Design and Analysis of a Single Seater BAJA ATV (All-Terrain Vehicle)

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Abstract- *The most crucial thing about designing an all-terrain vehicle is its capability to traverse over difficult undulated terrain. BAJA SAE gives us this exact opportunity to build our own buggy and race it against other collegiate teams throughout the nation. We designed a buggy using various software's like SOLIDWORKS, ANSYS, MATLAB and LOTUS. After deciding its blueprint, we manufactured it in house without any external help. This reflects in the main aspect of the event that is learning. We as a member of student team learned immensely in the fields of designing and manufacturing a buggy along with the finance required for completing this project. This helped us face real world problems and us overcome them in a cumulative fashion as one unit. This design document consists of an overview of the various sub systems in the buggy and their performance.*

Key Words: **BAJA SAE, Design, Manufacturing**

INTRODUCTION

The primary goal of this project is the scope of learning that the event gives us the students. Along with this it was to build a single seat ATV which should be rugged, reliable, ergonomically and most importantly economical. This was aimed to serve a recreational user market, sized at 4000 units per year. This vehicle should aspire to market-leading performance in terms of speed, handling, ride and tough off road conditions.

Roll cage

Objectives

- The roll cage/chassis houses the various subsystems of the vehicle and is the main supporting structure to which all the other components are attached.
- It should ensure driver safety in cases such as crash or rollover.
- It should be stiff enough to compensate for the load transfer during cornering and other dynamic scenarios.

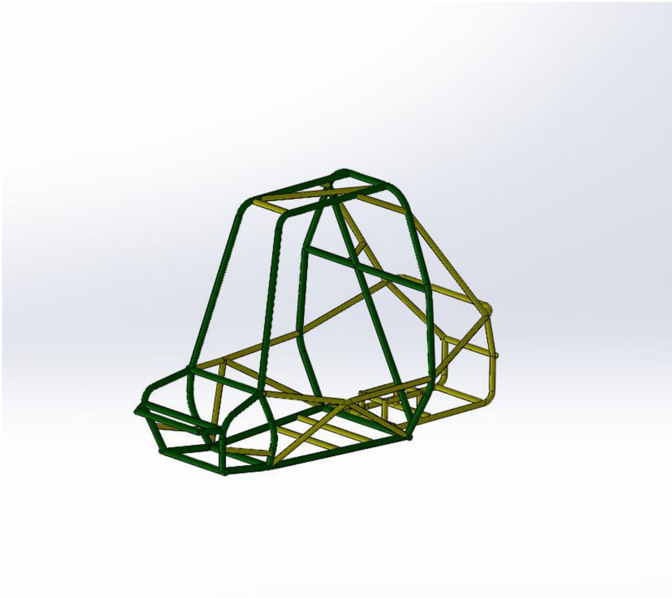

Fig. 1 Roll cage isometric view

Roll cage design methodology

Key aspects taken into consideration while designing the roll cage were

- Driver safety
- Suspension loading points
- Drive train integration
- Structural Rigidity
- Ergonomics and Aesthetic.
- Material Selection

A study was done to determine the ideal chassis material taking into consideration factors like tensile strength, bending stiffness etc. AISI 4130 was chosen for its high strength-to-weight ratio and also high Tensile strength and Yield strength. The material further undergoes heat treatment which improves its fatigue life and machinability.

Material properties AISI 1018 vs. AISI 4130

Property	AISI 1018	AISI 4130
Yield Strength (MPa)	370	460
Tensile Strength (MPa)	430	560
Strength-to-Weight Ratio (kN-m/kg)	54-60	71-130
Bending Moment (N-m)	387.3	808.77
Bending Stiffness (N-m^2)	2763.12	3633.29
Elongation (%)	15.0	20.5

A comparative study has been shown to highlight the differences between AISI 4130 and AISI 1018 (a material quite commonly used for frame design).

Welding

MIG welding was used to weld the Chromoly members together, it was done to retain the heat treatment was done on the tubes previously. Which isn’t possible with arc welding, which creates a large heat affected zone. Another advantage with MIG welding is it reduces splatter due to inert gas. The shields the weld, creating a clean weld bead.

Finite Element Analysis

Analysis of the chassis was done on ANSYS 17 using the coordinates obtained from SOLIDWORKS 2017

Various scenarios such as front impact, side impact etc. was taken into consideration. An example of force calculation method and justification has been shown

Case: Front Impact

The front impact scenario considers two vehicles travelling towards each other having a head-on collision and then coming to a stop. In an event scenario, the vehicles top-out at 40 km/hr, so this was taken as the maximum speed and both vehicles weighed 250 kg (laden weight of our vehicle). Impact time was set at 0.2 seconds after cross-referencing with various research papers.

Maximum Speed: 40km/hr (11.11 m/sec)

Impact Time: 0.2 sec

Mass of vehicle: 250 kg

Force= Mass * (Change in velocity/Impact time)

$= M*(Vrelative/\Delta t)$

$= 250 * ((22.22-0)/0.2)$

$= 27750$ N

Similarly, other forces were calculated and the FEA analysis was completed.

- **Rear Impact**: Stationary vehicle hit in the rear at 40 km/hr by another vehicle.
- **Side Impact**: Stationary vehicle hit in the side members at 40 km/hr by another vehicle.
- **Torsional Analysis**: Maximum load transfer at current turning radius.
- **Wheel Bump Analysis**: Force equivalent to dropping the vehicle on one wheel from a height of 1.5m, which is the average height of the jumps a vehicle makes during the event.

Analysis Type	Force(N)	Max. Deformation (mm)	FOS
Front Impact	4G	7.14	2.97
Rear Impact	4G	6.98	2.29
Side Impact	4G	13.23	1.37
Torsional Impact	2G	3.06	7.84
Wheel Bump	2G	8.18	2.34

Table 1 consisting of analysis type, force applied, deformation and its factor of safety.

Steering

Objectives

Steer the front wheels in response to driver inputs in order to provide overall directional control of the vehicle.

Reduce driver effort through suitable gearing system.

Provide necessary feedback from the road for proper feel and handling.

Selection of Steering Geometry

Ackermann geometry was chosen due to the following advantages:

- It maximizes tyre grip during low speed cornering by adding negative camber at outside front wheel.
- Reduces tyre wear by providing common centre of rotation for all the four wheels.

Selection of gearing system

A Rack and pinion steering system was designed based on the dynamic requirements, which has the following advantages:

- Easy to design and manufacture.
- Provides good amount of feedback to the driver which helps in gauging the limit of grip and improves drive ability.

Design of Rack and Pinion system

The design of the centralized rack and pinion system was based on the fulfillment of the following parameters:

- Quick and responsive steering.
- Proper feedback to the driver.
- Should perform well against fatigue loading and should be corrosion resistant.

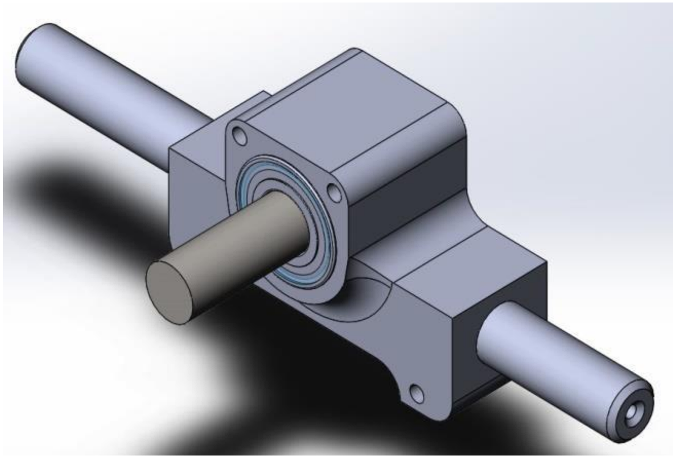

Fig. 2 Rack and pinion assembly cad model, EN24 used for pinion and EN8 for rack.

Particulars	Values
Turning radius (m)	2.6
Steering Ratio	4.5
Rack Travel (center to lock)	2.25 inch
Pinion Rotation (center to lock)	180 deg

Table 2 - Steering system data

Suspension

Objectives

It supports both handling and ride quality which are at odds which each other. Thus a compromise must be reached.

Should keep the wheel in contact with the surface at all times and provide ride stability.

Dissipate the energy from bumps and reduce vibrations for driver comfort.

Must provide comfort as well as performance on any type of terrain.

Design Methodology

Vehicle had to be more agile around corners and at the same time provide driver comfort.

CG height was lowered for improved handling and the distance between the roll centre and CG was reduced which resulted in less rolling in the corners.

Ride rates and roll rates were so chosen that the vehicle had maximum grip during cornering and also provided a certain level of driver comfort.

Overall weight of suspension components was reduced.

Proper caster and kingpin angles were given to the front wheels for desirable camber effects.

Front Suspension

Double wishbone suspension with unequal and non-parallel A-arms was used in the front.

It provides enhanced camber control over the front wheels and helps to maintain the maximum contact patch for better grip.

Roll centre can be obtained easily and link axes can be inclined to obtain anti-squat characteristics.

Rear Suspension

H-arm with camber link was used in the rear suspension.

It provides enhanced camber control over the front wheels and helps to maintain the maximum contact patch for better grip.

Easy installation and low weight of components used.

Camber links can be used to modify camber characteristics.

Dampers Used

FLOAT X EVOL shocks feature a main air chamber with an infinite adjustable air spring, velocity-sensitive damping control, additional air volume chamber (EVOL) for bottom-out adjustment, external rebound adjustment, external low & high speed compression damping adjustment, and an ultra-light weight of 4 to 4.5lbs depending on size.

Design of hubs and uprights

- Aluminium 7075-T6 was used as the base material for the design of the suspension components. It has a higher strength-to-weight ratio than conventional AISI 1020 and the temper grade T6 increases its UTS to 572 MPa and improves fatigue life and corrosion resistance. This also aids in overall weight reduction.

- Parameters such as bump forces, braking torque, reaction from brake pads and jacking forces were considered during the design process.

- Maximum bump force was obtained from considering the vehicle contacting the ground on one wheel from a height of 1.5m.

Particular	Values
CG Height (in)	15.63
Front roll center (in)	11.49
Rear roll center (in)	9.17
Wheel travel (in)	6
Front ride rate (N/mm)	942.8
Rear ride rate (N/mm)	1144.28

Table 3 - Suspension system data

Brake

Objectives

Provides a reliable and prompt deceleration for the vehicle.

All four wheels must lock when the brakes are applied irrespective of surface conditions.

Design Methodology

- Use of tandem master cylinder which isolates front and rear brake circuits.
- Use of steel braided flexi lines for better protection against wear and leakages.
- Customized SS410 brake rotor for improved strength and high corrosion resistance.
- Customized rotor allows for better heat dissipation due to ventilated design.
- Reverse swing arm pedal assembly for space optimization.

Particulars	Values
Pedal ratio	5:1
Rotor diameter	6.5 inch
Temperature max	60.90 deg Celsius
Temperature min	42.14 deg Celsius

Table 4 - Brake system data

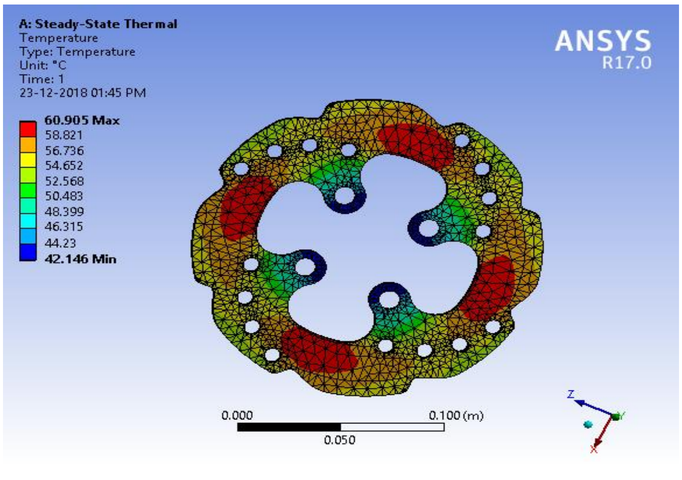

Fig. 3 Transient analysis of SS410 Rotor

Powertrain

Objectives

Transmission system should efficiently and effectively transfers power from a 10hp Briggs & Stratton engine to the wheel.

The system should provide high amount of torque while also allowing for quick acceleration.

The system should enable the vehicle to easily climb slopes as steep as 40 degrees while carrying the driver.

Design Methodology

- Use of Customized 2-Stage reduction gears with CVT.
- Customized gearbox casing and gears for meeting the dynamic requirements and improved weight reduction.
- Al 6061-T6 casing and EN24 gears ensure good structural integrity and high wear resistance.
- Continuously Variable Transmission (CVT) was used for uninterrupted power supply and increased driver comfort.
- Lightweight construction also improves dynamic performance.

Particulars	Value
Maximum torque (N-m) At wheel	626.34
Maximum acceleration (m/s^2)	5.51
Reduction ratio	11:1
Tractive effort (N)	1776.870 max

Table 5 - Brake system data

Fig. 4 2 stage reduction gearbox (11:1)

Fig. 5 Gear Plate

Conclusion

The process of designing a vehicle is not simple; as a matter of fact it takes a lot of effort from all members of the team to achieve a successful design.

The final prototype was the product of a collaborative multidisciplinary team design. The goal of the project was to create an off road recreational vehicle that met the SAE regulations for safety, durability and maintenance, as well as to achieve a vehicle performance, aesthetics and comfort that would have mass market appeal for the off-road enthusiast. All of the design decisions were made keeping these goals in mind.

Fig. 6 Assembled cad model

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