DESIGN AND ANALYSIS OF ATV CHASSIS

[1] Chetan N, [1] Darius Chirag, [1] Harshith B R, [1] Akshay Jayaraj, [2]Balaji. S

[1] Under graduate Students, [2]Assistant Professor

[1, 2,] School of Mechanical Engineering,

REVA University, Bengaluru, India.

Abstract : The aim of this study was to deal with designing and analysis of a BAJA ATV (All-Terrain Vehicle) Frame. BAJA is basically an ATV competition where students get to design and develop their own ATV keeping in mind various considerations of design as well as safety. An ATV is designed in order to run on various terrains such as soil, Gravel, pebbles, etc. so due to difficult terrain our main focus was on driver safety and better ergonomics at the same time. As the load acting on the frame is directly proportional to the weight of the frame so we also considered the factor of weight reduction as a key area of focus. In order to meet driver safety and reduce weight proper selection of material was needed to be done. The chassis design will be based on BAJA SAE India 2020 rule book taking safety and other aspects into account. The results from these simulations indicate that the frame is safe enough for the variety of worst-case scenarios tested.

Index Terms **– ATV, Chassis, Design, Ergonomics, Safety.**

I. INTRODUCTION

As per the name an ATV (All-Terrain Vehicle) is designed to run and maneuver on different terrains or in other words we can say that an ATV is designed especially for off-roading purpose. In off-roading conditions, we come across various loads which are finally transmitted to the frame. Frame is most important part of an automobile as all mountings and assemblies are done on frame itself, so it becomes necessary for an ATV frame to sustain both static and dynamic loads. In this study we have put forward a proper methodology for designing and analyzing the frame before the ATV is tested on vigorous terrains and conditions. Various types of frames are used depending on the type of loading which they will undergo, for example a ladder frame is used in heavy commercial vehicles where load has to be transferred from one place to another, similarly there are other types such as monocoque chassis, ULSAB, tubular space frame etc. Among this tubular space frame is one which we have considered for designing our ATV because it provides multi-directional impact safety as well as it is easier in fabrication.

II. LITERATURE REVIEW

D.Nagarjuna et al. [1] –has discussed about the various design considerations taken in account for building a perfect ATV. The loading analysis has been done considering the various parameters. Overall this report has dealt with various load analysis on chassis and optimization has been achieved by reducing the weight of the chassis frame. The usage of finite element analysis was invaluable to the design and analysis of the frame for All Terrain Vehicle. The designing and analysis is a difficult part to carry on as so many tests are needed to be conducted with lot of constraints. The chassis was designed so as the vehicle can withstand all kinds of loads and is capable of moving on terrains like hilly areas, Rocky Mountains etc. This report thoroughly dealt with various load analysis on chassis and optimization has been achieved by reducing the weight of the chassis frame (roll cage).

Hirak Patel et al. [2] – has designed the truck chassis analytically and the weight optimization is done by sensitivity analysis. In sensitivity analysis different cross section are used for stress analysis and we find a 17% weight reduction in the truck chassis. The stress and deformation are also compared for the different cross section.

William B. Riley et al. [3] – has discussed about a variety of issues related to frame and chassis design. A simple mathematical model was developed for comparing the structural stiffness to gain insight into proper design targets for the vehicle structure. The model was constructed on the ANSYS and some experimental methods were presented which best captured the load parts, suspension contributors. The different road loads and deformation modes were considered as well as some generic design targets based on experience and strain gauged suspension links. A simple mathematical model was developed for comparing the structural stiffness to the suspension stiffness to gain insight into proper design targets for the vehicle structure. These charts also aid in visualizing the tradeoff between stiffness and weight the designer must make. With these stiffness targets in mind, a finite element model was constructed for both the frame in isolation as well as the entire chassis/suspension. This model was constructed and analyzed in ANSYS. Finally, some experimental methods were presented with an emphasis on the whole-car torsion procedure. This method best captures load paths, suspension contributions and is easily performed by teams as they prepare for the competition.

Upendra S. Gupta et al. [4] – provides in-detail description of the design considerations, static & dynamic analysis and mathematical data involved in the design of a ATV Vehicle. The focus has been laid on the simplicity of design, high performance, easy maintenance and safety at very reasonable prices. The design and development comprises of material selection, chassis and frame design, cross section determination, determining strength requirements of roll cage, stress analysis and simulations to test the ATV against failure.

Deep Srivastav et al. [5] – the objective of designing a single passenger off-road race vehicle with high safety and low production costs seems to be accomplished. After initial testing it will be seen that our design should improve the durability of all systems on the car and make necessary changes. The objective of designing a single-passenger off-road race vehicle with high safety and low production costs seems to be accomplished. The design is first conceptualized based on personal experiences and intuition. Engineering principles and design processes are then used to verify and create a vehicle with optimal performance, safety, manufacturability, and ergonomics. The design process included using Solid Works, CATIA and ANSYS software packages to model, simulate, and assist in the analysis of the completed vehicle. After initial testing it will be seen that our design should improve the design and durability of all the systems on the car and make any necessary changes up until the leaves for the competition.

Savari Goutham et al. [6] – analysed BAJA SAE chassis using FEA. In this paper analysis on the chassis is carried out in four scenarios they are front impact test, side impact test, roll over test, rear impact test. It explores the ways of designing the roll cage of an all-terrain vehicle and also sheds on possible key points kept in mind for designing. You can also find analysis results in this paper along with their respective results and formulae used. During the static analysis of the roll cage the design of the roll cage was changed several times in order to obtain a higher FOS. A higher value of factor of safety insures the durability of the roll cage in the most extreme conditions and hence makes the roll cage safe in terms of production.

Shubham S. Kapadne et al. [7]- provides the details of design and analysis of ATV Review on Design & Analysis of All Terrain Vehicle Chassis. The designing and analysis is a difficult part to carry on as these tests need to be conducted with a lot of constraints. It has been a challenging task looking at all the time and study constraints available. This report put a time light on all the major work available on the chassis built-up. The main motive as per the objectives that have been achieved are a well-designed structure of chassis that will be optimized on parameters like weight and cost.

Thombre Pradeep et al. [8] –elaborates the design details taken into consideration and depicts the analysis of the process and sound engineering practices executed in the developing of the Electric ATV vehicle aimed at being very simple yet profound. The Roll Cage is designed for safety in various impacts and with good aesthetics, Steering aimed at minimizing turning radius, braking to minimize the braking distance and achieving four brake lock simultaneously, Transmission focusing to obtain intermediate gear ratio change between final drive and motor, maximum gradability, maximum acceleration and reliability, Suspension striving for maximum stability of the vehicle. Ergonomic design is the vital element of vehicle and hence the cost effective design is aimed and driver safety is to be the prime objective.

III. OBJECTIVES

The main purpose of the project work is:

a) To fabricate a ATV Chassis frame that is in compliance the SAE BAJA Rulebook.

b) To achieve compactness and increase the power to weight ratio by reducing the weight of the frame.

c) To select a suitable material which is stiff, light and cost effective.

The objectives of our project work are as follows:

a) To encapsulate all components of the car, including a driver, efficiently and safely.

b) Protect the vehicle from damage and wear from force of impact with obstacles (including landing after jumping).

c) Provide better safety driver.

d) To attain better ergonomics.

e) To reduce bodyweight.

f) To increase overall strength of chassis.

IV. METHODOLOGY

This section discusses how to build a chassis and how to model the chassis as well as the factors considered during the design process. In the field of safety and esthetics, we built the roll cage They are the two variables that matter most to us, and they are therefore of great importance. CAD modeling design of any component comprises of three major principles, Optimization, Safety and Comfort. The main features of chassis are Nodal geometry utilization, Less Weight, Driver Comfort Appropriate Triangulation The major factors considered in designing an ergonomically suited roll cage were, Seat location, Seat inclination, Steering, wheel location, Steering Column location, Design of the foot box area. Mesh size is calculated by checking the mesh independency. It means that there will be negligible changes in accuracy of results on further reduction in mesh size. The analysis will be carried out using progressively reducing elemental sizes. The elemental size having consecutive stress error less than 5% is considered as the optimum size of mesh. It means that any further decrease in size will only negligibly increase the accuracy the accuracy of the results.

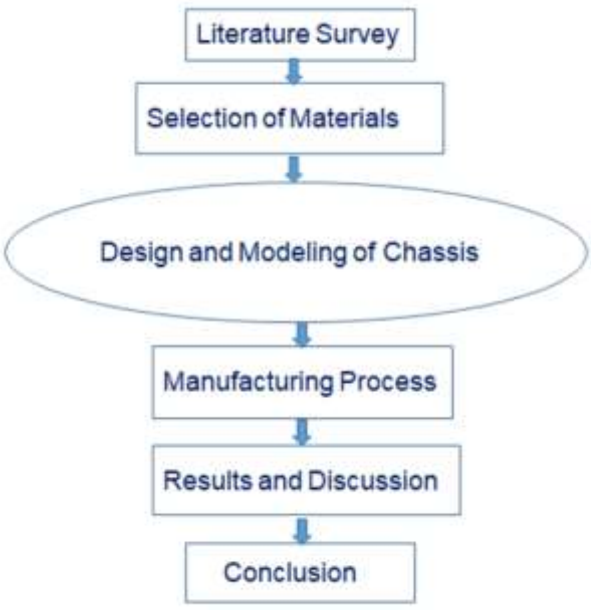

Fig 1: Methodology

4.1 Selection of material

There are a number of materials available in the market which can be used for the material of the roll cage. These include AISI 1018, AISI 1026, AISI 1040 and AISI 4130. The properties for the above materials are mentioned Table 4.1.

We have selected AISI 4130 grade as it has a greater strength to weight ratio. It has good strength, toughness, weldability and machinability. It has good atmospheric corrosion resistance and fatigue strength. AISI 4130 alloy steel contains chromium and molybdenum as strengthening agents. It has low carbon content, and can be welded easily.

Table 1: Material properties of tubes

roperty	AISI 1018	AISI 1026	AISI 1040	AISI 4130
Yield Tensile Strength	370 Mpa	490 Mpa	415 Mpa	440 Mpa
Ultimate Tensile Strength	440 Mpa	490 Mpa	620 Mpa	560 Mpa
Modulus of Elasticity	205 Gpa	210 Gpa	210 Gpa	190 Gpa
Poissions Ratio	0.290	0.300	0.300	0.290

4.2 Design of chassis

The preliminary design of a chassis is made using SOLIDWORKS 3D modelling software.

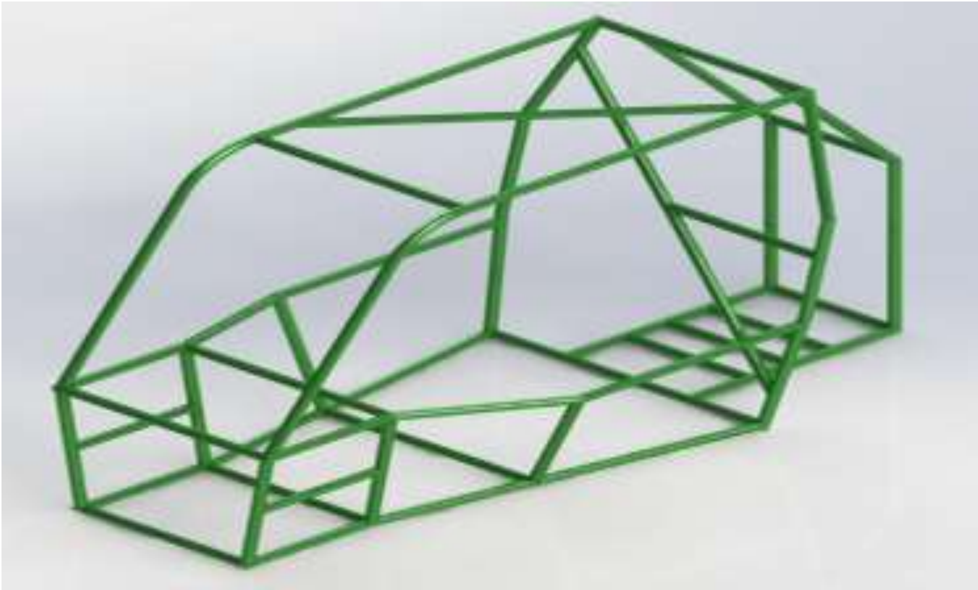

Fig 2: Isometric View of Frame

A custom template of circular cross section for the roll cage member was created as per the design and it was applied to members and chassis structure was made using weldments. The Rear Roll Hoop (RRH) defines the back side of the roll cage, it is a vertical member connected to rear Lateral Cross (LC) members on the top and bottom The RRH is a continuous tube and Lateral Diagonal Bracing (LDB) members are used for providing more support. Two Side Impact Members (SIM) define a horizontal mid-plane within the roll cage. These members are joined to the RRH and extend generally forward Two Lower Frame Side (LFS) members define the lower right and left edges of the roll cage. These members are joined to the bottom of the RRH and are extended forward. The forward ends of the LFS members are joined by the Front LC member. The LFS members are joined by the Under Seat Members (USM) that pass directly below the driver and is positioned in such a way to prevent the driver from passing through the plane of the LFS in the event of seat failure. The Roll Hoop Overhead (RHO) members form the top plane of the roll cage provides safety to the driver in case of roll over. The RHO are made up of two continuous members running from the intersection of front LC till the top of RRH. The lower right and left edges of the roll cage are defined by two Lower Frame Side (LFS) members.

These members are joined to the bottom of the RRH and extend generally forward. Front Bracing Members (FBM) are used to join the RHO, the SIM and the LFS.In the process of developing the chassis frame, a proper design method is employed. As the three-dimensional (3D) drawing is completed, a basic Finite Element Analysis is in progress. The analysis will be done using ANSYS.

It is important that the results of the analysis satisfy the technical requirement of the vehicle. Necessary modifications to the design need to be undergone if the analysis yields negative results.

4.3 Computer Aided Engineering (CAE) process

In this stage, the engineering drawing of the chassis frame is produced. Then, a simple finite element analysis is to be performed to determine the maximum stress and displacement of the chassis frame when a specific load is applied onto it. It is important to ensure that there will be no design failure during operation of the vehicle. If the results of the analysis meet the technical requirement, only then the frame is fabricated. The stress analysis was done under worst case scenarios and maximum forces were applied in the analysis. Adequate factor of safety was ensured for all the components under these worst-case conditions.

There were a few features of the design that might need some additional strengthening. For these reasons it was deemed that there should be an analysis of front impact, side impact, rollover impact, and the loading on the frame from the front shocks. However, before these analyses are performed an examination of the loading forces exerted on the vehicle must be completed. The finite element analysis software program used for this project was ANSYS. Loads are applied on the chassis frame area and the critical stresses that occur due to the load are analyzed. The factor of safety is then calculated using the obtained stress.

Assumptions for impact simulation:

1) The chassis material is considered isotropic and homogeneous

2) Chassis tube joints are assumed to be perfect joints

The Impact forces were calculated using Newton's second law which states that the net force acting on a body is equal to the product of mass and acceleration of the body.

Force= Mass * acceleration

Force= Rate of change of momentum

Impulse= Force * time= Change of momentum = Mass * Change in velocity

Force= M*V / impact time

V. Material Selection

According to SAE International 2021 Collegiate Design Series, Baja SAE® rules, under section B8.3.12 Roll Cage and Bracing Materials "(B) A steel shape with bending stiffness and bending strength exceeding that of circular steel tubing with an outside diameter of 25mm (1 in.) and a wall thickness of 3 mm (0.120 in.). The wall thickness must be at least 1.57 mm (0.062 in.) and the carbon content must be at least 0.18%, regardless of material or section size. The bending stiffness and bending strength must be calculated about a neutral axis that gives the minimum values.

Primary Rollcage member,

- Circular steel tube
- Carbon more than or equal to 0.18%
- Minimum wall thickness 1.57mm
- Bending strength and stiffness more than or equal to that of pipe having carbon 0.18%

Cross Section Selection Criteria,

Sb, Bending Strength = (δy * I)/C

δy = Yield Strength

C = Distance from neutral axis to extreme fiber

Kb, Bending stiffness = E * I

E - Modulus of elasticity (205 GPa for all steels)

I - Second moment of area for the structural cross section

Assumptions:

1) The material considered is AISI 4130 chromoly steel with yield strength of 460 MPa.
2) Tubes in same plane have same cross section considering fabrication and assembly feasibility
3) Cross members were placed from the available reference model
4) Tubes symmetric about XZ plane have same cross section
5) Gross Vehicle Mass was assumed to be 218 kg

Table 2: Comparison of Material Properties

Properties \ Material	AISI 1018	AISI 4130
Carbon Content	**0.18 %**	**0.28-0.33 %**
Yield Strength (MPa)	**365**	**435**
Young's Modulus (GPa)	**205**	**205**

Density (kg/m^3)	**7850**	**7850**
Outer Diameter (mm)	**25.4**	**31.75**
Wall Thickness (mm)	**3**	**1.6**
Bending Strength (Nm)	**387.378**	**473.19**
Bending Stiffness (Nm^2)	**2763.12**	**3540.11**
Weight / Unit Length (kg/m)	**1.65**	**1.18**

5.2 Finite Element Analysis

Assumptions

- Roll cage is deformable body
- Impact time in case of deformable body is taken as 0.30seconds
- Impact time in case of r=rigid body is taken as 0.13seconds

5.2.1 Front Impact

The Load required for frontal impact is obtained by creating a scenario where the car is moving at a top speed of 60 kmph undergoing a head on collision with rigid body. The mass of the car including the driver is assumed to be 300kg. The various loads are calculated using basic mechanics.

During front impact analysis front impact forces are considered with the help of Newton's 2nd law. We applied the calculated force to the front impact protection member of the chassis (Front part of bulk head) while applying the boundary conditions and considered the translation and rotation of all suspension mounts is locked when impact.

5.2.2 Rear Impact

This analysis is done to simulate those conditions when another ATV is going to hit ATV on its rear part. Under such conditions, the number of forces generated reacts at the rear most portion of vehicle. The Load required for rear impact is obtained by creating a scenario where the car is moving at a top speed of 40 kmph undergoing a head on collision with rigid body. The mass of the car including the driver is assumed to be 300kg. The various loads are calculated using basic mechanics.

For analysis, ATV is considered to be in static state and force corresponding to velocity 60 Km/hr. with the impact time 0.3 seconds is applied to the rear part of the roll cage of ATV keeping front suspension mounting to be fixed.

5.2.3 Roll over Impact

The SAE Baja car is designed for off-road rough terrain. The chances of the car rolling over is high when it encounters hills or valleys. Therefore, the car has to be designed taking care of the safety of the driver, addressing all the possible situations of danger. The Roll-over Impact analysis is performed to design the roll-cage for maximum safety during the roll-over incidents.

For analysis, ATV is considered to be in static state the force corresponding to the calculated velocity of 15 Km/hr for the corresponding height with the impact time of 0.13 seconds is applied to the top of the roll cage of the ATV keeping front and rear suspension mounting to be fixed.

5.2.4 Side Impact

This analysis is done to simulate those conditions when another ATV is going to hit ATV on lateral sides. Under such conditions, the number of forces generated reacts at side portion of vehicle. The Load required for side impact is obtained by creating a scenario where the car is moving at a top speed of 40 kmph undergoing a collision with rigid body. The mass of the car including the driver is assumed to be 300kg. The various loads are calculated using basic mechanics. In case of Side Impact, the opposite pickup points to which the load of 1.8G is applied are fixed and load is applied at the most protruding node of Side Impact member (SIM).

5.3 Factor of Safety

Appropriate design factors are based on several considerations, such as the accuracy of predictions on the imposed loads, strength, wear estimates, and the environmental effects to which the product will be exposed in service; the consequences of engineering failure; and the cost of over-engineering the component to achieve that factor of safety. For example, components whose failure could result in substantial financial loss, serious injury, or death may use a safety factor of four or higher (often ten). Non-critical components generally might have a design factor of two. Risk analysis, failure mode and effects analysis, and other tools are commonly used. Design factors for specific applications are often mandated by law, policy, or industry standards. Now we will be analyzing the Factor of Safety of the material, FOS helps us in ensuring that the design will be safe for the use. To validate the design, a simple test was simulated to show the stress distribution and yield safety factor.

Mathematically,

FOS = σ_y / σ_{max}

Where,

σ_y - yield stress of material

σ_{max} -maximum induced stress

The maximum stress values of various impact tests have been determined and we can easily find the factor of safety of the vehicle. Safety is of utmost concern in every respect; for the driver, crew & environment. Considerable factor of safety (FOS) or design factors is applied to the roll cage design to minimize the risk of failure & possible resulting injury. This FOS value implies the safe value of applied loads and deformations. The following table shows the various loading conditions, deformations, maximum stress values and factor of safety for various test conditions:

Table 3: Factory of Safety

IMPACT	MAXIMUM STRESS (MPa)	TOTAL DEFORMATION (mm)	FOS
Front	300.76	2.53	1.4
Rear	224.65	1.15	1.9
Side	425.7	9.27	1.02
Roll Over	152.51	2.02	2.85

VI RESULTS & DISCUSSIONS:

In a surface vehicle, ergonomics comes into picture with 5 aspects that are to be concentrated upon:

1. Safety
2. Comfort
3. Ease of use
4. Productivity
5. Aesthetics

It is important that the driver be comfortable for the endurance race in which he is to drive the vehicle for a time length of continuous 4 hours and thus from this point of consideration for ATV of BAJA SAE, the comfort and safety of the driver are vital in order to reduce the fatigue of the driver and hence increase his efficiency. The emphasis is on the driver comfort and driver vision taking the rulebook constraints into consideration. There is sufficient distance between brake pedal and accelerator for comfortable positioning of both shoe on pedal. There is bracing provided as a support to change position while sitting and prevention from fatigue due to constraint. The mannequin was most comfortably placed and different clearances from mannequin, its visibility, knee pivot and ankle angle were measured.

Fig. 3 Ergonomic consideration for roll cage

The cockpit was designed to protect the driver and permit easy egress in an emergency. The visibility of mannequin after placing comfortably on the seat was checked. The kill switch is in the visibility of the driver.

Ergonomics required as per the requirements of the competition -

- ➢ Strictly as per BAJASAEINDIA 2020 Rule Book.
- ➢ Spacious enough to accommodate 6'3" tall driver.
- ➢ Comfortable driving position and enough space.
- ➢ Designed to minimize the air drag.
- ➢ Easy entrance and exit for the driver.
- ➢ Proper mountings for safety harness belt, shockers, wishbones, steering, rear compartments for engine and motor.
- ➢ Proper positioning of steering wheel, making 90 deg. elbow.
- ➢ Proper positioning of seat and paddle assembly, making knees bend at 120 deg., as in rallies.

Table 4: Ergonomic Parameters

PARAMETER	STANDARD RANGE	DESIGNED
Angle of elbows	125^o - 140^o	128^o
Angle of knee	120^o - 150^o	125^o
Angle of back	8^o - 15^o	12^o
Steering wheel diameter (mm)		280
Angle of steering wheel	40^o - 50^o	43^o

5.5 Calculations

Common Considerations

Weight = 218 kg (kerb weight); Weight with driver (M) = 300 kg

Front Impact

Speed of vehicle = 60 Km/hr = 16.67 m/sec;

Initial Velocity (V_{if}) = 16.67 m/s; Final Velocity (V_{ff}) = 0 m/s; Time (t) = 0.30 sec

From work energy principle, Work done = change in Kinetic energy

$W = [½ * M * (V_{ff})^2 - ½ * M * (V_{if})^2]$

$W = [½ * 300 * (0)^2 - ½ * 300 * (16.67)^2] = 41683.33$ Nm

Displacement (s) = Velocity (v) * Time (t)

$s = (V_{ff} * t) = 16.67 * 0.3 = 5.001$ m

F = W/s = 41683.33/5.001 = 8335 N = 8335 / (300 * 9.81) = 2.83 G

Rear Impact

Speed of vehicle = 40km/hr = 11.11m/sec

Initial Velocity (V_{ir})= 11.11m/sec; Final Velocity (V_{fr}) = 0m/sec; Time (t) = 0.3sec

W= $[½ * M * (V_{fr})^2 - ½ * M * (V_{ir})^2]$ = $[½ * 300 * (0)^2 - ½ *300 * (11.11^2)]$ = 18514.815 Nm

Displacement (s) = Velocity (v) * Time (t)

s = V_{fr} * t = 11.11 * 0.3 = 3.33 m

F = W/S = 18514.815/3.35 = 5560.004 N

= 5560.004 / (300 * 9.81) = 1.889 G

Roll Over Impact

Speed of vehicle = 15 km/hr = 4.16m/sec

Initial Velocity (V_{iro})= 4.16 m/sec; Final Velocity (V_{fro}) = 0 m/sec; Time (t) = 0.13sec

W= $[½ * M * (V_{fro})^2 - ½ * M * (V_{iro})^2]$ = $[½ * 300 * (0)^2 - ½ *300 * (4.16^2)]$ = 2595.74 Nm

Displacement (s) = Velocity (v) * Time (t)

s = V_{fro} * t = 4.16 * 0.13 = 0.5408 m

F = W/S = 2595.74/0.5408 = 4800 N = 4800 / (300 * 9.81) = 1.63 G

Side Impact

Speed of vehicle = 40km/hr = 11.11m/sec

Initial Velocity (V_{is})= 11.11m/sec; Final Velocity (V_{fs}) = 0m/sec; Time (t) = 0.3sec

W= $[½ * M * (V_{fs})^2 - ½ * M * (V_{is})^2]$ = $[½ * 300 * (0)^2 - ½ *300 * (11.11^2)]$ = 18514.815 Nm

Displacement (s) = Velocity (v) * Time (t)

s = V_{fs} * t = 11.11 * 0.3 = 3.33 m

F = W/S = 18514.815/3.35 = 5560.004 N = 5560.004 / (300 * 9.81)

VII. CONCLUSIONS

The objective of designing a single-passenger off-road race vehicle with high safety and low production costs seems to be accomplished. The design is first conceptualized based on personal experiences and intuition. Engineering principles and design processes are then used to verify and create a vehicle with optimal performance, safety, manufacturability, and ergonomics. The design process included using Solid Works and ANSYS software packages to model, simulate, and assist in the analysis of the completed vehicle. After initial testing it will be seen that our design should improve the design and durability of all the systems on the car and make any necessary changes up until the leaves for the competition.

REFERENCES

1. D.Nagarjuna; J. M. Farooq; A.S.N. Saiteja; P. S. S. Teja, Optimization of Chassis of an All-Terrain Vehicle, International Journal of Innovative Technology and Exploring Engineering, Vol. 2, (2) (2013) 55-57.
2. Hirak Patel, Khushbu C. Panchal, Chetan S. Jadav, “Structural Analysis of Truck Chassis Frame and Design Optimization for Weight Reduction”, International Journal of Engineering and Advanced Technology(IJEAT) ISSN: 2249-8958, Vol 2, Issue 4, April 2013, pp. 665-668.
3. William B. Riley and Albert R. George, “Design, analysis and testing of a SAE car Chassis”, SAE Technical paper series 2002-01-3300, 2 December 2002.
4. Upendra S. Gupta, Sumit Chandak, Devashish Dixit, “Design & Manufacturing of All Terrain Vehicle (ATV)- Selection, Modification, Static & Dynamic Analysis of ATV Vehicle”, International Journal of Engineering Trends and Technology (IJETT), Vol 20 Number 3, Feb 2015, pp. 131-138.
5. Deep Shrivastav, “Designing of All Terrain Vehicle(ATV)”, International Journal of Scientific and Research Publications, Vol 4, Issue 12, December 2014, pp 1-16.
6. Savari Goutham, Arun Raj Dandothkar, “Design and Optimization of BAJA ATV Chassis”, pp 1-5.

7. Shubham S. Kapadne, Ajay S. Anap, Nikhil K. Jagdale, Aditya B. Bhutada, Subhash N. Khetre, “A Review on Design & Analysis of All Terrain Vehicle Chassis”, 06 Dec 2019.
8. Thombre Pradeep, Tambe Shubham, Sutkar Shubham, Tapare Bhushan, “Design of electric ATV”, 08 March 2019.