As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology, 8(05):209-218, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST0805030
Available online at: http://www.ijmtst.com/vol8issue05.html

Design and Analysis of Solar Powered Bicycle

Malla Rohan Kumar | Nikhil Kotha | Sundaragiri Kashyap

Department of Mechanical Engineering, Anurag Group of Institutions, Hyderabad, Telangana, India
*Corresponding Author Email ID: rohan18kumar1999@gmail.com

To Cite this Article
Malla Rohan Kumar, Nikhil Kotha and Sundaragiri Kashyap. Design and Analysis of Solar Powered Bicycle. International Journal for Modern Trends in Science and Technology 2022, 8(05), pp. 209-218. https://doi.org/10.46501/IJMTST0805030

Article Info
Received: 01 May 2022; Accepted: 05 May 2022; Published: 07 May 2022.

ABSTRACT

There are many transportation companies in today's tech era, but the soaring prices of fuels such as gasoline and diesel make buying them a big problem. Contamination with the above fuels is also a big issue. Therefore, in this article, we have described solar-based bicycles that operate on solar energy and do not generate pollution.

Vehicle pollution is due to harmful pollutants released into the environment through automobiles. The rapid growth of vehicles means that more fuel is burned, leading to the emission of harmful gases to the environment, which in turn causes serious health problems. Exposure to high levels of air pollution can have a variety of adverse health effects. Increases the risk of respiratory infections, heart disease and lung cancer.

Short-term and long-term exposure to pollutants is associated with health effects. So, in this current situation it very important to have an alternative soruce for polluted environment. The solar powered electric bicycle is one of the best alternatives for these heavily polluted vehicles. Simple design and low cost pollution free vehicle which isaffordable by all classes of people.

Solar-powered electric bikes are driven by solar panels attached to the bike and connected to a hub motor for a comfortable ride. A solar panel is connected to a solar cell to collect solar energy from the sun and convert this energy into electrical energy.

In this work the dimensions of cycle parts were measured and analyzed with the obtained design calculations. Solid works is used for modeling, assembling and analyses. Analyses was done with stress, deflection and von-mises stress in XYZ directions using 5 different loads 1000N,1250N,1500N,1750N and 2000N.The behavior of cycle frame for various loads are analyzed from the graphs drawn.

KEYWORDS: Contamination, Solar Panels, Renewable Energy, Hub.

1. INTRODUCTION

Traffic is one of the largest causes of air pollution in urban areas. Air pollutants have many implications for human health, climate, ecosystems, and the environment in which they are built. European and global authorities support zero-emission mobility and believe it is necessary for the development of national sustainability strategies. Since 2000, the government has promoted bicycles as an alternative to private cars, especially in urban areas where terrain and road networks allow. Bicycles can help reduce air pollution, traffic jams, noise emissions and energy consumption while enabling a healthier lifestyle for users. In addition, bicycles are one of the most accessible and cheapest means of transportation (for example, there are no additional taxes, driver's licenses, parking fees, high maintenance costs for services such as cars). Many cities encourage cycling, especially by introducing bicycle sharing schemes for public use.

An alternative of the conventional bicycle is the electric bicycle (e-bike). The term electrical bike or 'e-bike' refers to all two-wheeled electric vehicles (EVs), more specifically to bicycles, with different levels of assistance to the user. A small electric motor and a rechargeable battery are used to assist the power that is provided by the rider.

The battery can provide energy for high acceleration.

The motor power ranges from 200 Watts to 4000 Watts.

E-bike weight ranges from 20 kg to 45 kg.

Travel distance ranges as high as 150 km.

Speed is generally less than 45 km/h.

Due to the confusion that was mentioned above, electric bikes are divided into two categories according to the characteristics they present: bicycle-style electric bikes (BSEB)and speed peddles.

1 Purpose of the work

Solar E-cycle is a bicycle which runs using the electrical energy of battery to run the hub motor which ultimately runs the bicycle. Solar energy is used to charge the battery. Ebikes use rechargeable batteries and the lighter ones can travel up to 25 to 32 km/hr , while the more high-powered varieties can often do more than 45 km/hr.Since the fuel prices not only in India but throughout the world is increasing day by day thus there is a tremendous need to search for an alternative, to conserve these natural resources.Thus a solar bicycle is an electric vehicle that provides an alternative by harnessing solar energy to charge the battery and thus provide required voltage to run the motor. Since India is blessed with nine months of sunny climate thus concept of solar bicycle is very friendly in India. Hybrid bicycle uses solar energy to charge the battery which in turn runs the bicycle. Thus solar hybrid bicycle can become a very vital alternative to the fueled automobile thus its manufacturing is essential

Figure 1.1. Components of bicycle

Table 1.1: Specifications of Gear motor

S.No		
1	Maximum Power(Pmax)	20W
2	Voltage at Pmax	17V
3	O.C Voltage	12V
4	S.C Voltage	1.2A
5	NOCT	45

S.No		Details
1	Length	160mm
2	Shaft Diameter	6mm
3	A voltage	24V
4	Weight	2.5 kg

Table 1.2: Specification of Solar Panel

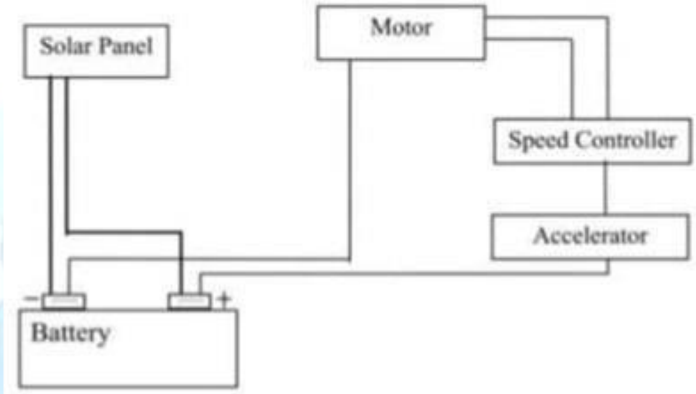

Figure 1.8: Circuit Diagram

Objectives of the present work

- To analyse bicycle frame by applying various loads.
- To find the maximum load that the bicycle can bear.
- To analyse the relation between load and stress for various values of load .
- To analyse the relation between load and vonmises stress for various valuesof load .
- To analyse the relation between load and displacement for various values ofload .

2. LITERATURE REVIEW

Global warming and traditional resources are becoming a major the problem in the current scenario. Due to the economic challenges india is facing in automated sector Solar bicycle has a huge growth potential. Previous researches have concentrated their work on inclined roads, finding kinetic energy where as in this work analyses isdone.

Jean-Marc Timmermns et al., [1] has given a comparative study on different types of electrically assisted bicycles in his paper with an idea to make the bicycle, to use the loss of energy with flywheel, when sudden brake is applied and how it can be automatically recharge by using renewable solar energy with normal pedaling method.

Todd Litman has presented in his paper a comparison of four transportation energy conservation strategies using a comprehensive evaluation framework that takes into account how each strategy affects annual vehicle travel, and therefore mileage-related impacts such as traffic congestion, road and parking facility costs,and crashes [2].

Hampus Ekblad et al., presented the result of a literature study concerning how different factors associated with bicycle planning influence the propensity to choosethe bicycle for transportation [3].

Bradley C. Keoun [4] in his paper Electric Vehicle Intelligent Control System has offered an ingenious and cost-effective way to monitor the speed of the electric motor and the electric vehicle. Furthermore, the Wireless Remote Desktop Control Moduleis an innovative integral of EVICS in providing real time problem solving and maintenance work done on the electric vehicle more effective and efficient without leaving the comfort of the engineer's seat.

3. MATERIALS AND METHODOLOGY

3.1 Materials for frame

There are a wide variety of materials used in bicycle frames. Bike frames were originally made from wood, but modern frames are made primarily from aluminum, steel, titanium and carbon fiber. Some of the less common materials used in creating frames include bamboo, thermoplastics and magnesium. Bicycle frames constructed from the more common frame materials can be seen in Figure

(A) Aluminum (B) Steel (C) Titanium (D) Carbon Fiber

The materials used for mountain bicycle frames have a wide range of mechanical properties. These properties can be seen in Table 1. There is not one material in the table that has advantageous properties in each category, which explains why manufacturers continue to fabricate framesfrom several different materials.

TABLE 3.1: SPECIFICATIONS OF MATERIALS FOR FRAME

Material	Modulus of Elasticity (GPa)	Yield Strength (MPa)	Tensile Strength (MPa)	Fatigue Strength at 50,000 Cycles (MPa)	Density (kg/m3)	Weldability and Machinability	Cost (rupess per kg)
Aluminum – 6061-T6	72	193-290	241-320	75	2,700	Excellent	280
Steel – 4130	205	800-1,000	650	250	7,800	Excellent	170
Titanium – Grade 9	91-95	483-620	621-750	250	4,480	Fair	4000
Carbon Fiber	275-415	Varies	Varies	Varies	1,800	Fair	Varies

3.2 Methodology

SolidWorks is a solid modeling computer-aided design (CAD) and computeraided engineering (CAE) computer program that runs on Microsoft Windows.

SolidWorks is published by Dassault Systems.

According to the publisher, over two million engineers and designers at more than 165,000 companies were using SolidWorks as of 2013. Fiscal year 2011–12 revenue for SolidWorks totaled $483 million

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through the use of relations, which allows them to capture design intent.

Design intent is how the creator of the part wants it to respond to changes and updates. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. SolidWorks allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the can.

Features refer to the building blocks of the part. They are theshapes and operation s that construct the part. Shape-based features typically begin with a 2D or 3D sketch of shapes such as bosses, holes, slots, etc. This shape is then extruded or cut to add or remove material from the part. Operation-based features arenot sketch-based, and include features such asfillets, chamfers, shells, applying draft to the faces of a part,etc.

Vehicle dynamics:

Total load = Vehicle load + Rider load

= 80+70

M=150kg

Aerodynamic drag: (Fa)

Fa=1/2 Pa Cd Af (Vbike – V wind)2 Cd= Aerodynamic drag coefficient = 0.75 Pa= Density of air = 1.225kg/m3

Af= Frontal area = 0.7

Vbike = 25kmph =6.94 Vwind =0.004

Fa =1/2 (1.225) (0.75) (0.07) (6.9)2

Fa=1/2(1.225)(0.75)(0.7)(6.9)2 Fa= 15.3N

2) Rolling Resistance : (Fr)

Fr =Cr mg cos α M=150kg = mass of vehicle α

= Road incination angle Cr

= 0.015

Fr = 0.015*9.8*150*1 Fr = 22.05N 3)

Grading force: (Fa)

If grade % =14 α = tan -1 (14/100) = 8.850

Fg =mg sin α Fg= 150*9.8*sin(s)

Fg =226.15N

If α =50 Fg = 128.11N

4) Angular force: (Fwa)

Angular acceleration = mr 2 /4 M= mass of wheel = 4kg R= 0.216 aw = = mr 2 /4=

0.046kg/m2

Angular force is negligible. Since we are not using hub motor.

5) Tractive power: (Ft)

Ft = Fa+ Fr+ Fg +Fwa +Fla Fla is linear force

Minimum grading angle = 3.8

A= 0.683m/s2

Fla =ma

Fla = 150*0.683 Fla

= 102.45N

Ft =139.8N

Motor selection

Ft = Fa+ Fr+ Fg +Fwa +Fla

Ft= 102.45+22.05+15.3+0+0

Ft= 139.8N

Traction power:

Pt = Ft *V V=25kmph =6.94m/s

Pt =139.8*6.94

back caluclation:

Pt =970.212W

100w rated power is selected Battery

Energy required=1kwh [for 1000w rated motor] Electrical energy = V*Ah 1 kwh =

480*Ah Ah=1000/48 Ah=20.88Ah

Ah can be more be 20.88Ah

Greater Ah can be used for more run time Design Calculations

Design of Bike:

Here we have uses permanent magnet self generating motor with 250 watt power and 2100rpm. The motor runs on 48volts and 7.5amp power source. This motor can reach a peak current during starting equal to 15 amp.

P = 2 × 3.14 × N × T/ 60

250 = 2 x 3.14 x 2100 x T/60 T = 1.13 N m = 1136 N-mm

Reduction in chain drive R chain = 66 / 11 = 6 : 1

Torque at wheel shaft = T × R chain = 1136 × 6 = 6820 N mm Speed of wheel shaft = 2100/6 = 350 rpm

Designing of shaft Bending:

The force which develops across a specific cross section of the shaft, it generates stress at that point of cross section that are subjected to maximum loading. This internal or resisting movement gives rise to the stress called as bending stresses.

Torsion:

When the shaft which is twisted by the couple such that the axis of the shaft and the axis of the couple harmonize, that shaft is subjected to pure torsion and the stresses generated at that point of cross section is torsion or shear stresses.

Combined bending and Torsion:

In actual practice the shaft is subjected to combination of the above two types of stresses i.e. bending and torsion. The bending stresses may occur due any one of the following reasons;1. Weight of belt2. Pull of belts3. Eccentric mounting of shafts / gears4. misalignment of shafts / gears On contrary, the torsional movement occurs due to direct or indirect twisting of the shaft. Hence at any given point on cross- section of the shaft, the shaft is subjected to both bending and torsional stresses simultaneously. Following stresses are taken in consideration while designing the shaft

Shaft Design

T = 36000 N mm

T = 3.14/ 16 × σs × d3 Fs allowable = 80 N/mm2 6820 = 3.14 × σs × d3 / 16 σs = 34.73 N/mm2

Material = C 45 (mild steel) σ ut = 320 N/mm2

--

PSG design data book. Factor of safety = 2 σt = σh

= σ ut / fos =320/2 = 160N/mm2 σs = 0.5 σt

= 0.5x160= 80 N/mm2 σs is less then allowable so our shaft design is safe

Design of sprocket and chain for electric bike We know,transmission ratio = Z2 / Z1 = 66/11 = 6For the above transmission ratio number of teeth on pinion and the number of teeth sprocket in the range of 21 to 10, so we have to select number of teeth on pinion sprocket as 11 teeth.So, Z1 = 11 teeth selection of pitch of sprocketThe pitch is decided on the basis of RPM of sprocket.RPM of pinion sprocket is variable in normal condition it is = 2100rpm For this rpm value we select pitch of sprocket as 6.35mm from table.

P = 6.35mmCaluclation of minimum center distance between sprockets THE TRANSMISSION RATIO = Z2 /Z1 = 66/11 = which is less than 7Dia of small sprocket,periphery = π × dia of sprocket 11 × 6.25 = π × DD=11 × 6.25 / πD = 21.8 mmDia. of sprocket,periphery = π × dia. of sprocket 66 × 6.25 = π × DD = 131.3 mm

So from table, referred from PSG

Design Data book The minimum center distance between the two sprocket

= C ' + (180 to 150 mm) Where C' = Dc1 + Dc2 ÷2

C' = 131.3 + 21.8 ÷ 2 C' = 76.5 mmMINIMUM CENTER DISTANCE = 76.5 + (30 to 150 mm)MINIMUM CENTER DISTANCE = 170 mm

Caluclation of values of constants K1 K2 K3 K4 K5 K6 – (with help of PSG Data)

Load factor K1 = 1.25 (Load with mild shock)Distance regulation factor K2 = 1.25 (Fixed center distance)

Center distance of sprocket factor k3 = 0.8 Factor for position of sprocket k4 = 1

Lubrication factor k5 = 1.5 (periodic)

Rating factor k6 = 1.0 (Single shift) Caluclation of value of Factor of Safety

For pitch = 6.35 & speed of rotation of small sprocket = 2100 rpm Factor of safety for this drive = 8.55

Caluclation of Allowable Bearing Stress:

For pitch = 6.35 & speed of rotation of small sprocket = 2100 rpm Allowable Bearing stress in the system in the system = 2.87kg/cm2

= 2.87*981/100=28N/mm2

Calculating maximum Tension On Chain

Maximum torque on shaft = Tmax = T2 = 6820N-mm

Where,

T1 = Tension in tight side T2 = Tension in slack side

O1, O2 = Center distance between two shaft

Sin α = R1- R2÷O1O2 Sin α = 65.65-10.9÷170

Sin α = 0.33 α

= 18.78

TO FIND θ θ = (180- 2α)X3.14/180 θ = (180-2*18.78) X 3.14/180 θ = 2.48 rad According to this relation, T1/T2 = e μ θ

T1/T2 = e0.35*2.48

T1 = 2.38T2we have, T = (T1-T2) X R

6820 = (2.38 T2 –T2) X 65.65 T2 =75.27N

T1 = 179.16N

So tension in tight side = 179.16 N We know stress = Force /area × 2

Stress induced = 179.16/(3.14*32/4) × 2 Stress induced = 12.67 N/mm2

As induced stress less than allowable stress = 28 N/mm2 design of sprocket is safe.

3.2.2 Part Modeling in SolidWorks

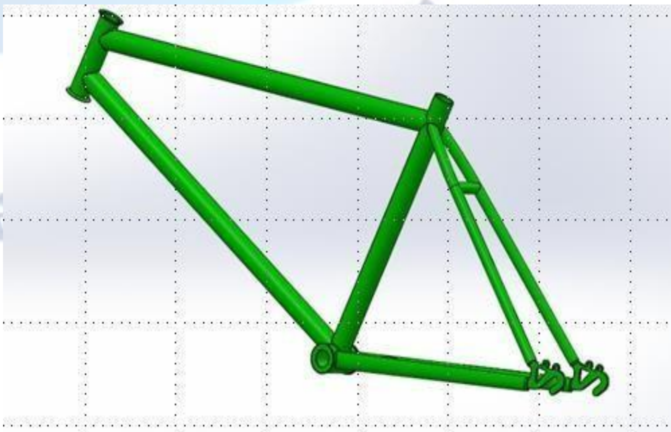

Fig 3.1 Frame

3.2.3 Fully assembled models:

Fig 3.4: Bicycle left side view

Fig 3.7: Fully Assembled Component

4 ANALYSIS

4.1 SolidWorks

Solid works is an American public company based in Canonsburg, Pennsylvania. It develops and markets engineering simulation software. Solid works software is used to design products and semiconductors, as well as to create simulations that test a product's durability, temperature distribution, fluid movements, and electromagnetic properties.

Solidworks was founded in 1970 by John Swanson. Swanson soldhis interest in th e company to venture capitalists in 1993. Solidworks went public on NASDAQ in 1996. In the 2000s, solid works made numerous acquisitions of other engineering design companies, acquiring additional technology for fluid dynamics, electronics design, and other physics analysis.

4.1.1. Solidworks simulation procedure

Step 1: Define your Study. Static, Thermal, Frequency, etc.

Step 2: Assign your Materials

Step 3: Apply the Boundary Conditions (Free Body Diagram)

Step 4: Mesh the Model

Step 5: Run the Analysis (Solve)

Step 6: View the Results Left to right on the command manager, or top-down in the Simulation feature tree these six steps are visible.

4.1.2 Deflection Analysis

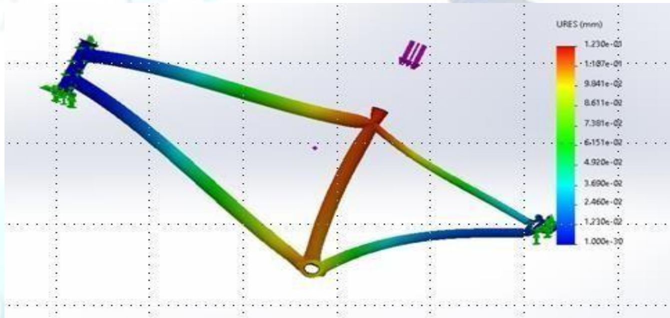

Figure: 4.1 displacement with load 1000N

From the figure it is observed that minimum deflection was -1.011e+08 at foreend and maximum of 9.711e+07 at seat tube due to vertical load acting on it.

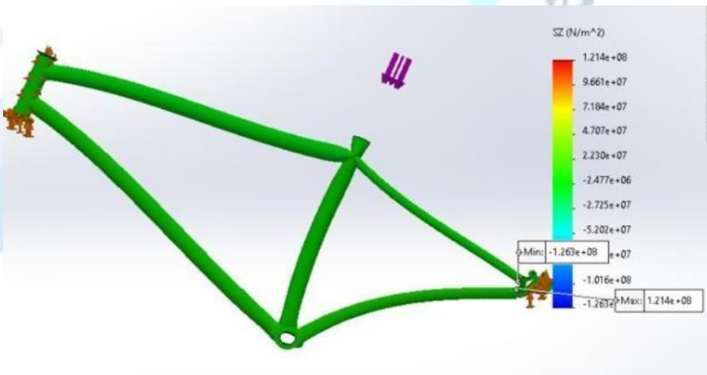

Figure 4.2 displacement with load 1250N

From the figure it is observed that minimum displacement was -4.660e-03 at foreend and maximum of 7.393e-02 at seat tube due to vertical load acting on it.

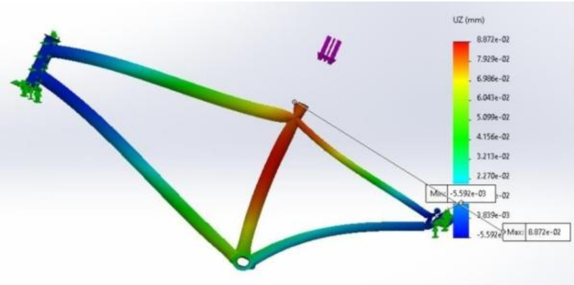

Figure: 4.3 displacement with load 1500N

From the figure it is observed that minimum displacement was -5.592e-03 at foreend and maximum of 8.872e-02 at seat tube due to vertical load acting on it.

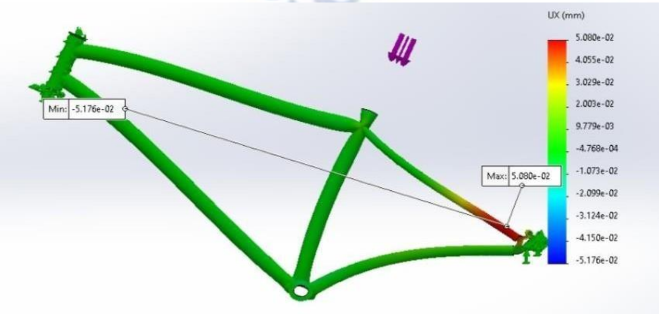

Figure 4.4 displacement with load 1750N

From the figure it is observed that minimum displacement was -6.525e-03 at fore end and maximum of 1.035e-01 at seat tube due to vertical load acting on it.

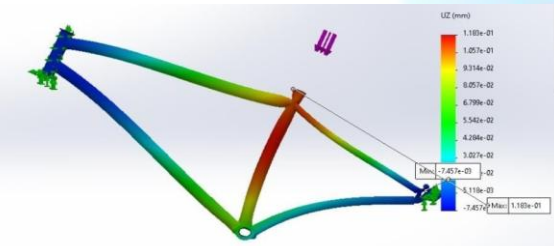

Figure 4.5 displacement with load 2000N

From the figure it is observed that minimum displacement was -7.457e-03 at foreend and maximum of 1.183e-01 at seat tube due to vertical load acting on it.

4.1.3 Vonmoise Stress Analysis

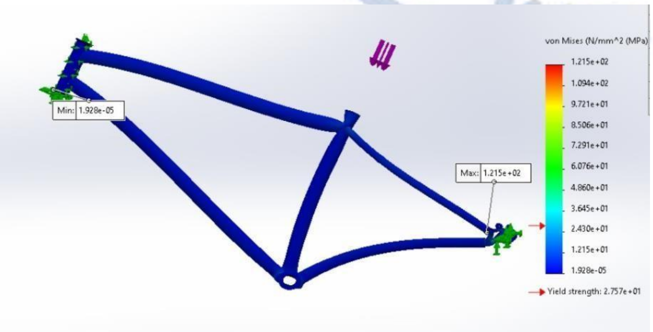

Figure: 4.6 Vonmises stress with load 1000N

From the figure it is observed that minimum von Mises stress was 1.982e-05 at foreend and maxim um of 1.215e+02 at back end

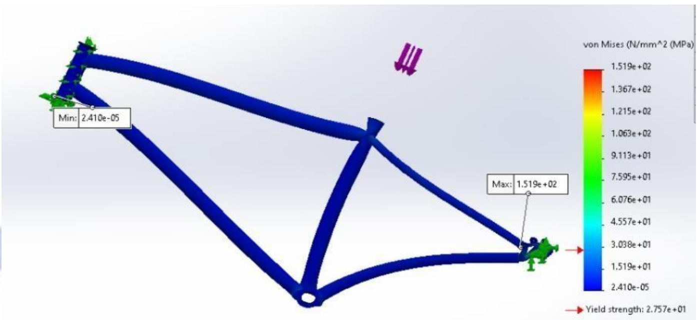

Figure: 4.7 Vonmises stress with load 1250N

From the figure it is observed that minimum von Mises stress was 2.410e-05 at foreend and maxim um of 1.519e+02 at back end.

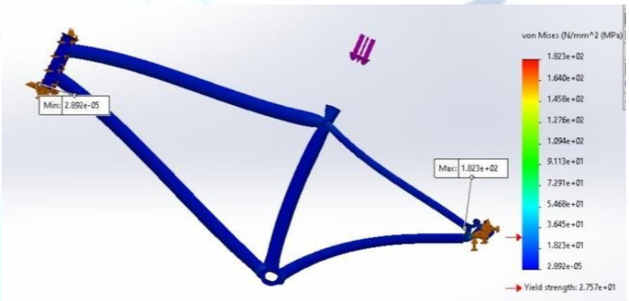

Figure: 4.8 Vonmises stress with load 1500N

From the figure it is observed that minimum von Mises stress was 2.892e-05 at foreend and maxim um of 1.823e+02 at back end

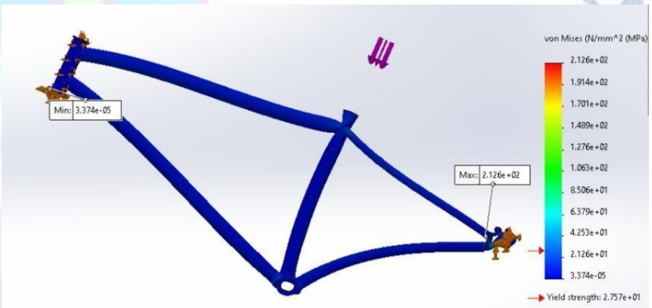

Figure: 4.9 Vonmises stress with load 1750N

From the figure it is observed that minimum von Mises stress was 3.374e-05 at foreend and maxim um of 2.126e+02 at back end

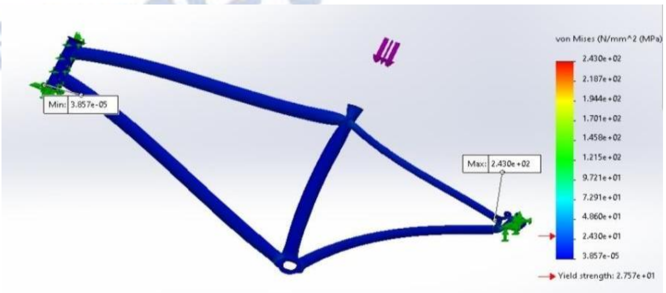

Figure : 4.10 Vonmises stress with load 2000N

From the figure it is observed that minimum von Mises stress was 3.857e-05 at foreend and maxim um of 2.43e+02 at back end

4.1.4 Stress Analysis:

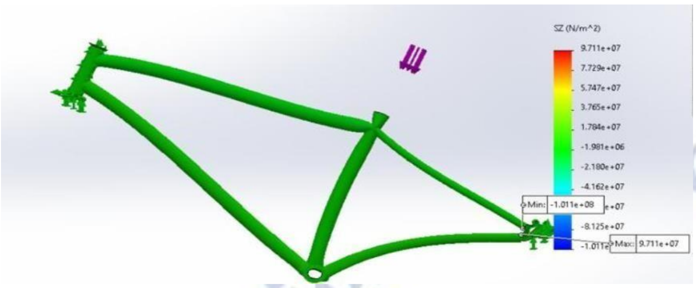

Figure: 4.11 stress with load 1000N

From the figure it is observed that minimum stress was -1.011e+08 at fore end andmaxim um of 9.711e+07 at seat tube due to vertical load acting on it.

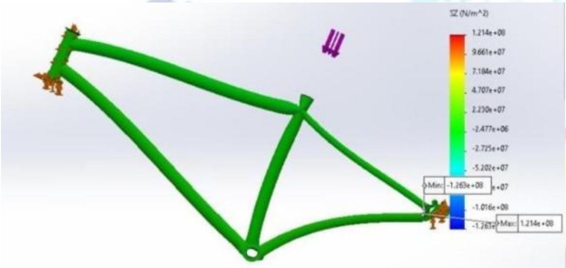

Figure: 4.12 stress with load 1250N

From the figure it is observed that minimum stress was -1.263e+08 at fore end andmaxim um of 1.214e+08 at seat tube due to vertical load acting on it

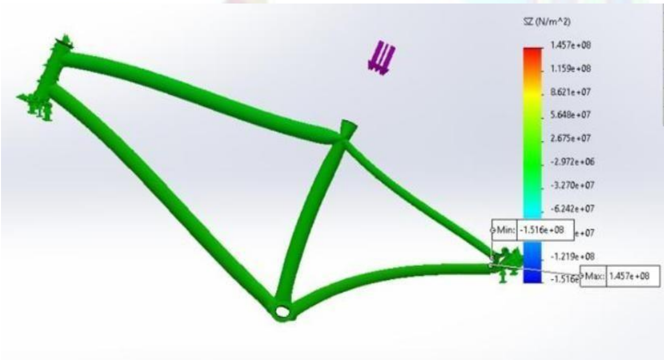

Figure: 4.13 stress with load 1500N

From the figure it is observed that minimum stress was -1.516e+08 at fore end andmaxim um of 1.457e+08 at seat tube due to vertical load acting on it

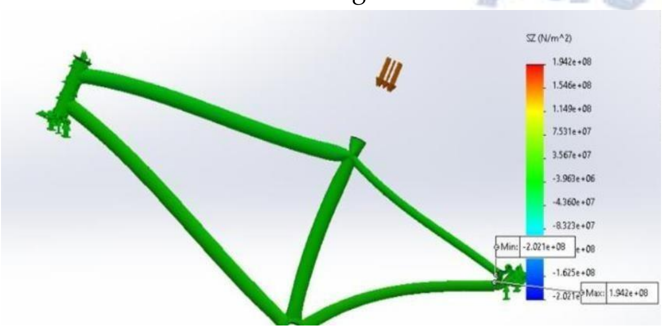

Figure: 4.14 stress with load 1750N

From the figure it is observed that minimum stress was -1.779e+08 at fore end andmaxim um of 4.61e+08 at seat tube due to vertical load acting on it

Figure: 4.15 stress with load 2000N

From the figure it is observed that minimum stress was -2.021e+08 at fore end andmaxim um of 9.637e+07 at seat tube due to vertical load acting on it

5. RESULTS AND CONCLUSION

Results

The results obtained from the analysis are shown below along with its tables and graphs. Table 5.1 shows the variation of load with stress in different directions for different loads.

Table 5.1: Load vs stress in different directions

S.NO	Load(N)	Stress in X direction (MPA)	Stress in Y direction (MPA)	Stress in Z direction (MPA)
1.	1000	4.81E+07	3.75E+07	3.52E+07
2.	1250	6.02E+07	4.69E+07	1.21E+08
3.	1500	7.22E+07	5.63E+07	1.45E+08
4.	1750	4.62E+07	6057E+07	1.70E+08
5.	2000	9.63E+07	7.51E+07	1.94E+08

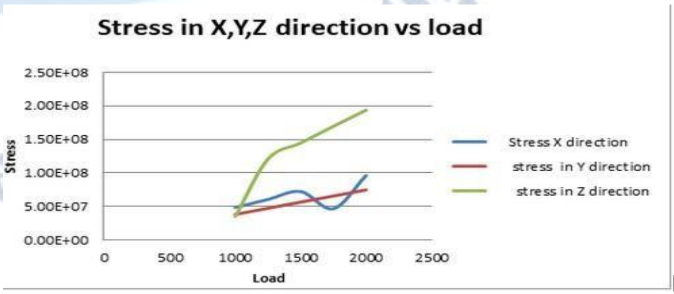

Figure 5.1: Load vs stress graph

From the figure 5.1 it is observed that

- The stress in X direction is linear till 1250n load value and from there thecurve decreases as load increases due to yielding.

- The stress in Y direction follows a linear path i.e. as the load increases thestress increases.

The stress in Z direction increases as load increases.

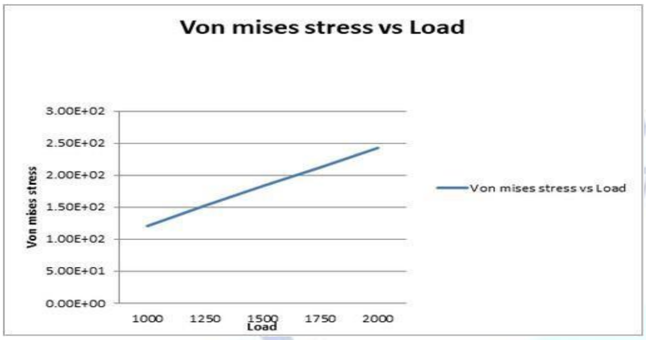

Figure 5.2: Load vs vonmises stress Graph

From the Figure 5.2 it is observed that the Vonmises stress increases as the loadincreases.

Table 5.3: Load vs displacement

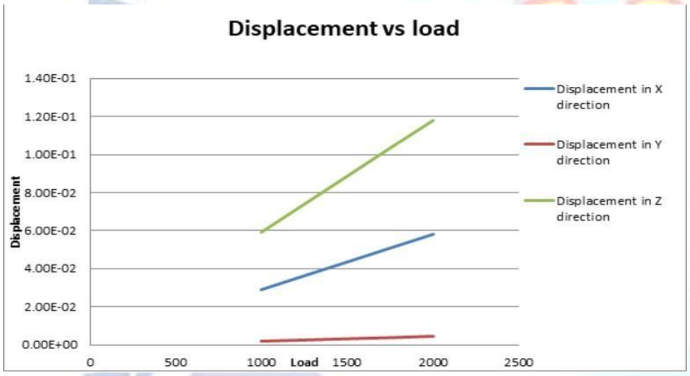

Figure 5.3: Displacement vs load Graph

From the figure 5.3 the following results are observed

- The displacement in X direction increases as the load increases.
- The displacemt in Y direction is constant with respect to load.
- The displacement in Z direction increases as load increases.

5.2 Conclusion

The major objective of study was analysis of solar bicycle frame and the following conclusions can be drawn.When the frame is subjected to different load conditions it is able to withstand weight of rider, solar pannel and battery The analysis was carried in solid works and it was found that the Vonmises stress induced in frame is with in the permissible limits. The frame shows very little displacement for various loads and ensures safety of the rider.

5.3 Future Scope

In addition, you can work by analyzing various other parameters such as boundary conditions (load application points), load types, mounting points, and different types of materials that can be used for the frame.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Jean-Marc Timmermns1, Julien Matheys, Philippe Lataire, Joeri Van Mierlo, Jan Cappelle2 "A Comparative Study of 12 Electrically Assisted Bicycles" World Electric Vehicle Journal Vol. 3 - ISSN 2032-6653 - © 2009 AVERE.

[2] Todd Litman, "Efficient Vehicles Versus Efficient Transportation "comparing transportation energy conservation strategies. Journal paper of Victoria Transport Policy Institute, 26 August 2009.

[3] Hampus Ekblad, Åse Svensson & Till Koglin "Bicycle planning in an urban context – A"

[4] Bradley C. Keoun,"DESIGNING AN ELECTRIC VEHICLE CONVERSION".

[5] Ajit B. Bachche, ** N. S. Hanamapure, on Design and Development of Solar Assisted Bicycle International Journal of Engineering and Innovative Technology (IJEIT) Volume 2, Issue 6, December 2012

[6] Sathisha K., Deepesh S. Kanchan a project report on "Concept of Solar and Pedal Powered Electric Bicycle"

[7] Amin, sayyad. r powered electric bicycle with kinetic energy restoration system (KERS). www.iraj.in/journal/journal_file/journal_pdf/1-262-146743037427-31.pdf.

[8] The Pandit G. Patil, Energy Systems Division, Argonne National Laboratory "Advanced Battery Technology for Electric Two-Wheelers" J²ournal of Energy Systems Division, Argonne National Laboratory June 2009.

[9] Ahmad A. Pesaran and Tony Markel, Harshad S. Tataria, David Howell "Battery Requirements for Plug-In Hybrid Electric Vehicles – Analysis and Rationale" Conference Paper of National Renewable Energy Laboratory, USA NREL/CP-54042240 July 2009.

[10] Tony Markel, Michael Kuss, and Paul Denholm "Communication and Control of Electric Drive Vehicles Supporting Renewables" Conference Paper of Center for Transportation Technologies and Systems National Renewable Energy Laboratory, NREL/CP-540-46224 August 2009.

[11] T. Markel, K. Bennion and W. Kramer, National Renewable Energy Laboratory & J. Bryan and J. Giedd Xcel Energy "Field Testing Plug-in Hybrid Electric Vehicles with Charge Control Technology in the Xcel Energy Territory." Technical Report of

National Renewable Energy Laboratory, NREL/TP-550-46345, August 2009.
[12] T. Markel, K. Bennion and W. Kramer, National Renewable Energy Laboratory & J. Bryan and J. Giedd Xcel Energy "Field Testing Plug-in Hybrid Electric Vehicles with Charge Control Technology in the Xcel Energy Territory" Journal of International Conference on Renewable Energies and Power Quality (ICREPQ'11) Las Palmas de Gran Canaria (Spain), 13th to 15th April, 2011.
[13] C. E. (Sandy) Thomas" Fuel Cell and Battery Electric Vehicles Compared" Journal ofH2Gen Innovations, Inc., Alexandria, Virginia, 22304, USA.