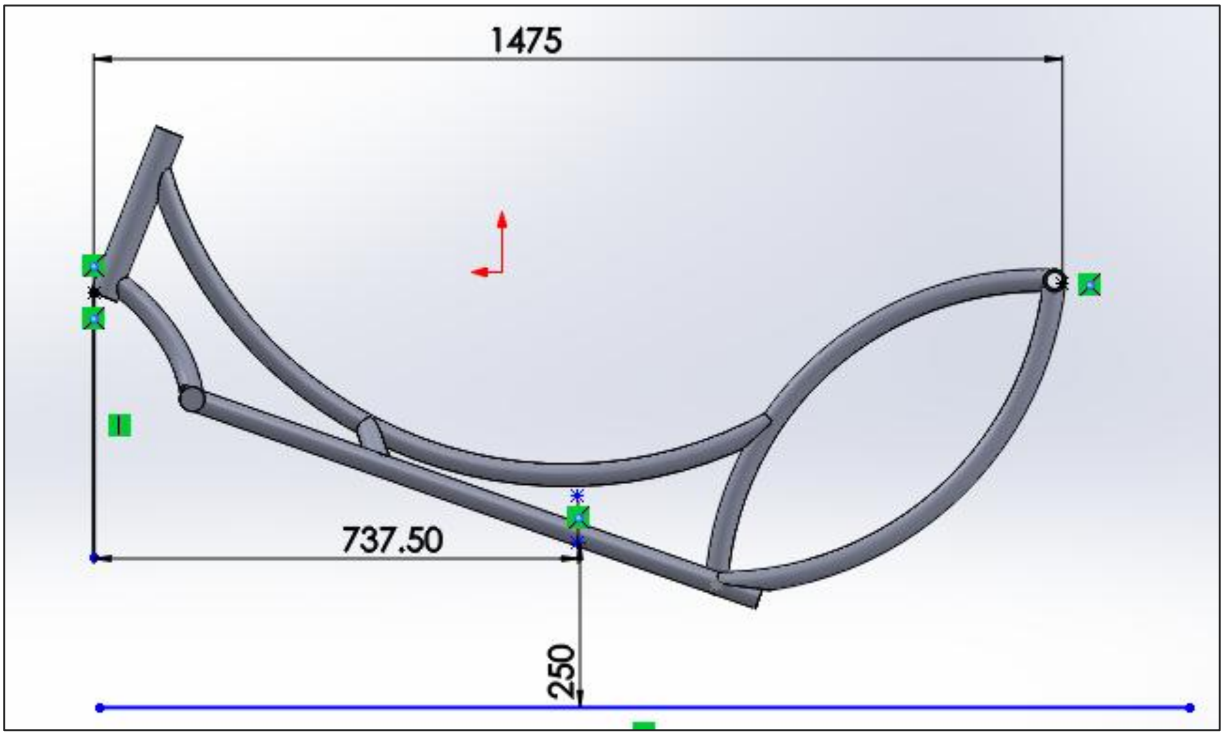


Fig 9.2.2:- Designing of the frame (ground Clearance)

The above figure shows the ground clearance suitable for the optimal design of an bicycle.

9.3. Drafting a CAD Model:-

Required CAD model was developed using 3-D modeling software (i.e. SOLIDWORKS '15). The cad geometry has basic requirement for Head tube, top tube, bottom tube, chain stays, bottom bracket shell and the two elliptical arcs commonly known as elliptical frame. This is the model of the bicycle frame. A bicycle frame is the main component of a bicycle, onto which wheels and other components are fitted. Frames are required to be strong, stiff and light, which they do by combining different materials and shapes.

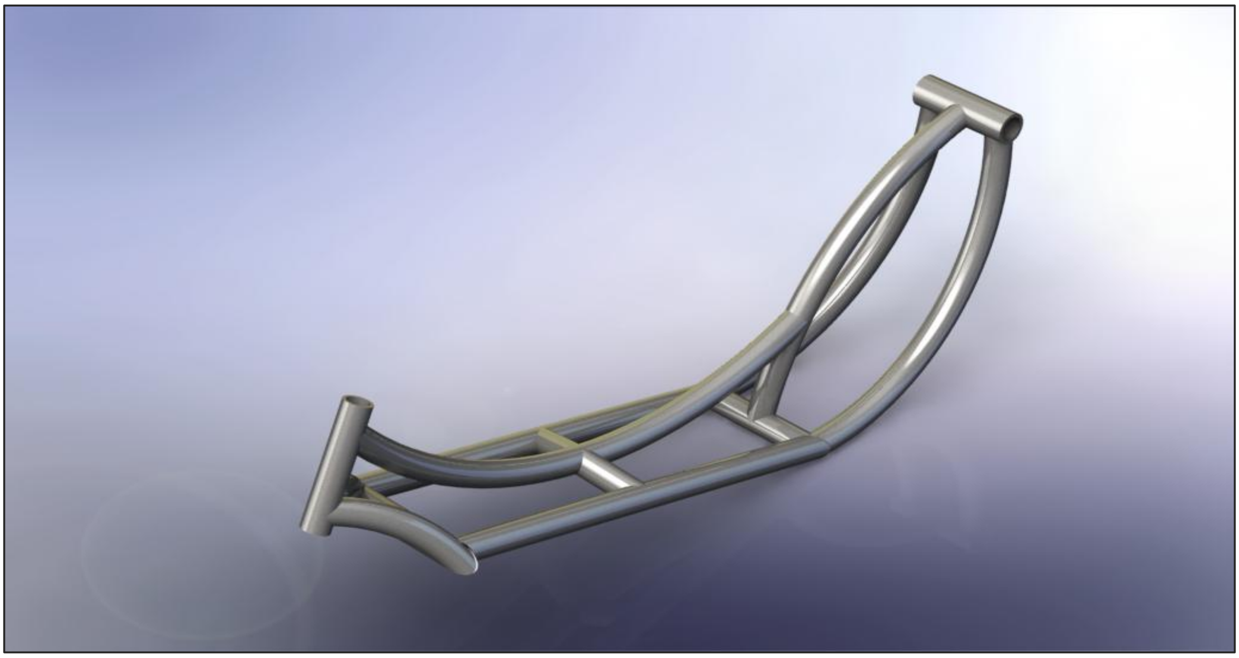


Fig 9.3.1:- ElliptiMove Frame Rendering 1

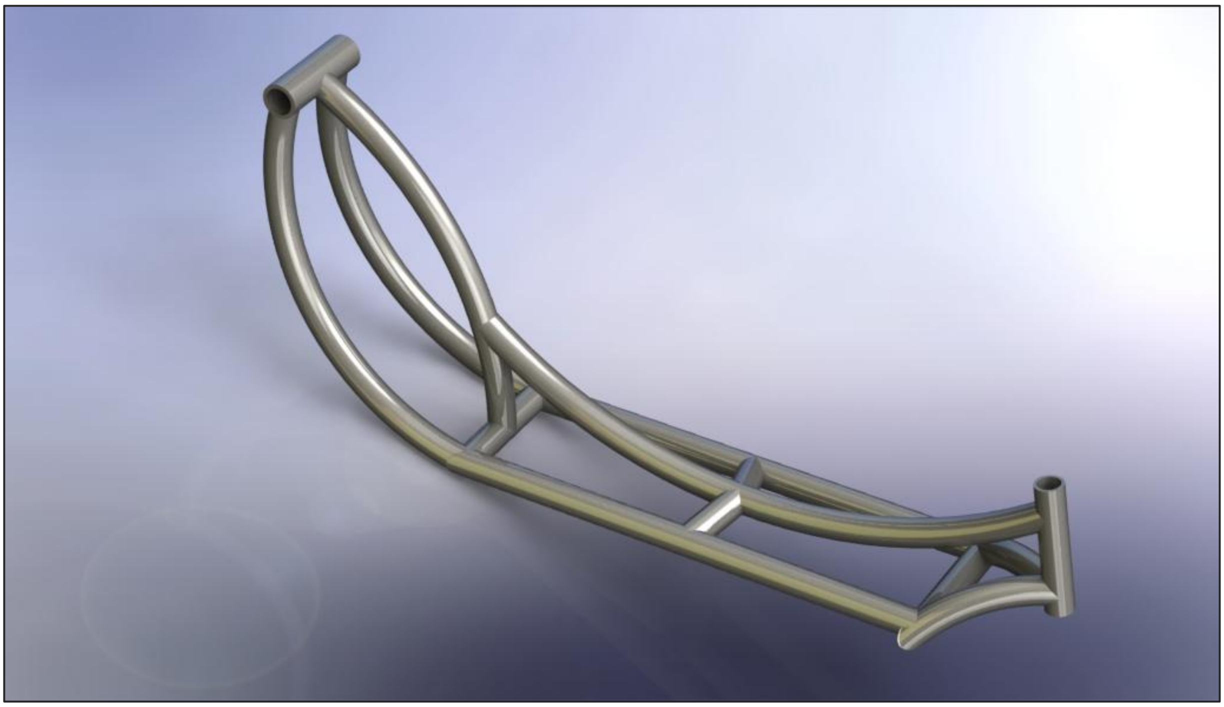


Fig 9.3.2:- ElliptiMove Frame Rendering 2

9.4. Meshing:-

For better quality mesh combination of first and second order tetra elements are to used. Surface meshing using triangular elements is to be performed to achieve better control on the meshing. Further this mesh will be converted into a tetra mesh. Selective tetra elements will be converted into second order and selective regions will be finely meshed using first order elements controlling the number of nodes formed.

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	39.9216 mm
Minimum element size	7.98433 mm
Mesh Quality	High

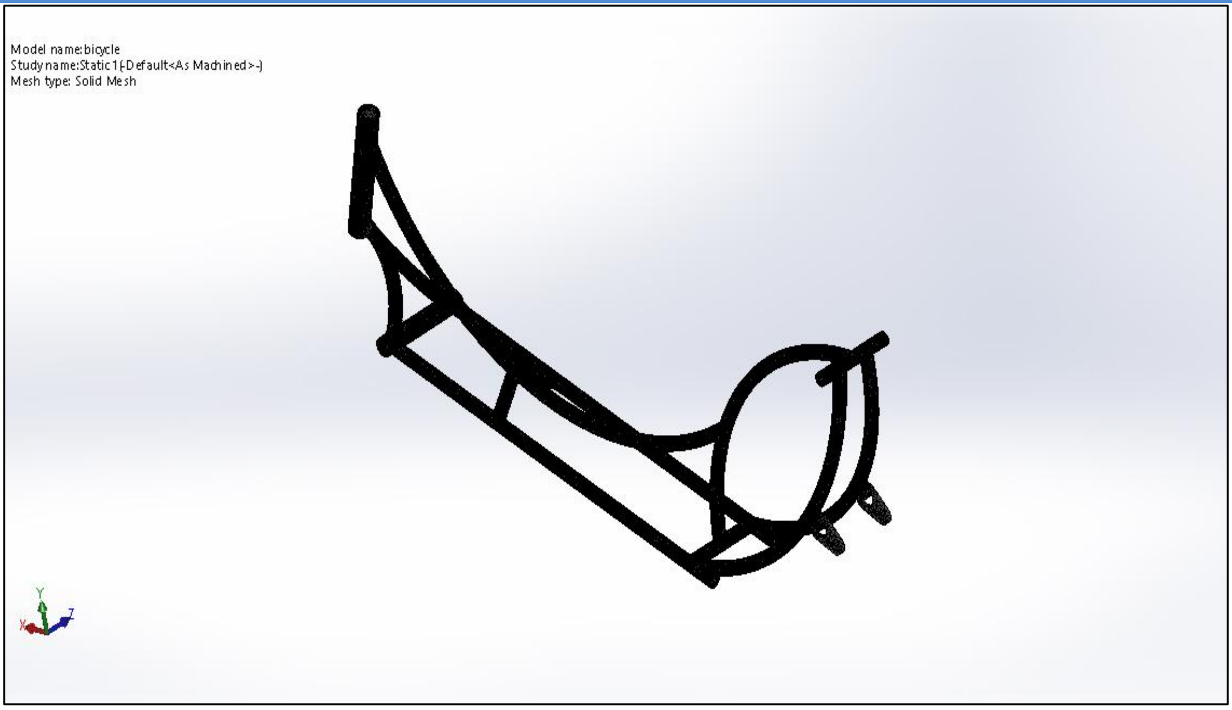


Fig 9.4.1:- Meshed frame

The above figure shows the completely meshed frame of the bicycle during the frame analysis with the information regarding the mesh size, element size and number of Jacobian points used.

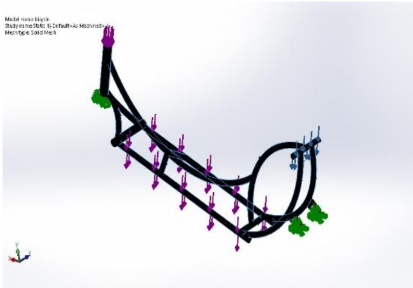
Mesh Control Name	Mesh Control Image	Mesh Control Details
Control-1		**Entities:** 15 face(s) **Units:** mm **Size:** 2.99417 **Ratio:** 1.5

Table 9.4.1:- Mesh control details.

9.5. Frame Analysis:-

Several properties of a material help decide whether it is appropriate in the construction of a bicycle frame:

1. Density (or specific gravity) is a measure of how light or heavy the material per unit volume.

2. Stiffness (or elastic modulus) can in theory affect the ride comfort and power transmission efficiency. In practice, because even a very flexible frame is much stiffer than the tires and saddle, ride comfort is in the end more a factor of saddle choice, frame geometry, tire choice, and bicycle fit. Lateral stiffness is far more difficult to achieve because of the narrow profile of a frame, and too much flexibility can affect power transmission, primarily through tire scrub on the road due to rear triangle distortion, brakes rubbing on the rims and the chain rubbing on gear mechanisms. In extreme cases gears can change themselves when the rider applies high torque out of the saddle.

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Table 9.5.1:- Units used during the analysis of the frame.

The above table shows various units used during the frame analysis.

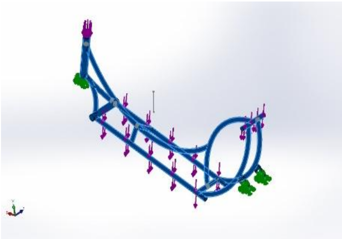
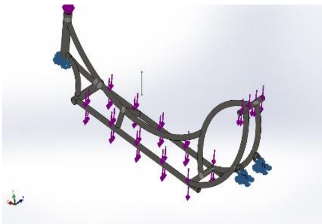
Model Reference	Properties	Components
	Name: **AISI 4130 Steel, normalized at 870C** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **4.6e+008 N/m^2** Tensile strength: **7.31e+008 N/m^2** Elastic modulus: **2.05e+011 N/m^2** Poisson's ratio: **0.285** Mass density: **7850 kg/m^3** Shear modulus: **8e+010 N/m^2**	**SolidBody 1(Combine20)(bicycle)**

Table 9.5.2:- Material information during frame analysis.

The above table shows material information used during the analysis of the frame which includes yield strength, tensile strength, elastic modulus, Poisson's ratio, mass density and shear modulus of the selected material (Mild Steel).

Fixture name	Fixture Image	Fixture Details
Fixed-1		**Entities:** **9 face(s)** **Type:** **Fixed Geometry**

Resultant Forces

Components	X	Y	Z	Resultant
Reaction force(N)	**-820.747**	**2073.53**	**-0.00953496**	**2230.05**
Reaction Moment(N.m)	**0**	**0**	**0**	**0**

Table 9.5.3:- Fixture details used in frame analysis.

The above table indicates the number of faces and entities on which the fixtures are applied during the analysis of the frame. It also indicates the components, reaction forces and reaction moments occurring during the analysis.

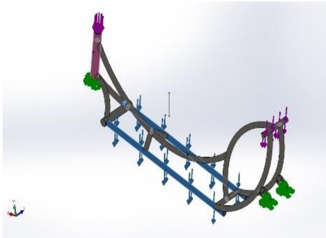
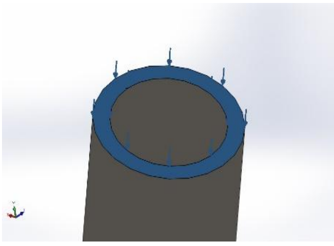
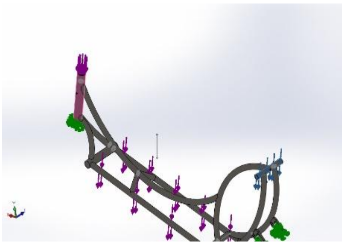
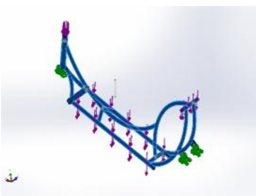
Load name	Load Image	Load Details
Force-2		**Entities:** 2 face(s) **Reference:** Face< 1 > **Type:** Apply force **Values:** ---, ---, -1500 N
Force-3		**Entities:** 1 face(s) **Type:** Apply normal force **Value:** 30 N
Force-4		**Entities:** 1 face(s) **Reference:** Face< 1 > **Type:** Apply force **Values:** ---, ---, -600 N

Table 9.5.4:- Loads and forces applied on the frame.

The above table shows the magnitude and direction of various forces applied on the different faces and joints of the frame during the analysis.

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Combine20 	Solid Body	Mass:14.5141 kg Volume:0.00184893 m^3 Density:7850 kg/m^3 Weight:142.238 N	E:\Analysis\bicycle.SLDPRT Jan 27 13:47:42 2016

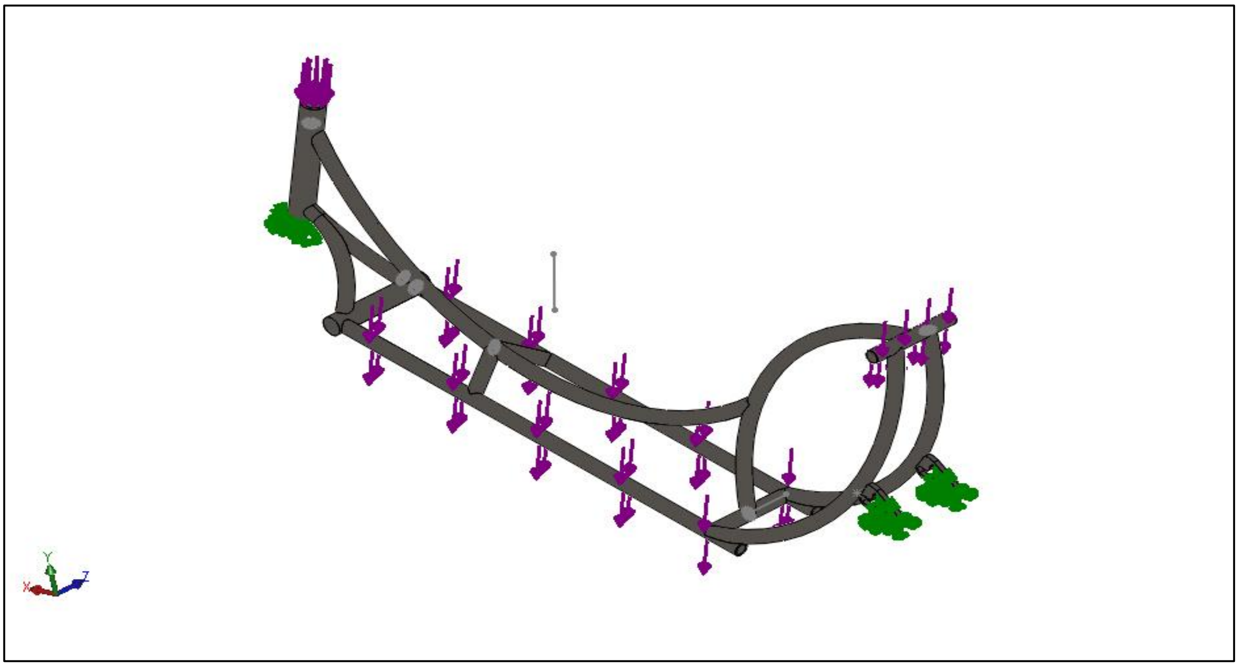


Fig 9.5.1:- Points on which the frame is supported and the direction of forces applied on the frame during the analysis.

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1956.94 N/m^2 Node: 422761	7.68179e+007 N/m^2 Node: 91579

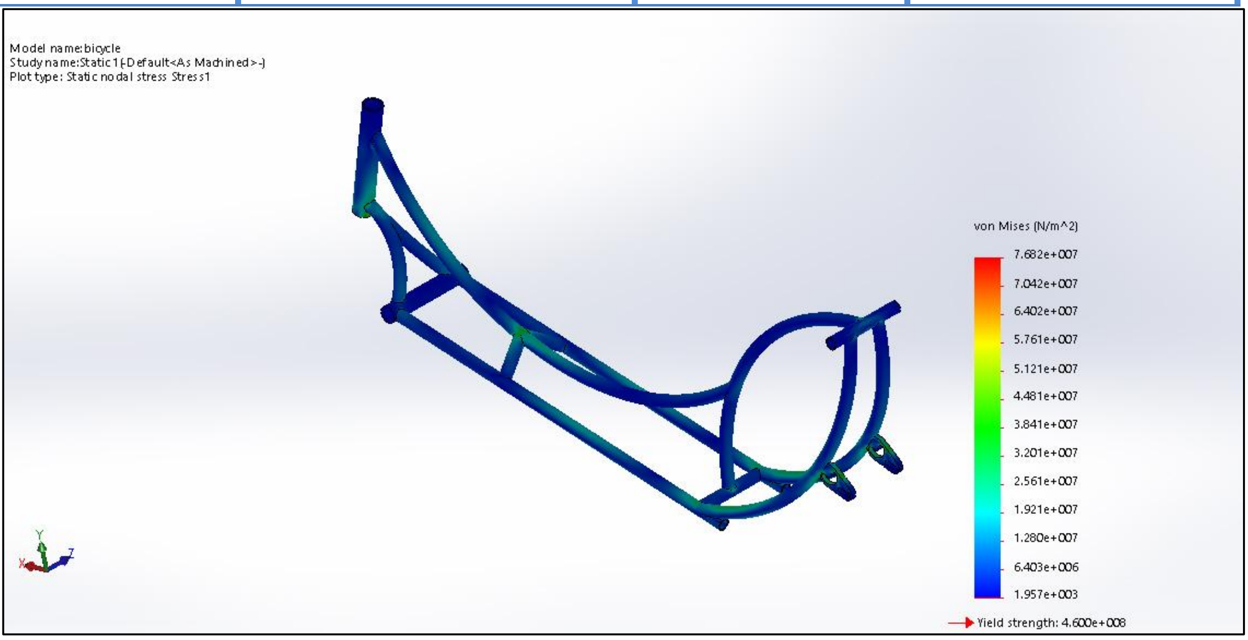


Fig 9.5.2:- Stresses induced in the frame

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 5	0.49713 mm Node: 150209

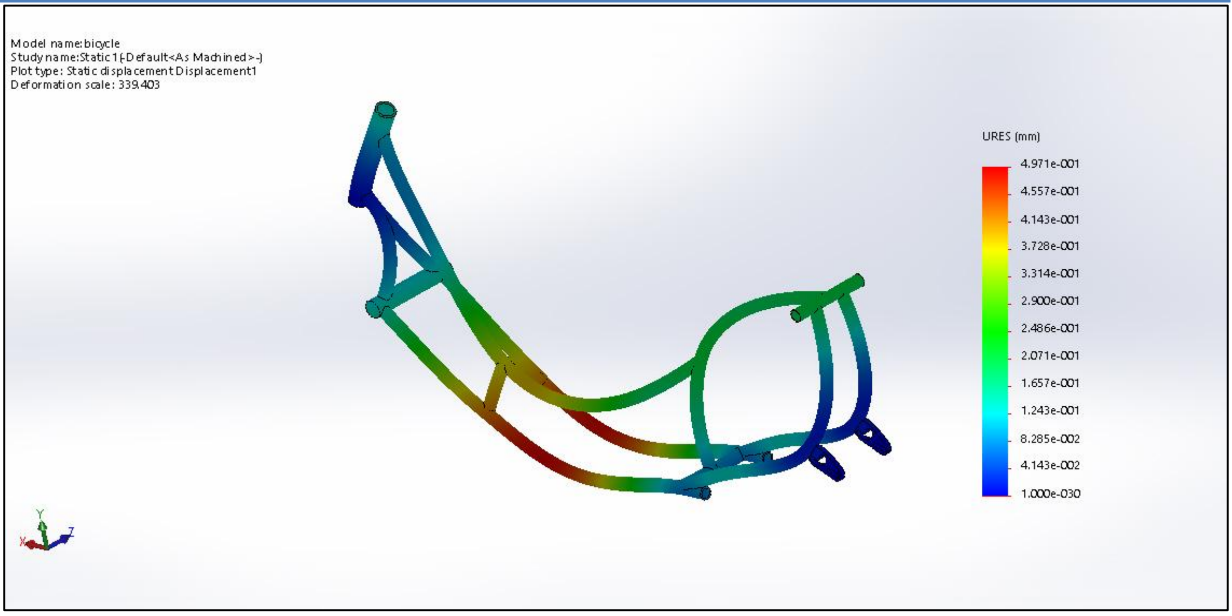


Fig 9.5.3:- Resultant displacement in the frame

The above figure shows the resultant displacement of the frame during the frame analysis which is comes out to be merely 0.5 mm under the applied load.

9.6. Fabrication of the Model:-

After successful analysis of the model on the analysis software for different loads and environmental conditions, the frame is fabricated successfully according to the design specifications. Fabrication techniques included arc welding, bending, cutting, grinding, punching, forging and assembly of various parts required.

Fabrication was carried out in two phases, namely phase-I which included initial spot welding of all the joints for assuring proper shape of the frame and phase-II included complete welding of all the joints in the frame, along with custom paint job and finally the assembly of all the parts.

Fig 9.6.1:- Fabrication phase –I started

The above figure shows the commencement of fabrication phase-I which includes bending of pipes, spot welding of basics joints while taking care of distortion caused during welding.

Fig 9.6.2:- Fabrication phase-I completed

The above figure shows the completion of fabrication phase-I, which includes spot welding of complete frame and assembly of tires and handle to ensure the frame is fabricated properly.

Fig 9.6.3:- Fabrication phase-II partially completed.

The above figure shows the partial completion of fabrication phase-II which includes complete welding of all the joints while taking care of distortion caused due to welding.

Fig 9.6.4:- Final look of ElliptiMove after completion of fabrication phase-II

The above figure shows the final look of ElliptiMove after the completion of fabrication phase –II which included assembly of all the essential components and a custom paint job.

9.7. Testing of the Fabricated Model:-

Followed by the fabrication of the actual model, the model has been tested for different road, different load and various environmental conditions to identify any defects or flaws in the design or fabrication processes, and eventually no defects or flaws where noticed or observed. The model was tested on smooth, rough, dirt and uneven road surfaces to observe the behavior of the bicycle on the above mentioned road conditions, and fortunately the bicycle behaved in a well mannered way, hence eliminating any chances of misbalance or mishap.

9.8. Troubleshooting:-

In case, if any defects or flaws are found in the fabricated model during the course of its future use the defects or flaws will be corrected/rectified by taking suitable steps. The rectification steps will include the change in chain length in case of falling of chain from the chain ring, change in the center distance between the chain ring and sprocket in case of tight or slack chain to avoid failure of chain, chain ring or sprocket, and lastly adjustment of the handle height according to the riders comfort.

10. Cost Optimization Table

Sr.No	Name of component/operation	Quantity	Rate per Piece (Rs.)	Total (Rs.)
1.	Chain wheel set	1	250	250
2.	Free wheel	1	60	60
3.	Chain	1	80	80
4.	Tyre (20’’)	2	150	300
5.	Ring (20’’)	2	250	500
6.	Tube (20’’)	2	100	200
7.	Handle set	1	250	250
8.	Fork	1	200	200
9.	Brake cable	1	50	50
10.	Brake lever	1	50	50
11.	Bottom axle	1	50	50
12.	Ball bearing (1/8)	1	10	10
13.	Fork set	1	60	60
14.	Bottom	1	50	50
15.	Brake Clamp	1	120	120
16.	Rollers	2	250	500
17.	**MS Pipe (round) 1 inch**	40 ft (27.8 kg)	42.50/ kg	1180
18.	**MS Pipe (square) 1 inch**	20 ft (6.2 kg)	44.50/kg	280
19.	**Bending Operation (pipe)**	40 ft	30/ft	1200
20.	**Fabrication charges**	-	-	3500
21.	**Custom Paint Job**	-	-	1500
22.	**Miscellaneous Charges**	-	-	110
TOTAL		**25**		**10500/-**

Table 10.1:- Cost optimization table.

The above table contains detailed information regarding the cost of different components required and various operations involved during the course of fabrication of the model. The total cost of the model after fabrication comes out to be Rs. 10500/- as compared to the cost of actual ElliptiGo which is Rs.1,20,000/-. Hence we have achieved cost optimization upto 80%.

11. Conclusions

Thus we conclude that ElliptiMove is designed and fabricated with the 80% cost optimization hence satisfying our aim of the project which was to design and fabricate the model while optimizing the cost which is successfully achieved with an added advantage of introducing this concept in the Indian market. ElliptiMove is designed in such a way that we have also achieved weight optimization up to 1 kg. ElliptiMove provides the rider a workout experience while eliminating the impact on the joints of the human body caused during running, bicycling or working on a elliptical trainer in the gym. The comfortable and better ergonomics of ElliptiMove ensures that the rider workouts with ease eliminating the pain caused due to constant cycling during the use conventional bicycle. Thus we have developed a fitness tool which allows the rider to work out and simultaneously explore the nature or carry out his daily chores without any problem of injuries or damage to the body. Thus ElliptiMove emulates the natural running movement, so the rider stands upright, in a very comfortable position and propels the ElliptiMove using a very comfortable motion. The upright riding position drastically improves the rider's ability to see over traffic and obstacles as compared to road cycling. The less aerodynamic upright position makes ElliptiMove riders work harder than cyclists to maintain the same pace, allowing ElliptiMove riders to get their workout done in less time and while covering less distance.

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13. Papers Published

1) Published:-

International Journal of Science, Engineering and Technology Research (IJSETR), Volume 5, Issue 1, January 2016

Literature Review for Design of Elliptical Bicycle

[1]**Prof. Saad Shaikh,** [2]**Yasser Arafat Shaikhnag,** [3]**MohammedJawwaad Surangiwala,** [4]**Saniya Aslam Khan,** [5]**FalakNaaz Shaikh**

Abstract:- **Customization design is a trend for developing a bicycle in recent years. Thus, the comfort of riding a bicycle is an important factor that should be paid much attention to while developing a bicycle. From the viewpoint of ergonomics, the concept of "fitting object to the human body" is designed into the bicycle frame in this study. Firstly the important feature points like riding posture, frame design, wheel size, materials required, method of manufacture and types of failures are discussed. Further this study proposes a detailed methodology which is helpful for the designer to develop an elliptical bicycle in an efficient and economical manner.**

Keywords:- Bicycle frame, suitable material, fatigue failures, FEA analysis, riding postures, ride height, frame joints, CFD.

ISSN: 2278 – 7798

2) To be published:-

International Journal of Materials Science and Engineering

Design and Fabrication of Elliptical Bicycle for Cost Optimization

[1]Prof. Saad Shaikh, [2]Yasser Arafat Shaikhnag, [3]MohammedJawwaad Surangiwala, [5]FalakNaaz Shaikh, [5]Saniya Aslam Khan,

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Abstract:-

ElliptiMOVE is a tool used in training by fitness enthusiasts and athletes to improve their performance with an innovative engineering concept that combines the motion of running, bicycling and elliptical machine. Elliptical cycling is for people who want to get physically fit, achieve their fitness goal and recover from hip and knee injuries. Its unique mechanism encourages maximum people to use this bike. Our aim is to design the elliptical bicycle in an optimized manner by reducing it's weight and cost in a such a way that it has low impact, high performance, exciting outdoor workouts and has an significant role in human welfare.

Keywords- ElliptiMOVE, Cost optimization, Elimination of impact, Fitness tool, Better ergonomics.
