International Journal of Latest Research in Engineering and Technology (IJLRET)
ISSN: 2454-5031
www.ijlret.com || Volume 09 - Issue 04 || April 2023 || PP. 34-43

Design and Analysis of an Elliptical Bicycle for Outdoor Exercise

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Abstract: Most people use fitness apparatus for workouts and to stay fit, but as the fitness equipment are placed in closed/ restricted spaces, unfortunately, the user stops working out in an artificial environment and misses the chance to explore nature. Another problem allied with fitness equipment's, 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 make an elliptical bicycle or a fitness instrument in a minimum cost. The Elliptical Movement is an elliptical bicycle. By modifying the elliptical trainer motion and uniting it with the functionality of a bicycle, the Elliptical movement bicycle delivers a high-performance workout experience and eliminates the impact that closely mimics outdoor running. It delivers the most comfortable, fun, and efficient way to get out and stay active. As we calculated that the calories burned in an elliptical bicycle in 10 min is 43kcal and the calories burned in a normal bicycle in 10 min is 31kcal. Thus, conclude that Elliptical Movement is designed and made up with 60% cost optimization hence filling 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. Thus, have established a fitness tool that allows the rider to work out and simultaneously explore nature. Thus, Elliptical Movement emulates the natural running movement, so the rider stands upright, in a very comfortable position and, propels the Elliptical Movement using a very comfortable motion. The upright riding posture drastically improves the rider's ability to see over traffic and obstacles as compared to road cycling.

Keywords: Cardiovascular workout, Elliptical bicycle, Elliptical movement, Outdoor exercise

I. Introduction

The Elliptical movement is an elliptical bicycle. By modifying the elliptical trainer motion and combining it with the functionality of a bicycle, the Elliptical movement 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. The Elliptical movement 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 running-like experience while giving their knees and joints a break from the wear and tear caused by running. The Elliptical movement is also ideal for cyclists who want to get the experience of cycling without the discomfort produced by sitting on a conventional bicycle seat or riding in a hunched-over position. Elliptical motion differs significantly from that of a conventional bicycle. The typical seat on a traditional bicycle typically has a backrest, whereas the elliptical movement has no seat at all. In contrast to the traditional bicycle, which requires the rider to keep their legs parallel to the ground while pedaling, the elliptical movement requires the rider to keep their legs perpendicular to the ground while standing and pedaling. Because they are closer to the ground and hence harder to see, conventional bicycle riders typically have poor visibility. This makes it tougher for them to see around obstructions like cars, buses, trucks, and other vehicles. In contrast, owing of their elevated line of sight, elliptical riders have unusually good visibility. On an elliptical movement, the average speed is about 24 km/h, although a truly powerful rider can reach speeds of more than 40 km/h on flat ground. The Elliptical movement climbs, descends, accelerates and maneuvers similarly to a bicycle, so anywhere you can take a road bike, you can take an Elliptical movement, including up and down steep hills and along twisty sections of road. The Elliptical movement 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. Bryan Pate et al. [1] have been motivated to develop the first elliptical bicycle after suffering from injuries that prevented him from running for exercise. Pate, a seasoned biker, decided against riding a bike to stay in shape because he found the elliptical trainer to be more pleasant. Pate had a vision of designing a product that would enable him to combine the outdoor "running experience" with the low-impact workout of the elliptical machine since he was dissatisfied with the experience of working out at a gym. The world's first elliptical bicycle was created in 2005 by Bryan in collaboration with mechanical engineer and ultra-marathoner Brent Teal, co-founder of ElliptiGO. After five prototypes and countless test miles, the ElliptiGO was created. Giro D'Italia et

al. [2] have discussed how immensely relevant minor performance improvements, on the order of about 3%, are. After several days of competition in a big Tour event, such time advantages can be the difference between placing on the podium or not for professional cyclists. These little variations affect whether professional and amateur triathletes will be able to compete at the World Championship event, a goal that is greatly desired in this athletic community. These athletes strive fiercely to win very few slots at qualifying events. athletes can now purchase time in wind tunnels to fine-tune and perfect their riding postures as a result of manufacturers of racing bicycles and bicycle components turning to wind tunnel testing in recent years to optimize component design3. The popular understanding that the rider, the frame, including the fork and aero bars, and the wheels are the key contributors to overall drag is supported by a number of initiatives, according to thorough evaluations by Burke4 Lukes. Kyle A.H et al. [3] have found that, compared to stationary wheels, moving wheels exhibit a very noticeable reduction in drag. It is important to note that Fackrell and Harvey also noticed a decrease in drag and side forces when comparing rotating and stationary wheels, despite the fact that their experimental work focused on studying the aerodynamic forces on much broader automotive tyres. Bicycles have established themselves as a safe and environmentally beneficial method of transportation for commuters and enthusiasts alike since their introduction in 1817. The world has drastically changed, even if the bicycle has remained commonplace over time. Automobiles, which are aggressive vehicles of human transportation, are now the majority on US roads. Unfortunately, when trying to share the road with vehicles, bicyclists are treated as second-class citizens. In actuality, this has been the case for the majority of the bicycle's existence. The first automotive accident in the United States to involve a bicycle happened in New York City in 1896, and it was fatal for the cyclist. Mestdagh de Vey et al. [4] have concluded and advocated that by adjusting saddle height, riding posture might be improved. With the rise in living standards, bicycle design has shifted from its historic importance in the realm of transportation to its promise in modern leisure sports. In light of this, individualized design has recently become popular in the bicycle industry. When designing a bicycle, the rider's comfort is a crucial issue that needs to be taken seriously. For instance, Hsiao and Chou (2005) attempted to improve the comfort of riding on bicycle products by translating the design concept of "fitting an object to the human body" into the design and development of an electric motorcycle. Peveler et al. [5have come to the conclusion and highlighted the fact that most bicycle-related accidents are caused by the improper saddle, handlebar, and/or pedal adjustment. With relatively minimum tools, a bicycle frame can be constructed. I completed it on my own. It was uncomfortable and required a lot of concentration, and it took me a lot longer than it would have if I had a couple more pieces of high-quality equipment. The choice of how much equipment to use is left to each frame builder. It will depend on how they want to manufacture frames, the amount of space they have to store their tools, and their financial situation. My case studies demonstrate that frame builders can succeed utilizingsing a variety of various "philosophies" with regard to equipment. Consider Richard Sachs, one of the most well-known and prosperous frame builders in the world, who is also without a milling or lathe. Apart from a frame jig, a few benches, a vice, and some hand tools, his workshop is visibly barren of tools. Laios And Giannatsis et al. [6] have concluded the a series of bicycles for kids between the ages of 7 and 14 have been redesigned using the suggested appropriate design technique for bicycle size, which took into account bicycle design in line with human body dimensions. Bicycle wheels with spokes are strong, well developed structural systems. A circular beam on a pre-stressed elastic base, fixed at the center and loaded radially at the circumference, is a helpful comparison for a bicycle wheel carrying vertical loads. By using this comparison, it is possible to model the spoke system as a disc with a constant stiffness along the circumference. By altering the spokes' interlacing geometry, wheels with set dimensions can have spokes of various lengths laced into them. Abraham J S et al. [7] have come to the conclusion that the idea of creating a bike with elliptical pedaling was only put forth to subtly entice people into purchasing an exercise bike, hence promoting the use of non-polluting automobiles for shorter distances. The idea behind elliptical pedaling is simply to combine a standard bicycle with a slider-crank mechanism. An elliptical bicycle is regarded as a standout product because to how simple it is to use compared to a regular bicycle. Though conceptually the concept is not new, this suggested product sets itself apart from previous elliptical bicycles by adding a feature that makes it float on water. The elliptical bicycle may float if floating supports are added to its sides that are removable. The Amphi elliptical bicycle was given its name because it can be used on both land and water by combining these two concepts, which is a brand-new idea. People are becoming more health conscious and trying to act responsibly to reduce pollution in the environment, so creating this type of vehicle at a significantly low cost with the qualities mentioned above will make it a successful product in the market. This item serves as an entertainment vehicle and will soon be available at tourist spots in place of standard bicycles. Kudale. P. P et al. [8] discussed recently, it has been stated how the trend towards customizing cycle designs is growing. The comfort of the cycle ride must be properly monitored during the development process. The idea behind this study is to create a cycle frame that is ergonomically appropriate in terms of size and shape to accommodate the human body. The frame design, the materials utilized, the riding position, and the different tests that were conducted are some of the key characteristics of the

bicycle. Additionally, a thorough approach is provided in this study to assist the designer in creating an elliptical cycle that is both inexpensive and effective. The cycle frame in this project is made with the ergonomic principle of "fitting objects to the human body" in mind. First, key features such as frame design, wheel size, materials needed, production process, and troubleshooting are covered. Ajith Arul Daniel et al. [9] have concluded that the bicycle is an essential part of our lives. One of the most economical modes of transportation is it. People now use bicycles for physical activity. New innovations have been appearing in bicycle design. More study is being done on how to make bicycles that are lighter and stronger. The primary load carrier for bicycles is the frame. The performance of the bicycle will be enhanced by optimizing the frame's design parameters. The ideal bicycle will be lighter and stronger thanks to the optimal design. In this paper, a brand-new bicycle frame design has been created.. The shape of the frame is in elliptical form. The model were designed and analyzed in CATIA. Finally, the analyzed frames are then optimized to reduce weight without affecting their capacity to be resistant to mechanical stresses. Naga Malleshwara Rao et al.[10] have discussed the Elliptical bicycle's design analysis. The main goal is to use software for mechanical engineering that is simple to grasp to design the fundamental parts of an elliptical bicycle. This elliptical bicycle is a unique and effective idea that is beneficial in a rapidly expanding planet. Bicycles are typically propelled by a pedaling system. However, because elliptical pedaling has been used in place of the traditional pedaling configuration, this bicycle provides the impression that you are walking on it. It feels simple to walk on this after a brief period of pedaling. The biggest benefit of using this elliptical bike is that it allows us to travel between locations while also exercising our entire body. This kind of device is typically found in gyms that are set up in fixed locations for workoutsut. However, the same technology is introduced in this work in place of conventional bicycles for travel purposes. The way the cycle is operated and how it looks completely differs from a typical bicycle[11].

II. Design Calculation and Modeling of Elliptical Bicycle

2.1 Design of Frame

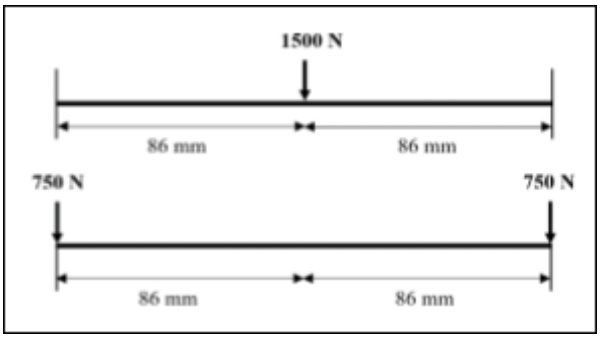


Fig1 Design of Frame

The distribution of the load placed on the frame, which is estimated to be 1500N, is shown in the above figure. Additionally, this load was split into two equal loads, each weighing 750N.

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

{where, F= 1500 N and r= 86mm}

$$T = F \times \text{r} \quad \text{.....(1)}$$

$$T = 750 \times 86$$

$$\therefore T = 64500\ N.mm$$

Because a human cannot move at a speed greater than 20 rpm, the estimates of the power delivered by the sprocket use the following assumptions: -

$$P = T\text{m}$$

$$P = \frac{T \times 2\pi N}{60} \quad \text{.....(2)}$$

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

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

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

$\therefore P = 135 \times 0.98$

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

2.2 Design of Chain

Fig. 2 Design of Chain

With proper installation and lubrication, the chain chosen using this procedure will have a minimum life expectancy of 15000 hours.

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

$$L = \frac{(Z_1 + Z_2)}{2} + \frac{2C}{p} + \frac{(Z_1 - Z_2)^2}{4\pi^2 C} \quad \text{.....(3)}$$

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=13 inch),

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

$$= 94\ pitches$$

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

III. Modelling of Elliptical Bicycle

3.1 Drafting of Cad Model [Frame]

Required CAD model was developed using 3-D modeling software. The head tube, top tube, bottom tube, chain stays, bottom bracket shell, and the two elliptical arcs, sometimes called as the elliptical frame, are the basic components of the cad geometry. The bicycle frame model is seen here. The main part of a bicycle is the frame, which is where the wheels and other parts are attached. Frames must combine various materials and geometries to achieve their desired properties of strength, stiffness, and lightness.

Fig.3 Frame Model 1

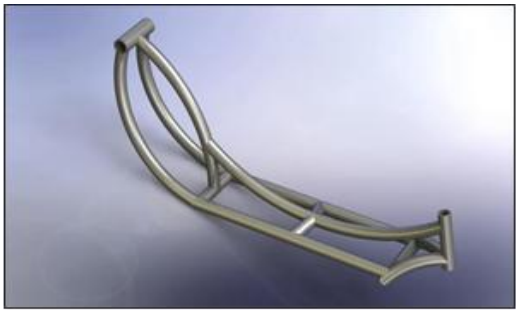


Fig.4 Frame Model 2

3.2 Meshing

Combining first and second order tetra components will result in a mesh of higher quality. To improve mesh control, it is necessary to execute surface meshing utilizing triangle components. This mesh will then be changed into a tetra mesh. Selective regions will be finely meshed utilizing first order elements determining the amount of nodes generated, and selective tetra elements will be turned into second order.

3.3 Meshing table

Table.1 Meshing Table

1. Mesh type:	Solid Mesh
2. Mesher Used:	Curvature-based mesh
3.Jacobian points:	4 Points
4. Maximum element size:	39.9216 mm
5. Minimum element size:	7.98433 mm
6. Mesh Quality:	High

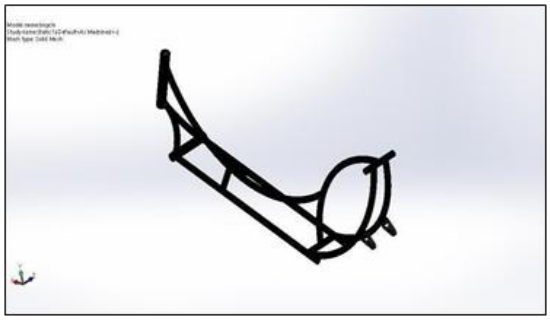


Fig. 5 Meshed Frame

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.

3.4 Modelling of Elliptical Bicycle Parts

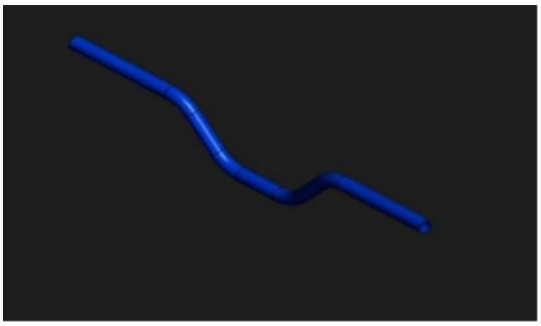


Fig (a) Handle

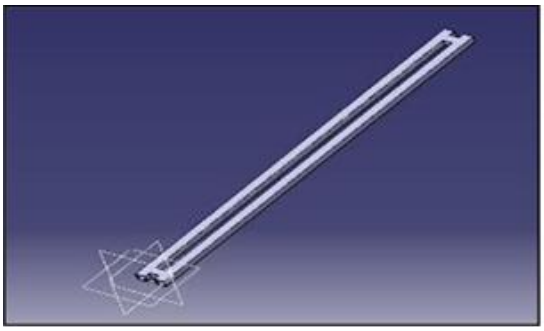


Fig (b) Connecting Rod

Fig (c) Wheel Assembly

Fig (d) Sprocket

Figure.6 (a) (b) (c) (d)

Figure 6 shows the 3D model of different components of the elliptical bicycle which are modeled in the 3D experience platform. The parts are made in Catia v5 R20 software the parts are bicycle handle, connecting rod, wheel assembly and bicycle sprocket.

IV. Result And Discussion

4.1 Frame Analysis

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

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

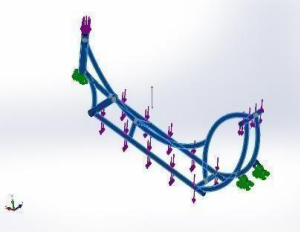
The efficiency of power transmission and the comfort of the ride may both be impacted by stiffness (or elastic modulus). In reality, ride comfort is more of a function of saddle selection, frame geometry, tire selection, and bicycle fit because even a very flexible frame is stiffer than the tires and saddle. Due to the compact profile of a frame, lateral stiffness is much more challenging to produce, and excessive flexibility can have an impact on power transmission, especially through tire scrub on the road brought on by rear triangle distortion, brakes rubbing against the rims, and the chain rubbing against gear mechanisms. In severe circumstances, gears may automatically shift when a rider exerts strong torque when standing up from the saddle.

Table.2 Units Used During the Analysis Of The Frame.

Unit system:	**SI (MKS)**
1)Length/Displacement	Mm
2)Temperature	Kelvin
3)Angular velocity	Rad/sec
4)Pressure/Stress	N/m2

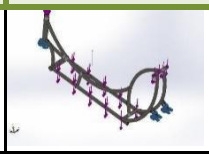
The above table shows various units used during the frame a

Table.3 Material Information During Fame Analysis.

Model Reference	Properties	Components
	Name: **AISI 4130 Steel, normalized at870C** Model type: **Linear Elastic Isotropic** Default failure **Max von Mises** criterion: **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**	**Solid Body 1 (Combine 20) (bicycle)**

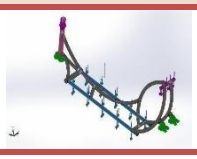
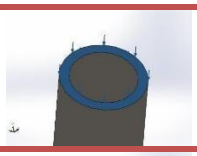
The above table shows material information used during the analysis of the frame which includes yield strength, tensile strength, elastic modulus, Poisson's ratio, mass density and shear modulus of the selected material (Mild Steel).

Table.4 Fixture Details Used in Frame Analysis

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

The above table shows the number of faces and entities that the fixtures are applied to during the analysis of the frame is shown in the above table. Additionally, it lists the elements, reaction forces, and reaction moments that took place throughout the analysis.

Table 5 Loads and Forces Applied on The Frame.

Load name	Load Image	Load Details	
		**Entities: Reference:**	**2 face(s)**
		Type: Values:	**Face**
			< 1 >
Force-2			**Apply**
			force
			---, ---, -1200 N
Force-3		**Entities: Type: Value:**	**1 face(s) Apply normal force 30 N**
		**Entities: Reference:**	**1 face(s)**
		Type: Values:	**Face**
			< 1 >
Force-4			**Apply**
			force
			---, ---, -600 N

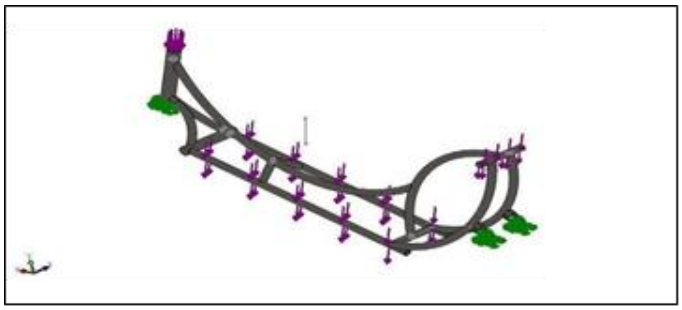


Fig 7: - Points on Which the Frame is Supported and the Direction of Forces Applied on the Frame During the Analysis.

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

4.2 Analysis and Result of Elliptical Bicycle

- **Analysis Result**

Ansys is a general-purpose, finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static/dynamic, structural analysis, heat transfer, and fluid problems, as well as acoustic and electromagnetic problems. The modules used in ANSYS Workbench are Static Structural, Modal, Response Spectrum, Explicit Dynamics, LS-Dyna, Modal Acousticsand Static Acoustics.

- **Stress Result**

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

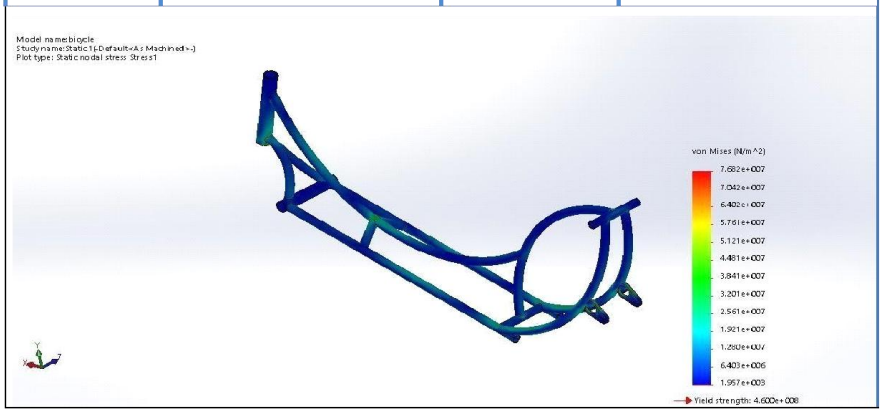


Fig.8 Stress Induced in The Frame

The above figure shows the stresses result as we fixed the frame at three points and the different forces applied to the different fixed points. And we calculated the maximum stress as 7.681+007 N/m at node 91579.

- **Displacement Result**

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

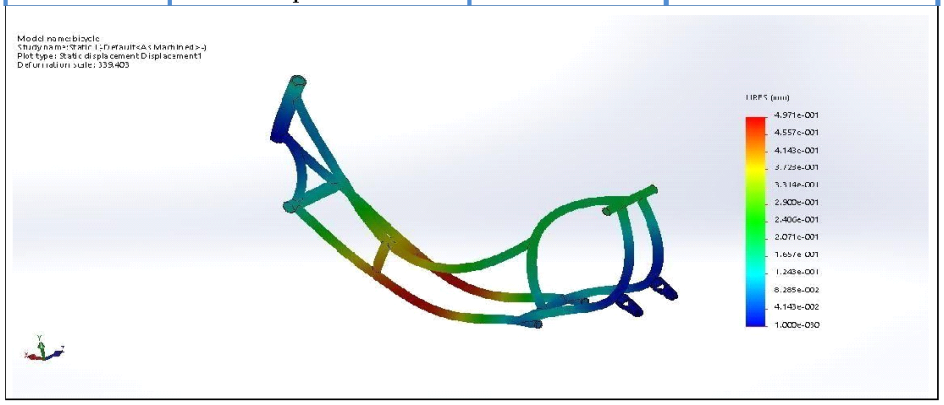


Fig.9 Resultant Displacement of Frame

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. In we have applied the load of 1200N the maximum displacement is at the bottom side of the frame.

4.3 Calories Burning Calculation

$$\text{Calories burned} = \frac{\text{Time in min x MET x 3.5 x weight in kg}}{200}$$

Where,

MET is "Metabolic equivalent task" MET for elliptical bicycle is 4.9.
MET for normal bicycle is 3.5.

As the graph shows the calories burning in elliptical bicycle in 10 min is 43kcal and the calories burning in normal bicycle in 10 min is 31kcal

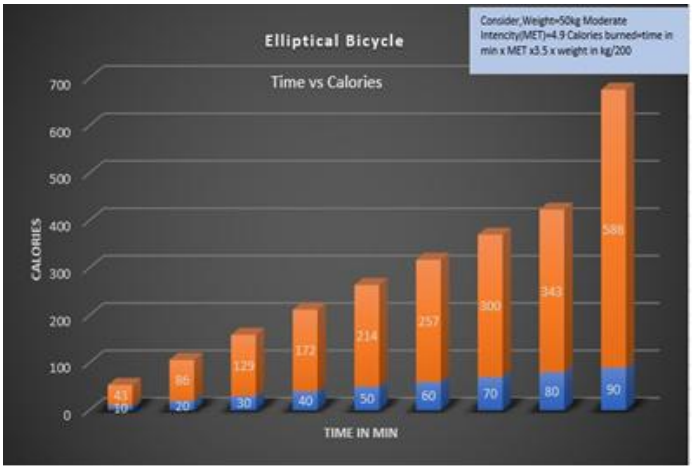


Fig.10 Calories Burning in Elliptical Bicycle

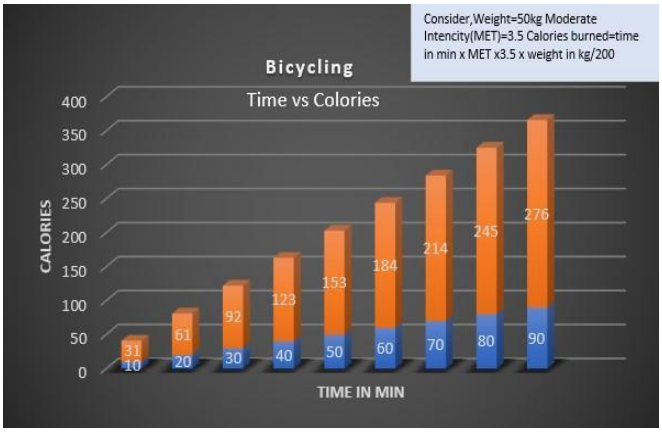


Fig. 11 Calories Burning in Normal Bicycle

V. Conclusion

Thus, conclude that Elliptical movement is designed and fabricated with the 60% cost optimization hence satisfying our aim of the project which was to design and fabricate the model while optimizing the cost. As the graph shows the calories burning in elliptical bicycle in 10 min is 43kcal and the calories burning in normal bicycle in 10 min is 31kcal from this we can say the is calories in elliptical bicycle is 12% more than the normal bicycle in 10 min of cycling. which is successfully achieved with an added advantage of introducing this concept in the Indian market. Elliptical movement provides 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. The comfortable and better ergonomics of Elliptical movement 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, Elliptical movement emulates the natural running movement, so the rider stands upright, in a very comfortable position and propels the Elliptical movement 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 Elliptical movement riders work harder than cyclists to maintain the same pace, allowing Elliptical movement riders to get their workout done in less time and while covering less distance.

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