ANALYSIS OF ROLL CAGE AND VARIOUS DESIGN PARAMETRES OF AN ALL TERRAIN VEHICLE (BAJA)

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Abstract

This Design report aims to generate conceptually sound and optimized design analysis of the all-terrain vehicle(ATV). In order to accomplish this task, there is a different designing and analysis can be carried out to enhance the safety of different sub-components of the quad bike like chassis, suspension, steering system, braking etc. It also describes in detail, there is a variety of methodology consideration in the entire design process. These effort have been validate the design by theoretical calculations, simulations are also carried out.

Keywords: *All Terrain Vehicle, Analysis, Chassis, Design, Powertrain*

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1. INTRODUCTION

The objective of this report is to highlight the design report of the all-terrain vehicle(ATV). We approached our design with a rough 2D sketch of the chassis in AutoCAD and we created the virtual assembly of our ATVusing solid works and the analysis was done using ANSYS simulation software. Based on the analysis the model was retested with boundary conditions under the practical parameters. So the design 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, light-weight, 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 ATV. Our college will be providing us a well-equipped laboratory and guided in all aspects. This started our goal and we set up some parameters for our work, distributed ourselves in groups.

2. RELATED WORK

In the design of today's vehicles there is a strong emphasis on reducing the vehicle weight and to lower the aerodynamic drag in order to leave a smaller ecological and economical footprint. This has shown to affect the crosswind sensitivity for ground vehicles, which is of importance for handling and safety [1].Most engines have a single spark plug per cylinder, a notable exception being in aircraft where the complete ignition system is duplicated to improve reliability. The spark usually is provided by a battery and coil, although until the 1920s, a magneto often was used.For a continuously variable transmission (CVT) to produce an improvement in fuel economy, it must be efficient and have a wide span (range of ratios). There are two significant types of CVT-the Van Doorne belt system, and the Torotrak system-both of which have been the subject of much development work [2]. The steering system is a mechanism on a vehicle that serves to regulate the direction of the vehicle by means of deflecting the front wheels [3, 4].It takes an astonishing amount of energy to decelerate a moving vehicle-in fact it takes the same amount of energy to decelerate from one speed to another as it would to accelerate between the two speeds-except that we can decelerate faster because most of the inertial forces are working for us rather than against us [5].

Table 1: Vehicle Specification

Parameters	Values
Overall Length	88”
Overall width	54”
Overall Height	44”
Ground Clearance	14.5”
Wheelbase	55”
C.G. Height	16”
Tube Dimension	25.4mm x 3mm
Total mass	330 kg
Overall Length	88”
Overall width	54”
Overall Height	44”
Ground Clearance	14.5”
Wheelbase	55”
C.G. Height	16”
Tube Dimension	25.4mm x 3mm
Total mass	330 kg

3. CHASSIS

3.1 Material Selection

A good strength material is important in a roll cage because the roll cage needs to absorb as much energy as possible to prevent the roll cage material from fracturing at the time of high impact. This **AISI 4130 STEEL** gains hardness and

strength with heat treatment. This carbon steel is a commonly used plain carbon steel. It has a good combination of strength and ductility.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. The chassis was mainly designed through solid works software.

Fig 1: 3-d model of chassis

Then it is also assured by analysis in solid works software. The various Physical properties of the material are follows

Table 2: Material Properties

S.No	PROPERTIES	VALUES
1	Density	7.87 g/cm3
2	Ultimate Tensile strength	560 MPa
3	Yield strength	350 MPa
4	Modulus of elasticity	210 MPa
5	Shear modulus	80 GPa
6	Poisson's ratio	0.29
7	Elongation at break (in50mm)	21.5%

The material **AISI 4130** with 0.28 to 0.33% of carbon is used in the frame design because of its good weld ability relatively soft and strengthens as well as good manufacturability. The following table shows various chemical composition of the selected material. The below mentioned properties satisfy the technical requirement of material which is to be used in frame.

Table 3: Chemical Composition

S. No.	ELEMENTS	VALUE
01	Carbon, C	0.28 – 0.33%
02	Manganese, Mn	0.40 - 0.60%
03	Silicon, Si	0.15-0.30%
04	Sulphur, S	0.040% (max)
05	Phosphorus, P	0.035% (max)
06	Iron, Fe	97.03-98.22%

The Frame was designed using 1.25 inch diameter tube with a thicker wall of 3 mm is used instead of 1.5 inch diameter tube with a thinner wall for manufacturability purposes. Although the thinner wall, 1.25 inch diameter tube would be slightly lighter than the thicker wall, 1 inch diameter tube, it would have been more material and more difficult to weld. Then it is also assured by analysis in solid works software.

4. SIMULATION & RESULTS

4.1. Frontal Impact

Generally in the case of pure elastic collision in frontal impact the linear velocity remains at 60Kmph according to ENCAP (The European new car assessment program).Hence the value of force is calculated by mass moment equation that is-**$F = P \times \Delta T$**

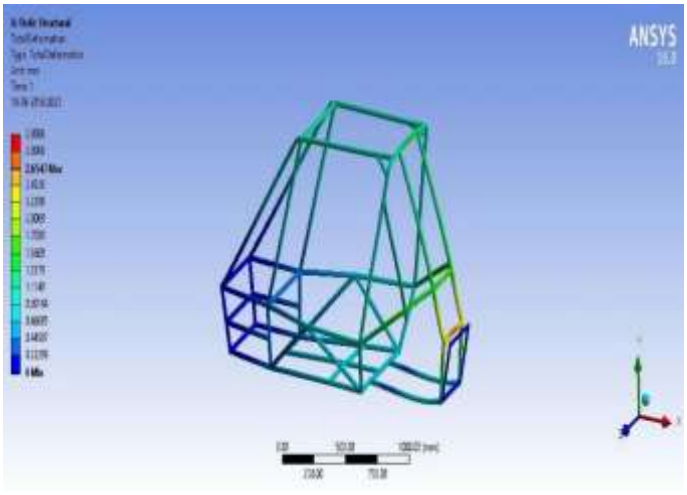

Fig 1: Total Deformation

4.2. Rear Impact

The rear impact force is also calculated in the same way as remaining two. In this case the velocity of collision was taken 72kmph or 20 m/s by the calculations and also as according to the ENCAP standards.

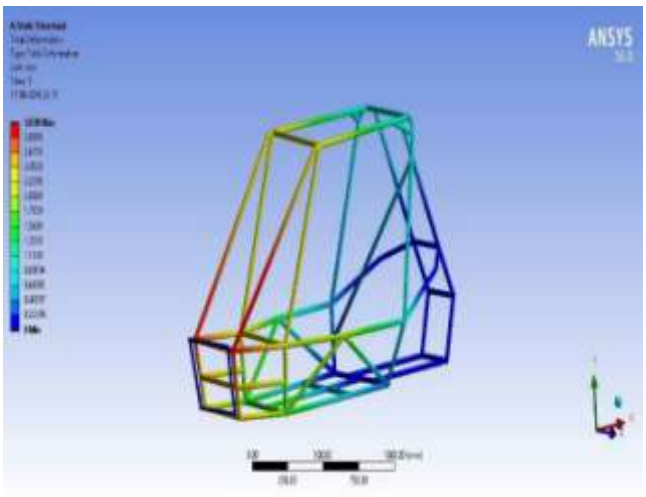

Fig 2: Total Deformation

The following table shows simulation results of various impacts

Table 4: Load & Constraints

	Front Impact	**Side Impact**	**Rear Impact**
Constraints	Front,Rear Suspension Mountings	Opposite SIM Member	Front,Rear Suspension Mountings
Load Given	5G	4G	5G
Max. Deformation	3.08mm	2.87mm	2.65mm

The mass of the vehicle is 330 kg. Generally in the case of pure elastic collision in frontal impact the linear velocity remains at 60Kmph. The collision is assumed to be perfectly plastic.

The following Conditions were followed during analysis:
Mesh Type : Shell
Mesh Size :5mm
Factor of Safety : 4.0
Platform : Ansys 16.0

Note: Design is safe when FOS>2

5. DRIVE TRAIN

5.1 Engine & Transmission

The engine used here isBriggs & Stratton runs cooler and cleaner, delivering more power, smoother operation, longer engine life and improved fuel economy. Excellent performer for mid-duty applications.

Fig 3: B&S Engine

This high quality B&S305cc engine comes from and peak power through its OHV design. It delivers plenty of torque.Dura bore cast iron cylinder sleeve withstands wear and abuse to provide improved oil control and extended life. Gear driven Dura Lube splash lubrication system continuously supply oil to all internal parts magneto electronic ignition system delivers quick and dependable start with no maintenance required. Float feed one start carburetor delivers constant one pull start-ups.

Table 5: Engine Specifications

Parameters	**Values**
Torque	14.5 ft-lbs
Displacement	305cc
No .of cylinder	single
Configuration	horizontal
Technology	OHV
bore	3.12 in
stroke	2.4 in
Engine fuel	Gasoline
Spark plug	RC12YC

6. STEERING & BRAKING SYSTEMS

6.1 Steering Systems

The steering system is the responsible for overall direction of motion of the vehicle.The steering system is designed to withstand the stress of safely maneuvering the vehicle through any type of possible condition at the time of driving. The purpose of the steering system is to provide directional control of the vehicle with minimum input.Simplicity and safety were the main design specifications for the vehicle's steering system.

Table 7: Steering Specifications

Parameters	**Values**
Wheel Base	1397mm
Track Width	1250mm
Steering Ratio	11:1
Inner Angle	36.4 deg
Outer Angle	28 deg
Rack Length	381mm
Rack Mounting Height	83.82mm
Steering Geometry	Ackermann
King Pin Inclination	7 deg
Turning Radius	3m
Caster Angle	5 deg (+ve)
Camber Angle	2 deg (+ve)

6.2 Braking Systems

The purpose of the brakes is to stop the bike safely and effectively. In order to achieve maximum performance from the braking system, the brakes have been designed to lock up all four wheels at the same time. It is desired from a ATV that it should have effective braking capability to negotiate rigid terrains.

Table 8: Steering Specifications

Parameters	**Values**
Master Cylinder	Maruti 800
Caliper	Maruti 800 (Front)
Pedal Ratio	6:1
Pedal Size	7.5"
Braking Torque	70 N-m

Split Type	X-split
Stopping Distance (@60 km/h)	15.5 m
Braking Time	2.3s
Max. Dynamic wt. Front Axle	2275 N
Max. Dynamic wt. Rear Axle	1225 N

7. SUSPENSION

7.1 Objective

Designing a suspension which will influence significantly on comfort, safety and manoeuvrability.Protect the vehicle from damage and wear from force of impact with obstacles (including landing after jumping) Maintaining correct wheel alignment. The overall purpose of a suspension system is to absorb impacts from course irregularities, such as bumps, and distribute that force with the least amount of discomfort to the driver. Proper camber and caster angles of the suspension were applied.

Table 9: Suspension Specifications

Parameters	**Front**	**Rear**
Suspension Type	Double wishbone	Double wishbone
Natural Frequency	2Hz	2.4Hz
Material (wishbone)	AISI 4130	AISI 4130
Roll centre	175mm	197mm
Spring Constant	24 N/mm	32N/mm
Weight Transfer	40%	60%
Static camber	2 deg	
Static Caster	3 deg	
Sprung mass	280 Kg	
Unsprung mass	50 Kg	

8. SUPPORT COMPONENTS AND PARAMETERS

8.1 Body Panels

The purpose of the body is to prevent debris from entering the vehicle, with the intent of protecting the driver and the vehicle's components. The design of the body works has been done in the cad software and the material mild steel with a reduced thickness supporting aerodynamic stability is selected for the body works. The body panels are made out of .080 inch thick mild steel plates. The mild steel material has desirable properties for a body panel. The panels are designed such that they tends to reduce the aerodynamic moments like pitching from front, yawing from side and also helps to create the downward force to which tends to make the good traction of vehicle with the road & also provide the properties necessary to protect the driver and vehicle components from rocks and other debris.

8.2 Tires & Rims

Traction is one of the most important aspects of both steering and getting the power to the ground. The ideal tire has low weight and low internal forces. In addition, it must have strong traction on various surfaces and be capable of providing power while in puddles. After going through the engine, transmission and some basic torque and angular velocity calculations we have finalized the diameter of front tires to 19 inches and the diameter of rear tires to 18 inches which would help us to transmit maximum power. The dimension of Front tires is finalized as 25×10×12 inches and Rear tires 25×10×12. We used ATV tires in our quad bike.The Rims which is made up of Aluminum to minimize the unsprang weight. We choose scooter rims with diameter of all four rims are 8 inches each.

8.3 Ergonomics

The seat in our quad bike is also designed to be very light it is very simple made of plastic material and is attached to the chassis by two points only and can be adjusted in angle of back rest according to the requirement of the drivers comfort the back side angle of the seat is at 180 degrees which is the good position of the drivers body rest according to the ergonomics point of view .the seat implemented in our quad bike provides a good combination of weight reduction and ergonomics. Ergonomically the quad-bike is building up with proper dimensions as given by the rule book. The driver seat is well cushioned. Alignment of the driver seat/driver sitting direction is parallel to vehicle's longitudinal axis.

8.4 Kill Switch

First, the electronics system supports the mandatory safety equipment, specifically the kill switch circuit.The bike's electrical system has been designed around main power buses, each with an independently fused circuit. These buses are for safety kill switch**.** Kill switch is provided in our vehicle as a safety to our driver in a case of emergency. If driver wants to kill the engine or stop the engine in case of emergency so he pushes the kill switch gently and our engine would stop. The electronics are designed so that when the kill switch is depressed, power is disabled on primary ignition coil of engine.

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