Designing of All Terrain Vehicle - Quad Bike

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Abstract

ATV stands for all terrain vehicle also known as Quad-Bike. The purpose of designing Quad-Bike was to manufacture an off-road vehicle that could help in transportation in hilly areas, farming field and as a reliable experience for a weekend enthusiast. The software used as per the designing purpose was Catia, Solidworks and Fusion 360. Material used was AISI 1020 steel. The purpose was to successfully modify a 2-wheeler bike (Yamaha RX-100) into a 4-wheeler ATV. The objective of designing a single passenger off-road race vehicle with high safety and low production costs seems to be accomplished. The design was first conceptualized based on personal experiences and intuition.

Keywords: ATV, Quad-Bike, Designing

Introduction

The **All Terrain Vehicle** (**ATV**), also known as a Quad-Bike, three-wheeler, four-wheeler as defined by the American National Standards Institute (ANSI) is a vehicle that travels on low pressure tires, with a seat that is straddled by the operator, along with handlebars for steering control. As the name implies, it is designed to handle a wider variety of terrain than most other vehicles.

By the current ANSI definition, ATVs are intended for use by a single operator, although some companies have developed ATVs intended for use by the operator and one passenger. These ATVs are referred to as tandem ATVs.

The rider sits on and operates these vehicles like a motorcycle, but the extra wheels give more stability at slower speeds. Although equipped with three or four wheels, six-wheel models exist for specialized applications.

The objective of this report is to highlight the design of the Quad-Bike vehicle. We approached our design with a rough 3D sketch of the chassis in Catia and Fusion 360 Cad software, we have created the virtual assembly of our Quad-Bike using SolidWorks and the analysis was done using Fusion 360 simulation software. Based on the analysis the model was retested with boundary conditions under the practical parameters and fabrication of the chassis was done after the design process was completed. So the design and body layout focuses on safety, serviceability, strength, ruggedness, standardization, cost, ergonomics and aesthetics. The design objectives set out to be achieved were three simple goals applied to every component of the bike: durable, lightweight, and high performance, to optimizing the design by avoiding over designing, which would also help in reducing the cost. With this we had a view of our Quad-Bike. Our college has provided us a well equipped laboratory and guided in all aspects. This started our goal and we set up some parameters for our work and distributed ourselves in groups.

Materials and Methods

The metal rod used in the chassis frame was AISI 1020 steel and the dimensions of the rod was 1 inch outer diameter and ¾ inch inner diameter and the sheet metal used in the body design was stainless steel of 2 mm thickness. The material used for the chassis of this Quad-Bike is AISI 1020 steel and the chemical composition is given in Table 1.1. as there is also a seamless bar available of mild steel which is very good for automobile manufacturing though it has good absorbing, vibration, strength and other properties our motive is to minimize the cost of our product as this material is not easily available in our local market for this we have to import this material from other market which is able to increase transportation cost and thus our product cost so we just went for the different material which has similar property which is easily available in our local market at low cost. The Material of AISI 1020 Steel Properties is given in Table 1.2.

TABLE 1.1: Chemical compositions of AISI 1020 steel

Element	Content (%)
Manganese, Mn	0.30-0.60
Carbon, C	0.18-0.23
Sulphur, S	0.05 (max)
Phosphorous, P	0.04 (max)
Iron, Fe	Balance

TABLE 1.2: Material properties of AISI 1020 steel

Properties	Metric
Tensile strength	420 MPa
Yield strength	350 MPa
Modulus of elasticity	205 GPa
Shear modulus (typical for steel)	80 GPa
Poisson's ratio	0.29
Hardness, Brinell	121
Hardness, Rockwell B (converted from Brinell hardness)	68

Specification of the Quad-Bike

Table 1.3: Technical Specification

Description	Specification	Description	Specification
Wheel Base	42 inches	Tire Size	16*3.5(front)16*3.5(rear)
Overall Length	58 inches	Power	8.206 kW@ / 8500 RPM
Overall Height	42 inches	Engine Max Torque	11 Nm
Overall Width	39 inches	Max Speed	50 km/h
Overall Weight	180 kg	Transmission	Four-speed constant mesh, multiplate clutch
Ground Clearance	7 inches	Steering	Ackermann

1 Frame design

1.1 Objective

The chassis is the component in charge of supporting all other vehicle's subsystems with the plus of taking care of the driver safety at all time. The chassis design need to be prepared for impacts created in any certain crash or rollover. It must be strong and durable taking always in account the weight distribution for a better performance. We used AISI 1020 steel for the chassis as it is easily available at low cost.

1.2 Frame Design Considerations:

Table 4: Design consideration during frame design

Consideration	**PRIORITY**	**REASON**
Light-Weight	Essential	A light race Quad-Bike is a fast race Quad-Bike
Durable	Essential	Must not deform during rugged Driving
Meet Requirements	Essential	Must meet requirements to Compete
Simple Frame	High	Majority of frame fabrication was done in The college
Attractive Design	Desired	Easier to sell an aesthetically pleasing vehicle
Cost	Low	Quad-Bike needs to be within budget

1.3 Design and analysis of the frame

For the designing and analysis, we used Fusion 360 software and for the analysis part we provided impact on the front of the chassis.

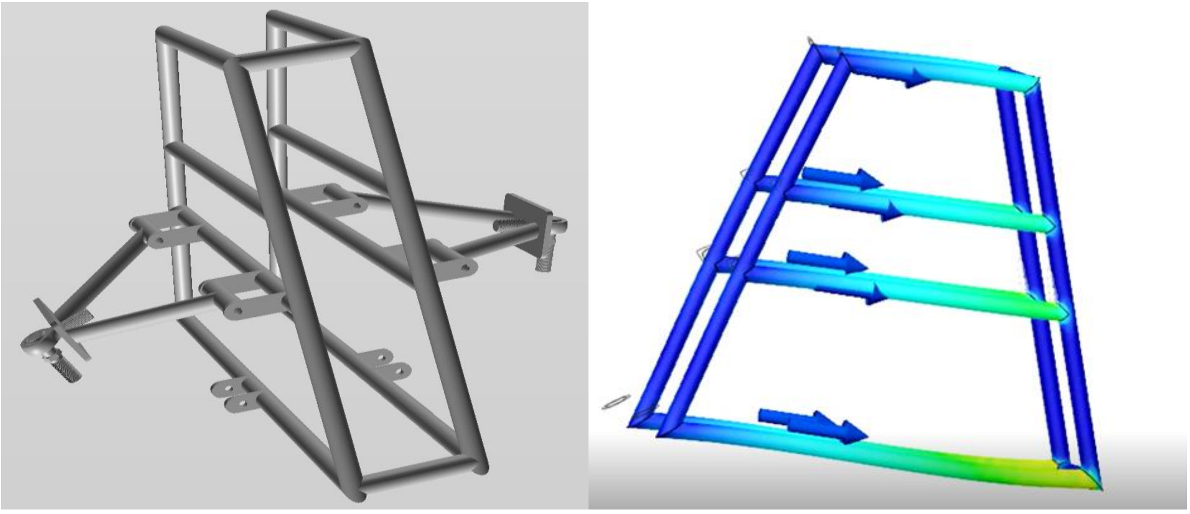

Fig 1: Design and analysis of the chassis

2 Steering system

The steering system is responsible for the overall direction of motion of the vehicle. In accordance to basic automobile rules governing the drive of a two wheeler or a vehicle being driven with a steering, it must be of mechanical links and must not be round or H-type. The steering was of handle type with a bell crank mechanism at the end of the steering column. The steering column or stem was made out of the same material as the rest of the chassis. The tie rods for the steering had knuckle joints to compensate for the suspension jounce, we used Yamaha RX-100 steering system. While designing the steering system the constraints that we possessed were centre alignment of steering system, track width, human effort at the steering wheel. After analysis all these we prefer Yamaha RX-100 steering system.

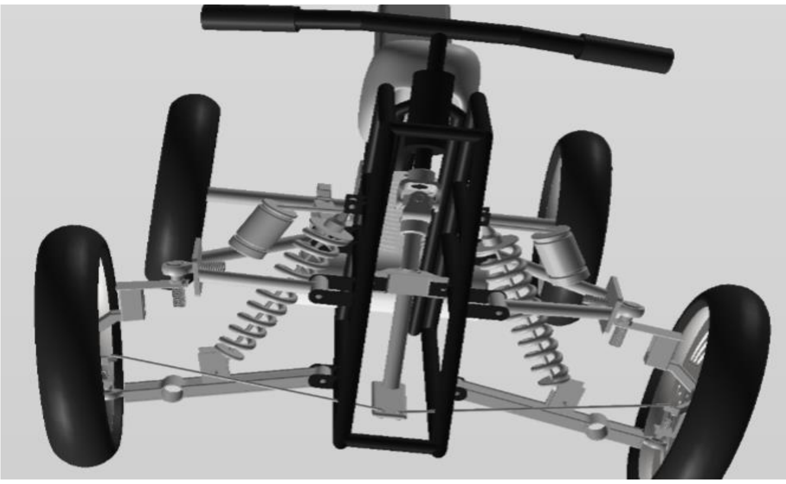

Fig 2: Front view of the design in the Fusion 360 software showing Steering of the Quad-Bike

3 Front suspension

In the front suspension we have used A-arm and TVS Apache suspension, so for the front the A-arm was adjusted on the chassis and then suspension was fitted as per the alignment.

3.1 A-arm

The A-arm get the name because of the shape as the shape of the arm resemblance to a letter A the A-arm was fitted on the chassis and the fabrication of A-arm was done after designing and analysis of the arm on Fusion 360 software. During the analysis part the load was provided on the arm.

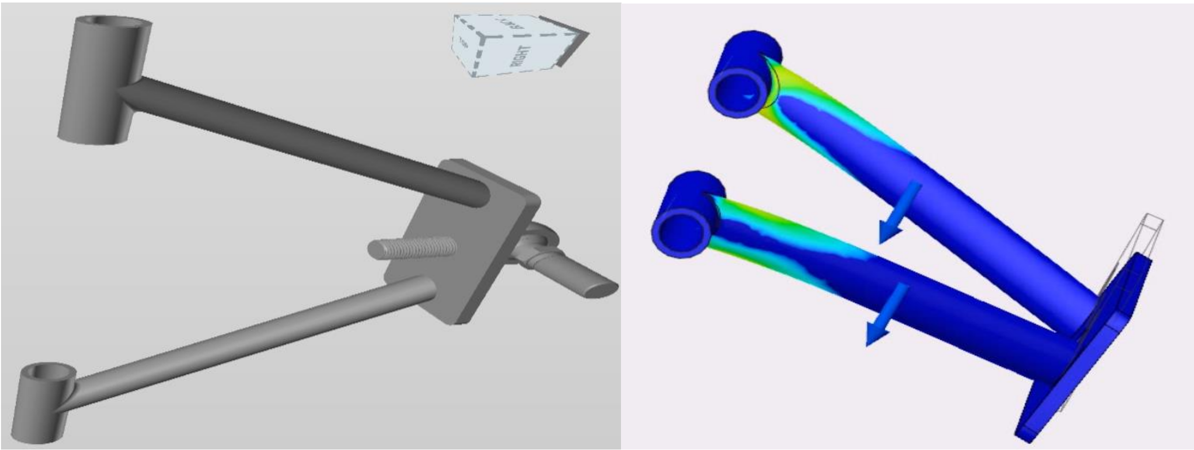

Fig 3: Designing and analysis of the A-arm

3.2 Helical spring suspension

A coil spring, also known as a helical spring, is a mechanical device which is typically used to store energy and subsequently release it, to absorb shock, or to maintain a force between contacting surfaces. They are made of an elastic material formed into the shape of a helix which returns to its natural length when unloaded. We used TVS Apache suspension on the front as it was easily available in low cost.

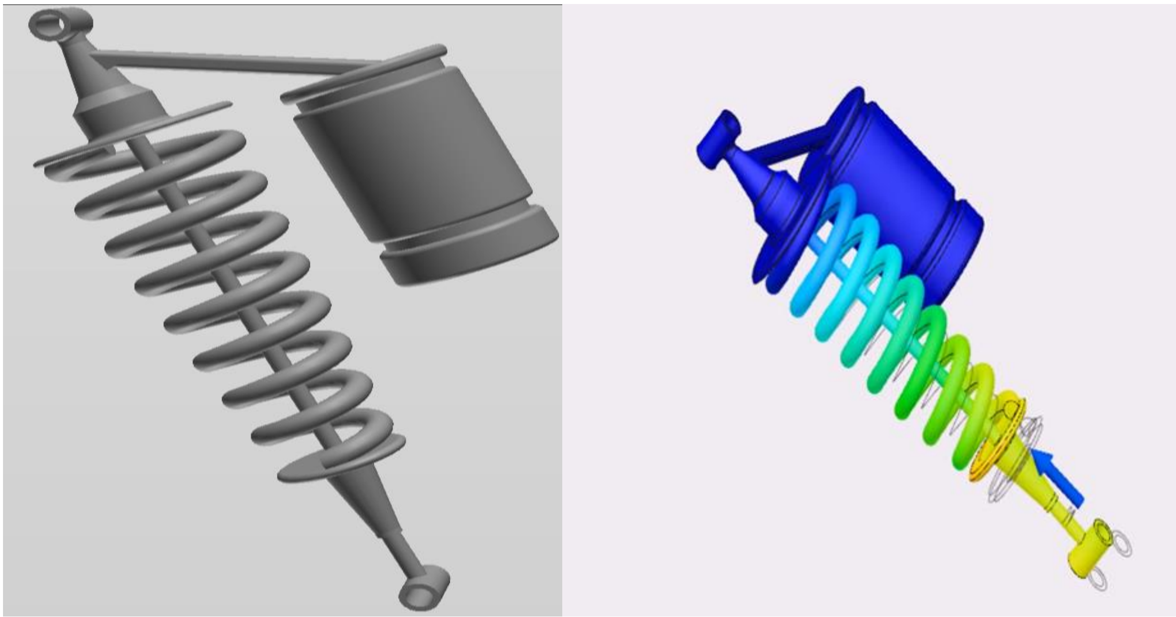

Fig 4: Design and analysis of the helical spring suspension

Fig 5: front suspension with A-arm

4 Rear suspension

In the rear part we used the mono-suspension attached to the swing arm which is being used in Quad-Bikes. For the swing arm we used the Yamaha RX-100 swingarm and for the mono-suspension we used pulsar 200-ns rear suspension as mono suspension. On a Quad-Bike with a mono-shock rear suspension, a single shock absorber connects the rear swingarm to the motorcycle's frame.

4.1 Swingarm

Originally known as a swing fork or pivoted fork, is the main component of the rear suspension of most modern motorcycles and ATVs. It is used to hold the rear axle firmly, while pivoting vertically, to allow the suspension to absorb bumps in the road, the pulsar 200ns suspension's first end was connected on the frame of the Quad-Bike and second end to the swingarm, which provide good comfort in Quad-Bike. Before adjusting on the Quad-Bike we create the proper layout on the CAD software and during analysis part we fixed one end and on other we applied force on the side of the swingarm.

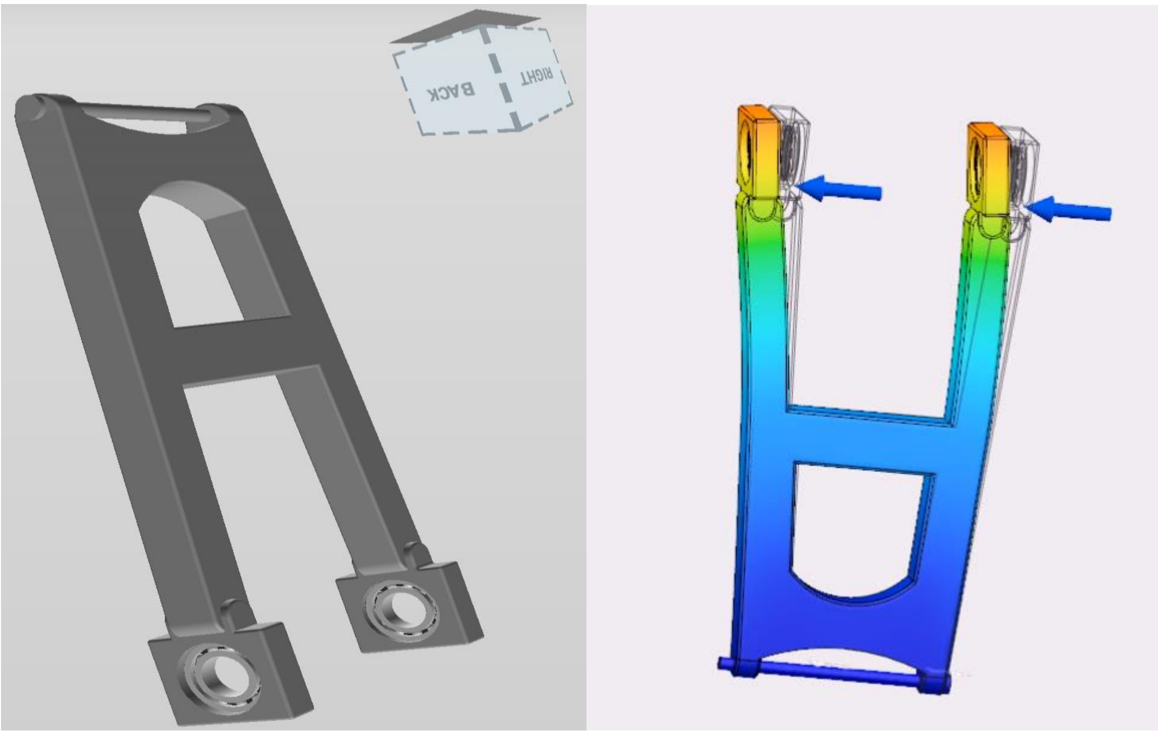

Fig 6: Designed and analysed swingarm on the Fusion 360

Fig 7: Used Rx-100 swingarm on the Quad-Bike

5 Front and rear suspension calculation

In the rear part we used the pulsar 200-NS shock suspension attached to the swing arm. Using this suspension, it covers the dual shocks in the road which is an advantage due to ease of adjustment as there was only single damping unit and smaller unstrung mass. The shock absorber had necessary stiffness needed to swing arm to maintain ground contact as well as simpler in design and had reduced overall weight of the vehicle. And for the front we used TVS Apache suspension.

5.1 Suspension Simulation result and calculation

During the simulation of the spring we have provided the force from one end and put the second end fixed.

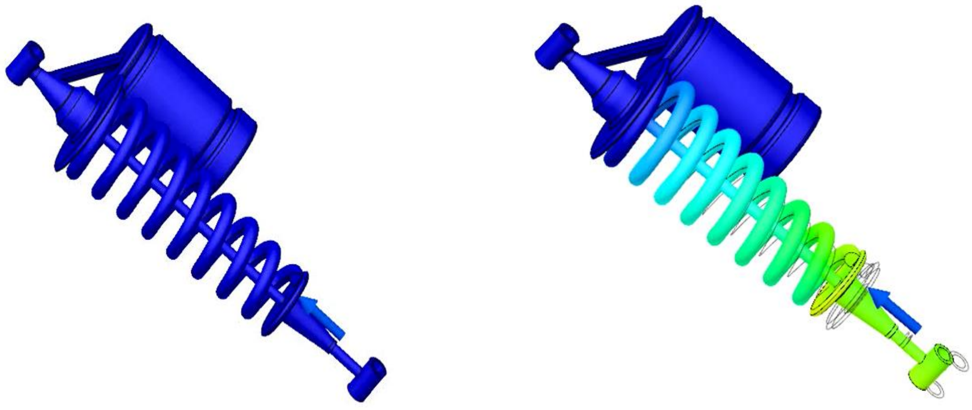

Fig 8: Analysis of suspension

Table 5: Dimension of Front and Rear suspension

Factors	Spring index	WireDia (mm)	Spring OD (mm)	No. of turns	Free length of spring (mm)
FRONT	4.73	13	61.5	18	325
REAR	4.32	18.5	80	10	254.6

5.2 Calculation

Stiffness of the spring (K) = G x d4 / 8 D3 n

Where, G = Modulus of rigidity = 84 GPa

d = Wire diameter in mm

Do = Spring outer Diameter in mm

n = No. of Turns

Spring Force (Fs) = KX

Where, X = Spring Travel

Spring Index (C) = D/d

Ka = 4C-1/4C-4 + 0.615/ c

Front load = 100 kg = 950N (491N for each suspension)

Shear stress τ = ka 8PD/ πd3

τ front = 39.84 N/mm^2 and τ rear = 54.92 N/mm^2

Deflection of the spring, y= 8PD3n/ Gd4

y front = 3.3N/ $mm^2$and y rear = 2.78 N/mm^2

Stiffness, k = Gd4 / 8D3n

k front = 146.04 N/mm and k rear = 528.75 N/mm

Maximum load, y= 8 PD3n/ Gd4

P front = 461.1 kg and P rear = 1471.5 kg

6 Axle

An axle is a central shaft for a rotating wheel or gear. On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to the vehicle, with the wheels rotating around the axle. In the former case, bearings or bushings are provided at the mounting points where the axle is supported. In the latter case, a bearing or bushing sits inside a central hole in the wheel to allow the wheel or gear to rotate around the axle.

The primary purpose of Axle shaft is to act as power transmitting member from final drive to wheels in our Quad-Bike we used the AISI 1040 as it provides great strength on the axle shaft.

6.1 Material considered on the axle shaft

Table 6: Material selection for Axle

Properties	AISI 1020	AISI 4130	AISI 1040
Yield strength	294.74MPa	460 MPa	415MPa
Ultimate strength	394.72MPa	560 MPa	620MPa
Carbon %	0.14-0.24%	0.28-0.33%	0.370-0.440%
Young's Modulus	200 GPa	205 GPa	200GPa
Density	7.87 g/cc	7.85 g/cc	7.84 g/cc

From above table AISI 1040 was selected for axle shaft material.

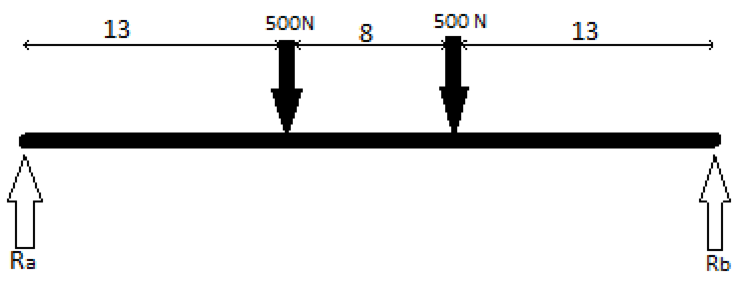

FIG 9: Axle diagram for calculation

The above dimensions are in inches.

6.2 Bmd and Sfd representation of the shaft

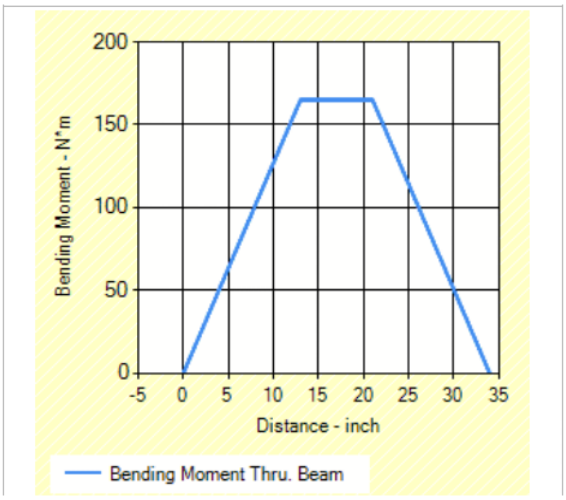

Fig 10: Bmd diagram

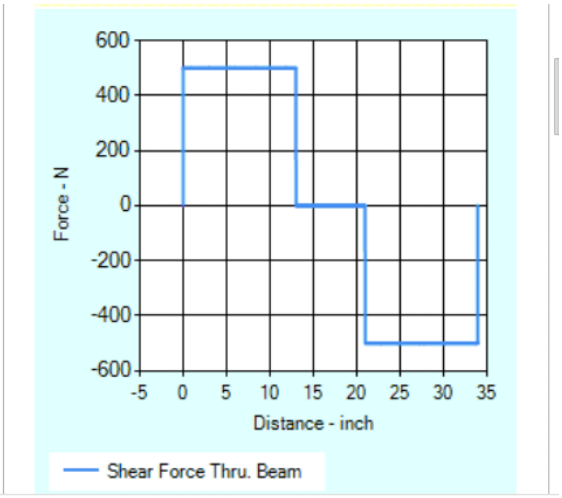

Fig11: Sfd diagram

Mb =165400 N-mm

Power =8.202 KW (from engine specification)

$$power = \frac{2\pi n T}{60}$$

$$M_t = 10500\ Nmm$$

$\sigma_b = 32M_b/\pi d^3$

$\sigma_b = 102.80$ N/mm^2

$$\tau_{max} = \frac{16\sqrt{M_b{}^2 + M_t{}^2}}{\pi d^3}$$

τ_{max}=51.50 N/mm^2

$$\tau = \frac{S_{sy}}{f.s}$$

$S_{sy} = 0.5S_{ut}$

From above equation factor of safety = 4

6.3 AXLE SIMULATION RESULTS

As the load is up lied on the top of the shaft

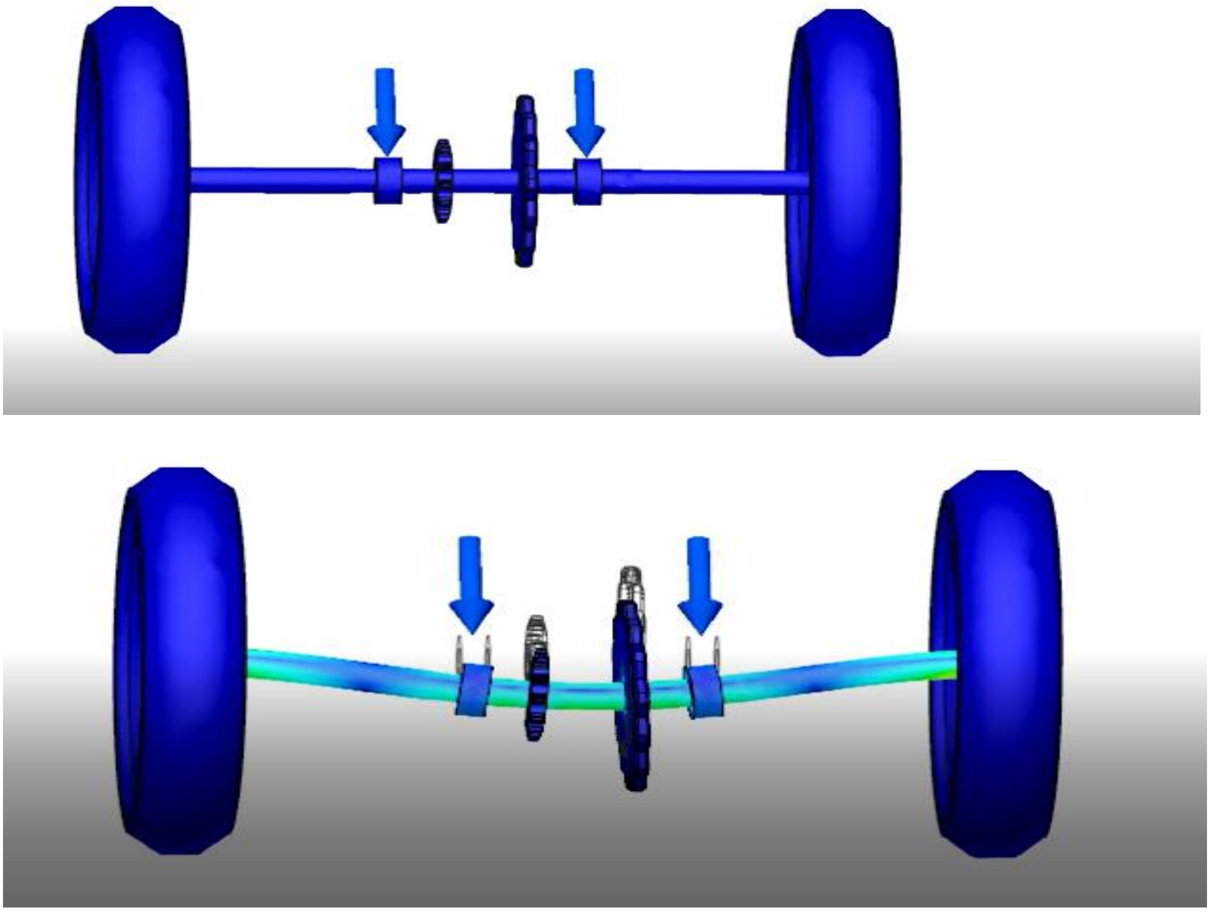

Fig 12: Rear axle

Result and discussion

The design of ATV was completed in the CAD software afterwards, fabrication group by taking the design studied the old two-wheel bike and modified into a 4-wheel Quad-Bike, many trials were conducted and these results were compared to a series of tests collected from the other completed ATV projects. In starting of the project, we faced lots of difficulty as what type of material we must use? What is the design of our Quad-Bike? And what the other feature will be added to it? And we fabricated our Quad-Bike as to carry the same layout and feature as compare to other completed ATV project.

Final CAD model

The CAD model was created in the Fusion 360 software.

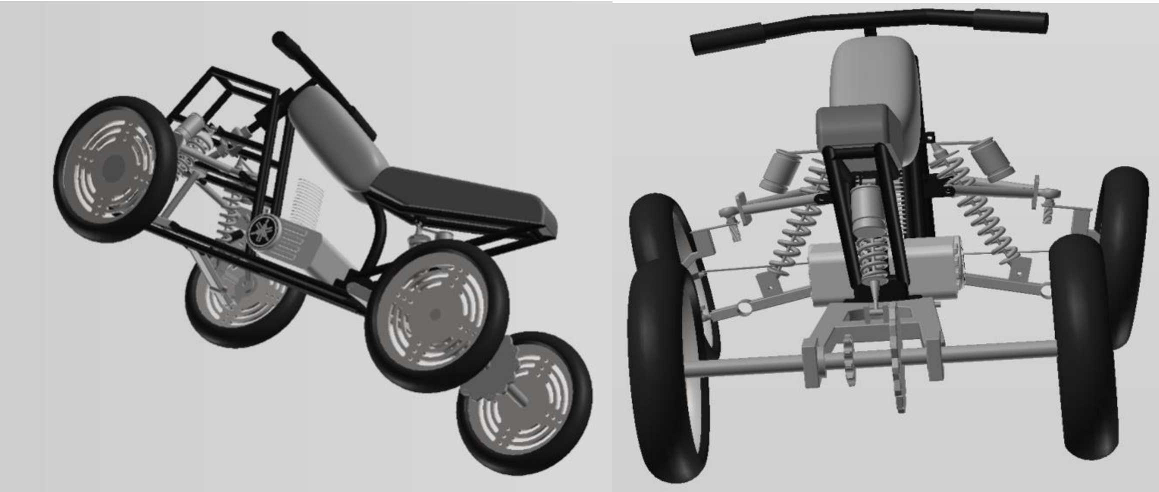

Fig 13: Orthogonal and Rear view in the cad software

Final actual image of the Quad- Bike

Fig 14: Rear view and Side view

Conclusion

The objective of design a single-passenger off-road race vehicle with high safety and costs seems to be accomplished as before working on the project our main motto was to complete the project in low time and minimum production cost. The design was first conceptually based on personal experiences. Engineering principles and design processes were then used to verify and create a vehicle with optimal performance, safety, and ergonomics. The design process included using SolidWorks, Catia, Fusion 360 software packages to model, simulate, and assist in the analysis of the completed vehicle. After initial testing it was seen that our design must improve the design and durability of all the systems on the bike and make any necessary modification.

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