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Reverse Engineering of Bicycle

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***Abstract*:-In the automobile industry, Reverse Engineering is the process of collecting design data from automotive parts and reproducing it with modification. It can also be used to learn the process and subsequently improve the design. In the present work CAD model of an old unused Bicycle is created using the technique of reverse engineering and applying some conditions to the same model of bicycle to compare their behaviour in different scenarios. The framework of this work is to learn and apply the concept of reverse engineering, CAD modelling, FEA and to apply this to a bicycle and try to make it efficient.**

I. INTRODUCTION

There are broadly two types of engineering, one is forward engineering and the other one is reverse engineering. These involve the process of designing, manufacturing, assembling, and maintaining products and systems. Reverse engineering (RE) is a vital brand especially in the geometrical design and manufacture application area, and this technique has been widely recognized as a key step in the product development cycle. It is the process by which an artificial object is deconstructed to reveal its design, architecture, code, or to extract knowledge from the object. It is similar to scientific research; the only difference is the scientific research occurs for a natural phenomenon.

It is applicable in fields of –

- Computer engineering
- Mechanical engineering
- Electronic engineering
- Chemical engineering

This study tries to examine the stress response and displacement of bicycle frames using models and then analyze solid structures. The material used in this study is Steel AISI 1202.A structural analysis is an essential aspect for evaluating the strength and existence of the frame structure, which will be used for structural optimization

II. BACKGROUND

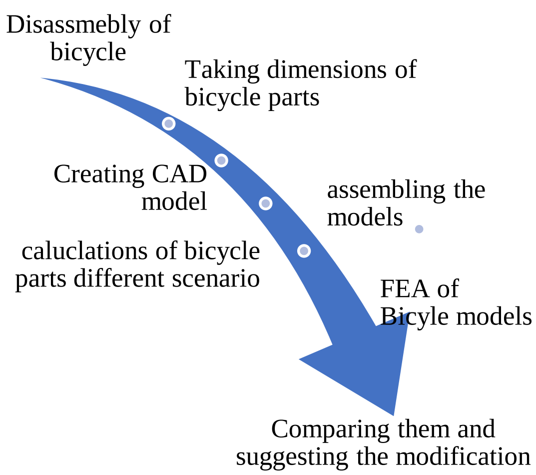
Finite Element Analysis or FEA is that the simulation of a natural phenomenon employing a numerical mathematic technique named as the Finite Element Method, or FEM. This process is at the core of engineering , also as a range of other disciplines. It is also one among the key principles utilized in the development of simulation software. Engineers can use these FEM to scale back the quantity of physical prototypes and run virtual experiments to optimize their designs. This practical intention of the methodology meant that from the start , these methods were designed as quite just mathematical theory. These mathematical principles of FEA are useful in different sectors, like computational fluid dynamics or CFD. In this study we are focusing on structural analysis .To run a FEA simulation first a mesh is generated . This is a way of transcribing a 3D object into a series of mathematical points that can then be analysed. The density of the mesh can be changed based upon how complex or simple a simulation is needed. Calculations are run every single element or point of the mesh and so combined to form up the general outcome for the structure. Since the calculations are done on a mesh, instead of everything of an object ,it means some interpolation must occur between the points. These approximations are usually within the bounds of what's needed. The points of the mesh where the info is understood mathematically are mentioned as nodal points and have a tendency to be grouped around boundaries or other areas of change in an object's design.

III. METHODOLOGY

This project has been divided into 7 modules-

It is initiated with disassembling the bicycle followed by measurement of the parts ,later CAD model is created for the disassembled parts followed by assembling and FEA of model under different scenario.

The detailed flow chart of the reverse engineering process is mentioned below-



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i.DISASSEMBLING OF BICYCLE:

The bicycle had taken to the bicycle shop for disassembling it. The tools that are used to disassemble are –

A. D/F 12111 Collet/Tip Wrench
B. Long 5/16” Open Ended Wrench
C. Small Narrow Flat Head Screwdriver

The parts from bicycle after disassembling include-

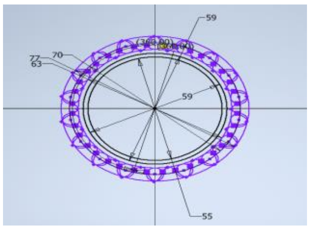
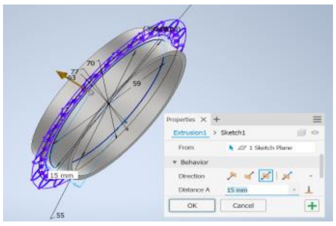
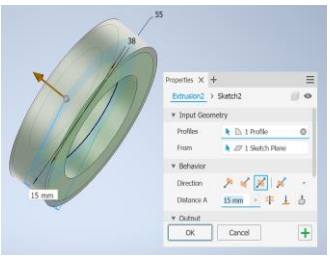
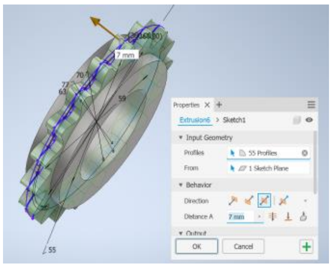
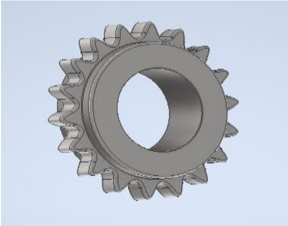
a) Front and back sprocket
b) Chain
c) Frame body
d) Frame bar
e) Handle bar
f) Handle grip
g) Bearing
h) Rim
i) Wheel hub
j) Rubber tyre
k) Crank
l) Pedal with shaft
m) Brake lever
n) Brake pad
o) V brake
p) Axle
q) Seat with clip
r) Nut and bolt

ii.TAKING MEASURMENT

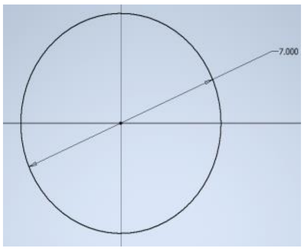
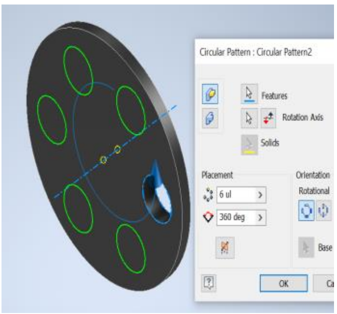
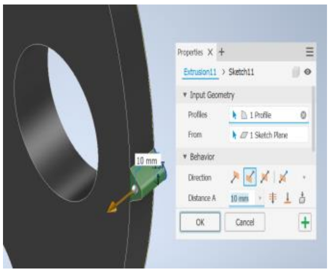
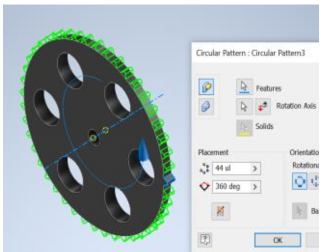
The disassembled parts have been measured using vernier calliper and inch tape. The measurements were recorded and was used for creating the CAD model of bicycle. It had also been documented for further reference or studies.

iii. CREATING CAD MODEL AND ASSEMBLING

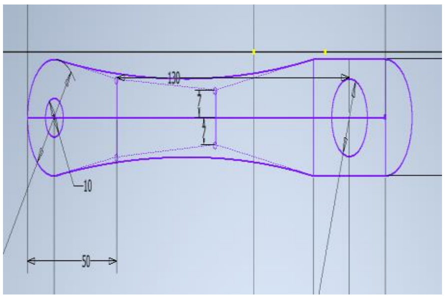
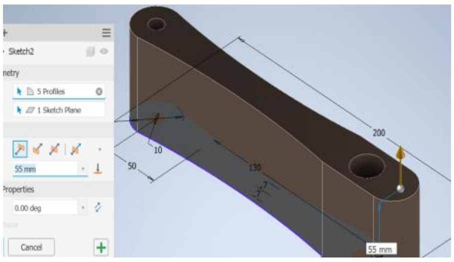
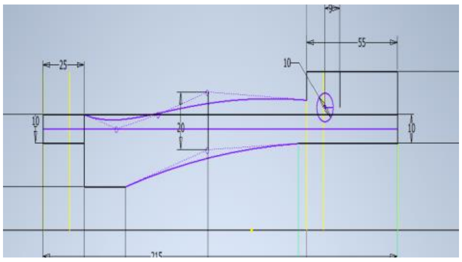
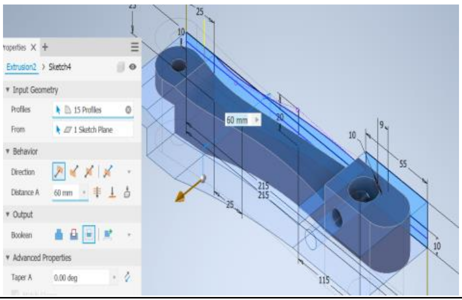
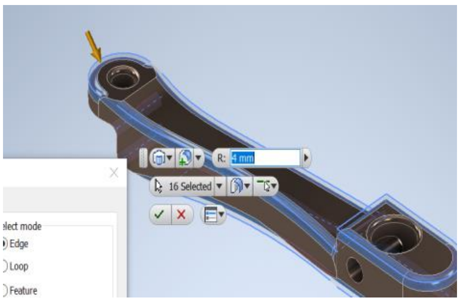
Back sprocket

Creating 2d sketch of sprocket with the given dimensions.	
Making extrusion of inner side	
Creating second extrusion	
Creating extrusion of teeth	
Final model of back sprocket	

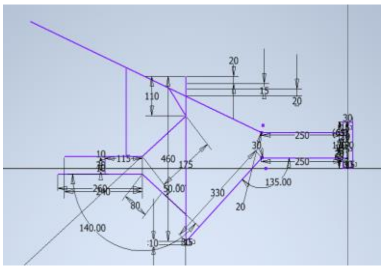
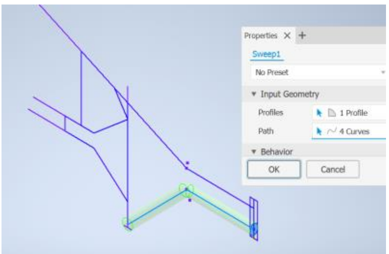
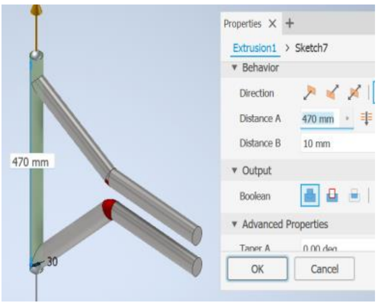
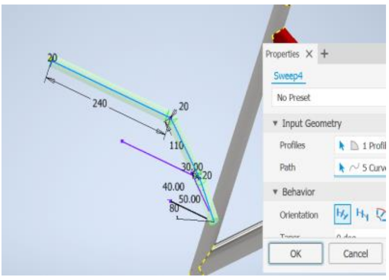
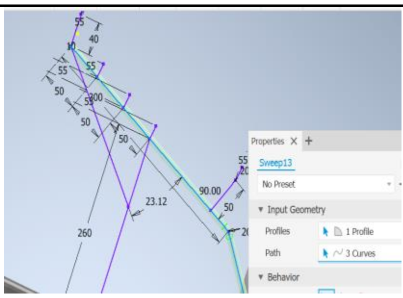
Front sprocket

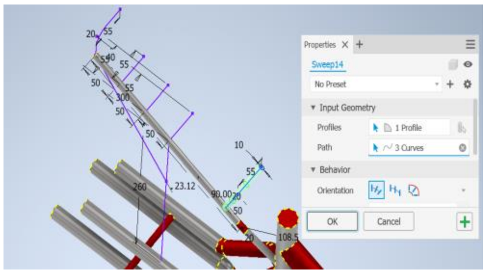
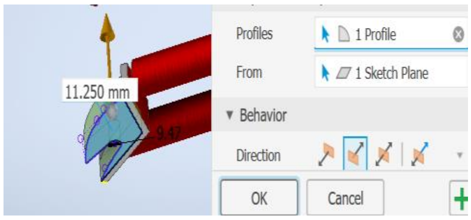
Creating 2D sketch of front sprocket using recorded data and Extruding the sketch	
Making circular pattern and extruding it	
Creating sketches of teeth and extruding it	
Using pattern command to create an extrusion pattern of teeth	
Final model of front sprocket	

Crank

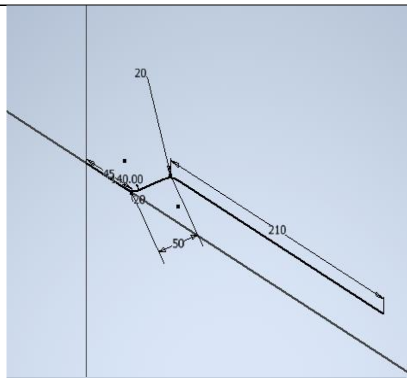
Sketch of crank has been drawn by commands of circle, arc, trim etc	
Extrusion of the sketch has been done.	
Another sketch has been created on side of crank.	
Extrusion of sketch has been done.	
Fillet command has been used .	

Frame

Creating the 2d sketch of bicycle frame.	
With the help of sweep function the frame tube has been created.	
Extrusion has been done	
With the help of sweep function back side tube has been created	
Using sweep function to create a rod on backside	

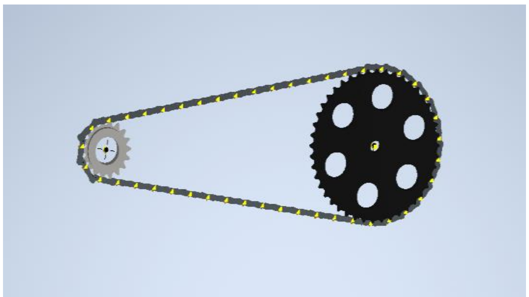
Using sweep function to create the back seat	
Making sketches of rear side	

Handle

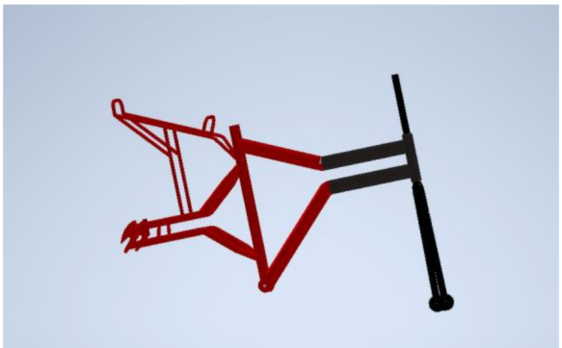
Sketching, sweeping and mirroring of cycle handle	  

Brake assembly

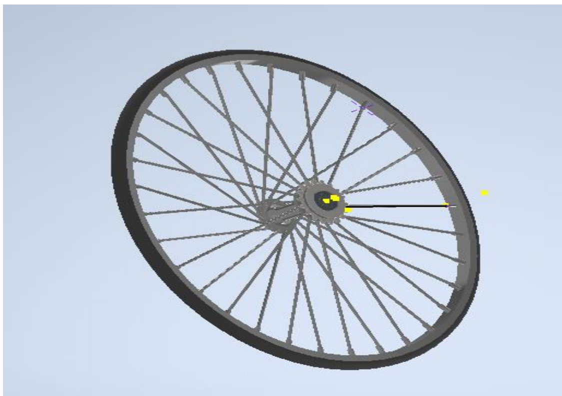
Chain assembly



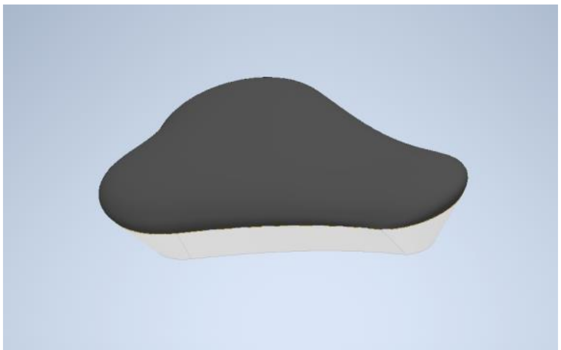
Frame assembly



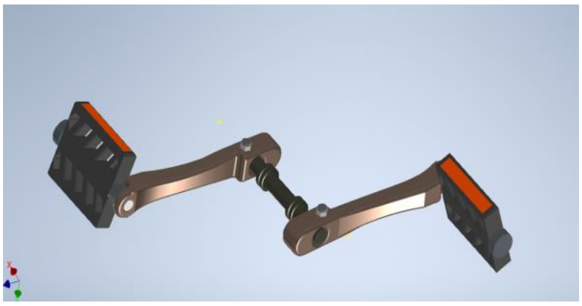
Wheel and rim assembly



Seat



Pedal assembly



Handle assembly

Main assembly

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iv. CALCULATION OF BICYCLE PARTS AT DIFFERENT SCENERIO

Acceleration observed=16m/s^2

Climbing speed obtain =26.3Km/h

Total rolling air resistance=16N

Weight of rider=784.8N ~784N

Weight of bicycle =127.53N~127N

Total opposing motions and weight acting down on climb is 0.1136times the rider weight i.e., 89N

Therefore ,total resistance to motion 89+16=105N

Tractive power =total resistance *forward velocity

=105N*(26.3Km/h)

=105N*7.305N

Tractive power=767N

Size of gear =chain wheel*wheel diameter/18

=54/18*24

=72in

Angular velocity of crank=

forward velocity/effective driving wheel radius

=8rad/sec

=76rev/min

Mean torque= tractive power/angular Velocity

=95.8Nm

Mean torque=π/2*mean torque

=150.48Nm

Crank radius =200mm=0.2m

Pedal force=max torque/crank radius

Pedal force =150.48/0.

Pedal force=752.4N

Average acceleration=2.6m/s^2

Total weight ~910N

Horizontal force at rear wheel=2.6/9.81*pedal force

=2.6/9.81*752

=199.4N~200N

The inertia produced is sufficient so ,choice a higher gear size

Now pedal force=2.75times rider body weight

Pedal force =2156N

For normal speeding ,speed =37km/hr

Total resistance (rolling +aerodynamic)=25N

Power output=drag force * forward velocity

=25*10.33

=258.32N ~260N

Mean crank torque=260/8=32.5N

*When rider is in seating position-

a) Vertical force is maximum
Pedal in horizontal and lever arm is maximum
b) Vertical force is minimum
Pedal in vertical and lever arm is zero

Maximum torque=2*mean torque

=2*32.5

=65N

Maximum pedal force=65/0.2=325N

Measured value L1 = 600 mm, L5= 1050 mm

The rider weighed 784 N and the horizontal force

required to accelerate the rider at 2.6 m/sec^2 was 200 N.

The weight and inertia of the bicycle itself are neglected. These forces are relatively small but could be readily incorporated in the analysis if required. The acceleration is produced by a horizontal force, T of 200 N acting at the rear wheel and this force is transmitted to the rider's body by horizontal forces F3 F4., at the handlebars. Horizontal forces at the pedals are ignored.

Thus, for horizontal equilibrium of the bicycle

$F_3 + F_4 = 200$ N

The vertical reactions at the wheels can be de-ermined by considering the equilibrium of the rider and bicycle together.

$R_1+R_2=784$N

Taking moments about B

$R_1*1050+I*L_5=784*L_1$

Hence $R_1=248$N and $R_2=536$N

Although the riders' centre of gravity was well forward, the horizontal inertia force increased R1, the reaction at the rear wheel, and helped prevent wheel
spin. In this case wheel spin would occur only if the coefficient of friction between the wheel and the ground was less than 175/460 = 0.38.
The effective pedal force calculated previously was 2156 N.

The effective pedal force was taken as a
combination of a vertical push, P,, on the front pedal and a vertical pull, P2, on the rear pedal,
$P_1 + P_2 = 2156$.
Considering vertical equilibrium of the bicycle
$F_1 - F_2 – P_1 + P_2 + R_1 + R_2 = 0$

$P_2 =$ (0.56 times body weight);[5]

$P_1 =$ (2.19 times body weight),[5]

$F_1 - F_2 =$(0.64 times body weight).[5]

(Here P_1,P_2 are pedal forces ;F_1,F_2 are vertical forces on handle bar; F_3, F_4 are horizontal force on handle bar; S_H ,S_V are horizontal and vertical force on saddle)

The vertical forces applied to the two handlebars are not equal. Consider the front view in Fig. . The pedal loads produce a couple which is resisted by the hands. Taking moments about the line of contact of the wheels with the ground,

$F_1 \times L_1 + F_2 \times L_1 = P_1 \times L_9 + P_2 L_{10}$.

1.STANDING PEDALLING

$P_1 = + 1716.96$ N , $P_2 = - 439.04$ N

$S_H = S_V = 0$

$F_1 = + 846$ N , $F_2 = - 345$ N

$F_3 = - 100$ N ,$F_4 = - 100$N

2.CLIMBING

$P_1 = + 1448$ N ,$P_2 = - 367$ N

$S_H = S_V = 0$N

$F_1 = + 741$N ,$F_2 = - 293$N

$F_3 = + 100$N ,$F_4 = + 100$N

3.SEATING PEDALLING

$P_1 = +732$ N ,$P_2 = -54$ N

$S_H = 18$N ; $S_V = 392$N

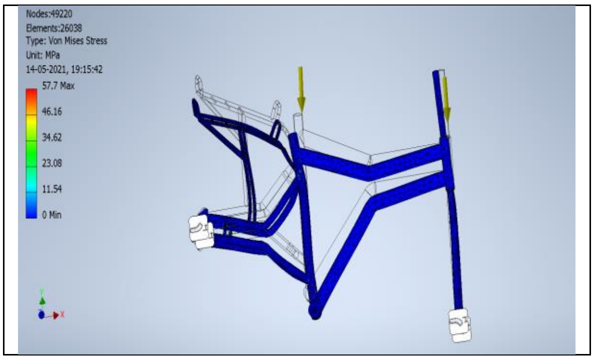
$F_1 = + 235$N , $F_2 = - 181$N

$F_3 = 0$N ,$F_4 = 0$

v. FEA OF MODELS IN DIFFERENT SCENERIO

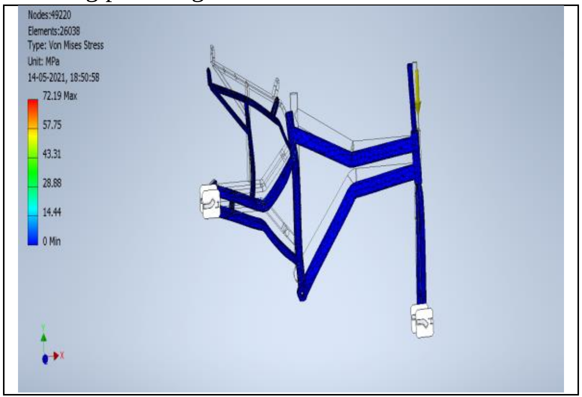
a) Frame

Seating pedalling



Force applied	S_H =18N, S_V =-392N, F_b=-339N F_h=-54N
Max stress	57.7MPa
Max deflection	0.1299mm
Factor of safety	15

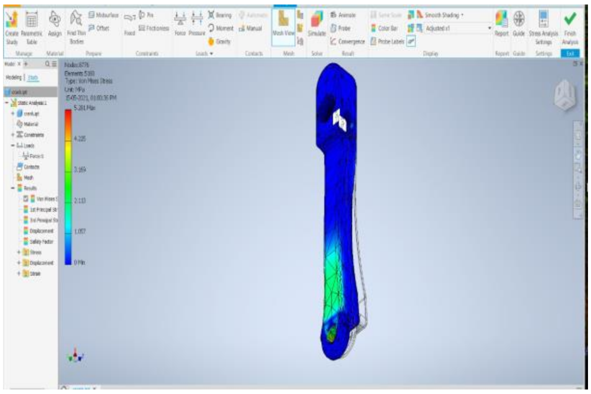
Standing pedalling



Force applied	S_H = S_V =0, F_b=-339N F_h=-54N
Max stress	72.29MPa
Max deflection	0.160mm
Factor of safety	15

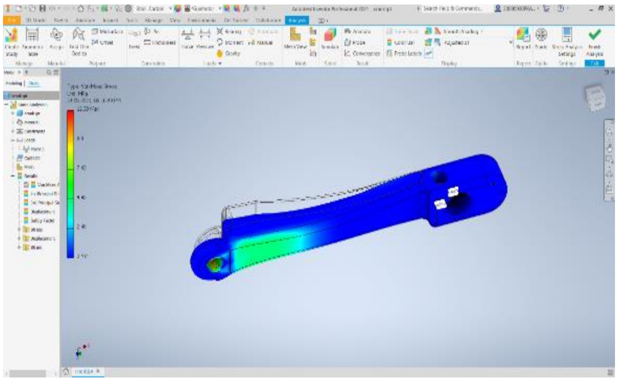
b) Crank

Normal riding



Force applied	366N
Max stress	5.281MPa
Max deflection	0.0023mm
Factor of safety	15

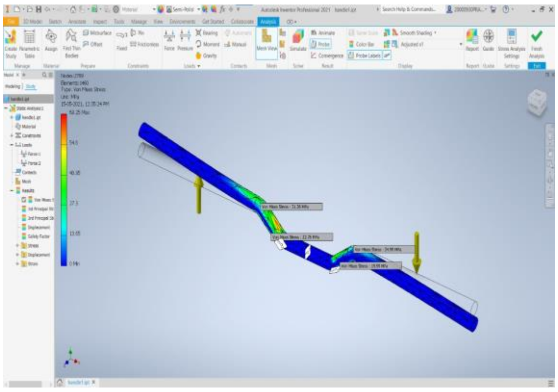
Standing pedalling



Force applied	858N
Max stress	12.38MPa
Max deflection	0.005mm
Factor of safety	15

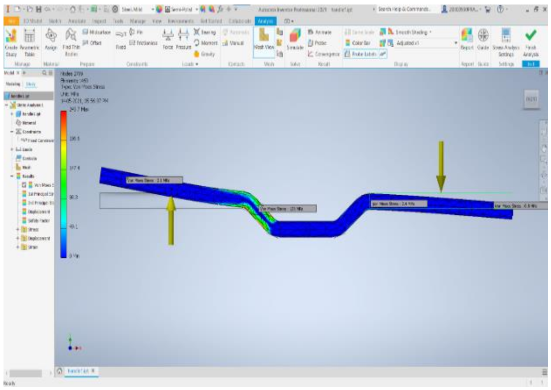
c) Handle

Normal riding



Force applied	+846N,-345N
Max stress	58.25MPa
Max deflection	0.5046mm
Factor of safety	15

Standing pedalling



Force applied	+235N,-181N
Max stress	245.7MPa
Max deflection	1.87mm
Factor of safety	15

IV. RESULTS

Yield strength	Normal riding	Uphill riding	Downhill riding	Standing pedalling
350 MPa	57.7MPa; 5.281MPa; 58.25MPa	12.38MPa	245.7MPa	72.29MPa

The finite element method has been used to measure the stresses and deflections of a bicycle frame caused by loads applied while cycling.

In above comparison more deflection is observed in standing pedalling, uphill riding and downhill riding respectively. This deflection is occurred due to higher stress of models in above conditions. Since the deflections are in mm we aren't able to see them with the naked eye.There may be other riding conditions which produce higher tube stresses than the cases considered here. In particular the influence of dynamic loading due to rough and bumpy roads could be significant.

When we compare yield strength and max stress obtain in bicycle model during FEA we can say that the bicycle is in safe condition but when we observe the breaking point in results we can say that ,the material will start to fracture in these breaking points over a period of time. We can observe the respectively. These factory of safety of bicycle is 15 so the bicycle will experience failure at 15 times the design load.

V. CONCLUSION

The bicycle has been disassembled and measured in a bicycle shop. These measured values have been used to create the CAD model of bicycle parts in AUTODESK INVENTOR. The bicycle models have been assembled on the same software and the whole bicycle has been created. Four loading conditions have been calculated in this project, i.e., normal pedaling, uphill riding, downhill riding and standing pedaling. This calculated value of loading has been imposed on bicycle model using Stress analysis in INVENTOR software. When we examine the results and compare them to the yield strength, we can conclude that the bicycle is safe; however, in the long run, there may have been some fractures, as evidenced by the results. The FEA simulation results show there are still many opportunities for optimization of this bicycle model design with the aim not only of reducing material used but also increasing the life of the bicycle. Optimization is required to reduce the amount of material used in bicycle models, but the importance is that the bicycle remains within a safe tolerance and provides comfort to users.

VI. REFERENCES

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