Material Selection And Optimization Of Atv For Sae Baja 2018

Anup Tayde[1], Meraj Sayyad[2], Vivek Naidu[3], Dr.C.C. Handa[4], Prof.B.D. Sarode[5]
[1, 2, 3, 4] Dept of Mechanical Engineering
[5]Professor Dept of Mechanical Engineering
[1, 2] KDKCE, Nagpur-44009, India

Abstract- *Baja SAE is an intercollegiate competition to design, fabricate, and race a small, single passenger, off-road vehicle powered by a 10 HP, Briggs & Stratton 4-Stroke petrol engine and to bring students into a real-world engineering scenario and have these students to work in teams and to compete in the tests and races against other teams of students. The purpose of the present paper is to optimize the design of a vehicle on the basis of hill climb, rock crawl, acceleration, maneuverability and endurance on land as well as in muddy terrain and to fabricate the vehicle in compliance with SAE guidelines.*

While designing this Baja vehicle, all the design aspects were taken as per the rules of Society of Automotive Engineers (SAE)-2018. The main objective of this paper was to design and optimize the roll cage, front and rear suspension system, power train system. The finite element analysis (FEA) is also done on the roll cage for validating the design. Initially, a preliminary design of the roll cage was made as a 3-D model using CAD. Material selection was based on the basis of factors like weight, cost, availability and performance. In present work, the overall design of vehicle has been categorized into subsystems: Roll cage, engine, Powertrain, suspension, steering, braking and ergonomics. This paper also provides an overview of the design for each of the subsystems of the vehicle. The designed and fabricated subsystems are equally strong and rugged.

Keywords- Material, SAE Baja, All-Terrain Vehicle, Off-Road Vehicle, Baja Roll Cage, optimization, MATLAB, Selection.

I. INTRODUCTION

A roll cage is a specially engineered and constructed frame built in (or sometimes around, in which case it is known as an exo cage) the passenger compartment of a vehicle to protect its occupants from being injured in an accident, particularly in the event of a roll-over.

There are many different roll cage designs depending on the application, hence different racing organizations have differing specifications and regulations. They also help stiffen the chassis, which is desirable in racing applications.

A roll bar is a single bar behind the driver that provides moderate roll-over protection. Due to the lack of a protective top, some modern convertibles utilize a strong windscreen frame acting as a roll bar. Also, a roll hoop may be placed behind both headrests (usually one on older cars), which is essentially a roll bar spanning the width of a passenger's shoulders.

The objective of the study is to design, develop and fabricate the roll cage for All - Terrain Vehicle accordance with the rulebook of BAJA 2018 given by SAE. Material for the roll cage is selected based on strength, cost and availability. The roll cage is designed to incorporate all the automotive sub-systems. A software model is prepared in Pro-engineer. Later the design is tested against all modes of failure by conducting various simulations and stress analysis with the aid of Autodesk Multi-physics. Based on the result obtained from these tests the design is modified accordingly. After successfully designing the roll cage, it is fabricated.

II. OBJECTIVES

The chassis serves many critical functions that include linking the powertrain, control, and suspension systems together. The driver must also be comfortable in order to operate the vehicle effectively, thus driver ergonomics and safety take precedence. Mounting points and the overall frame geometry are crucial design considerations that affect desired characteristics such as the weight distribution and suspension operation. The chassis must also be resilient enough to endure all of the loads imposed upon it yet maintain a lightweight. The team used the previously designed chassis as a knowledge base and benchmark for many of the design considerations this year and thus much of the material property data and design processes were referenced. This was necessary because of a severe lack of materials testing data available for AISI4130 as well as to effectively continue the iterative process of SAE Baja vehicle design.

- Always an parameter to look after. It is the parameter that affects the vehicle performance the most. Back few years previous the roll cage use to be heavy and stiff. This would result in lack of performance of the vehicle. Most out of engine power would result in loss i.e. to overcome weight of the roll cage. This would result low speed during endurance and reliability issues
- Size always affects vehicle performance. Huge size roll cage would result in high centre of gravity which is not suitable for an all-terrain vehicle. High centre of gravity means vehicle would easily get damaged or become unstable in terrains
- In off road racings safety plays an important role. The roll cage is the prime factor for safety. Drivers life is most important. During accidents or incidents of racings the first thing that protects the driver is the roll cage. so, safety norms of it should be more high in standards
- To win any race acceleration is must. We may have the best vehicle but it doesn't accelerate that well then no use of it . The roll cage design affects the acceleration as it would help in power dissipation and other aerodynamics factors

III. ERGONOMICS

One of the major design criterium that was used in the design of the chassis is the idea of driver ergonomics. Ergonomics is the study of how to layout and design the driver controls and safety features of the car according to the needs of the driver in order to optimize human wellbeing and overall system performance in a given situation. For the application of Baja, it was necessary to create a driver envelope that would not only fit the planned drivers, but allow comfort, safety, and stability to the driver for a period of time of up to 2 hours. This time period was chosen so that one driver could complete at least half of the endurance competition without becoming tired or uncomfortable, while still remaining safely within the vehicle. The ideal driver that has been determined for this car is a person roughly 6 feet tall and weighing around 75 Kg. This driver's envelope is the cornerstone of our design and answers many of the questions that the group had about the design of the vehicle. Some of the major ergonomic factors that were taken into consideration were the seat location and inclination, the location of the steering wheel, the design of the foot box area so that the driver will be able to properly operate the vehicle in all driving scenarios, and most importantly to comply with all the rules and regulations that were set forth in the 2018 Baja SAE competition rulebook.

Table3.1: Design Ergonomics of Roll Cage

Parameter	St. Range	Designed values
Angle of elbows	125°-140°	128°
Angle of knee	120°-150°	125°
Angle of back	8°-15°	12°
Steering wheel diameter (mm)	-	280
Angle of steering wheel	40°-50°	43°

IV. OPTIMIZATION CALCULATION

- Most importantly the prior aim of the optimization was to select the material which possess the minimum diameter for the same load.
- It was also considered to select the material which possess making load strength.
- While calculating for optimization the yield strength and modulus of elasticity were taken for each material.

While calculating for optimization we considered the following parameters of material.

Input data:

Length of Specimen L=1000; in mm
Load acting W=5000; in N
Factor of Safety FOS=2 ;
Thickness t= 2.54; in mm

Material Specification;

Yield Strength , Syt= (440); in N/mm2
Modulus of Elasticity, E= (190*(10^3)); in N/mm2

Calculation:

M=(W.L)/4; bending moment(N.mm)
Bs = Syt/FoS; Limiting Equation (in N/mm2)
d= 8*W*L*FoS/pi*Syt; Result equation of S.D.E and L.E (in mm)

I= (pi/64)*((d)^4 - (d-(2*t))^4); Moment of Inertia for Hollow Cylinder (in mm4)
Ymin=(W*(L^3))/(48*E*I); Result equation of S.D.E and P.D.E (in mm) (here, Ymin= Minimum Deflection)
Bs=(M/I)*(d/2); bending stress (in N/mm2)

Using this Data for the formulation in Matlab Program

```
optimization.m

clear all
close all
clc

%inputs data
L=1000 ; %in mm
W=5000 ; %in N
FoS=2 ; %factor of safety
t= 2.54 ;% in mm

%Material Specification;

Syt=(440); % in N/mm2

E=(190*(10^3)); % in N/mm2


%initial formulaton;

M=(W*L)/4; %bending moment(N.mm)

Bs = Syt/FoS; %Limiting Equation (in N/mm2)

d=nthroot(((8*W*L*FoS)/(pi*Syt)), 3); %Result euation

I= (pi/64)*((d)^4 - (d-(2*t))^4); %Moment of Inertia

Ymin=(W*(L^3))/(48*E*I); %Result equation of S.D.E an

Bs=(M/I)*(d/2); %bending stress (in N/mm2)
```

the above calculation was provided for the result generation of Diameter and Minimum Deflection Selection of the material insert in the program. The values which we considered while input of program was **Syt** i.e. Yield Strength**,** **E** i.e Modulus of Elasticity.

Hence, for the above input we get the result as follows,

Table 4.1: Diameter and Ymin for Materials.

Material	Yield strength(MPa)	Mod. Of elasticity(GPa)	Ymin(in mm)	Diameter(in mm)	Remark
AISI 1018	370	205	8.929	40.98	For Minimum Deflection
AISI 1026	415	210	9.84	39.44	
AISI 1040	415	210	9.84	39.44	
AISI 4130	440	190	11.56	38.68	For minimum Diameter

V. MATERIAL SELECTION

As per the constraint given in the rulebook [1], the roll cage material must have at least 0.18% carbon content. After an exhaustive market survey, the following materials which are commercially available and are currently being used for the roll cage of an ATV are shortlisted. A comparative study of these shortlisted materials is done on the basis of strength, availability and cost. The shortlisted materials are as follows.

Table 5.1: Selection of Material

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

After a successful research and market study the material selected is SAE4130 due to its superiority which is shown below.

5.1. MATERIAL: SAE 4130 Normalized at 870 deg.

5.2. PROPERTIES:

1) Density = 7.85 g/cc
2) Tensile Strength, Ultimate = 670Mpa
3) Tensile Strength, Yield = 435Mpa
4) Elongation of Brake = 25.5%
5) Modulus of Elasticity = 205Gpa
6) Bulk Modulus = 140Gpa

These properties are way better than other materials such as AISI1080

VI. METHODOLOGY

To begin the initial design of the frame, some design guidelines were required to be set. They included intended transmission, steering and suspension systems and their placement, mounting of seat, design features and manufacturing methods. It is also required to keep a minimum clearance of 3 inches between the driver and the roll cage members. It is necessary to keep the center of gravity of the vehicle as low as possible to avoid toppling. Mounting heavier components such as engine, driver seat etc. directly on the chassis is one way of achieving low center of gravity. Also, it is imperative to maintain the integrity of the structure. This is done by providing bends instead of welds which in turn reduces the cost.

6.1. Cross Section Determination:

After finalizing the design, it is a very important to define the cross-section of the structural members. It is strictly mentioned in rulebook to incorporate only circular tubing. While deciding the cross section, bending strength and ease in fabrication processes is taken into consideration.

As per the material requirements specified in rulebook, the material used for the Primary Roll cage must be:

1) Circular steel tubing with an outside diameter of 25mm (1 in) and a wall thickness of 2.54 mm and a carbon content of at least 0.18% , OR
2) 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.) and a carbon content of 0.18 %. The wall thickness must be at least 1.57 mm (0.062 in.).

VII. CALCULATION

7.1. Calculations for reference as per rulebook

- Bending strength=(Sy*I)/c
- Bending stiffness = E*I

For AISI 1080 having 0.18% carbon

- Sy=365MPa
- E=205GPa
- C=12.7mm
- I=3.14(Ro^2 – Ri^2)/2

Bending Strength = 365*10^6{3.14[(12.7*10^-3)^4-(9.7*10^-3)^4]}/2*12.7 =387 N/m.
Bending Stiffness = 205*10^9*{3.14[(12.7*10^-3)^4-(9.7*10^-3)^4]}/2
=2758 Nm^2.

7.2 CALCULATION FOR AISI 4130

- Bending Strength=(Sy*I)/c
- Bending Stiffness = E*I

For AISI 4130

- Sy=460 MPa
- E=210 GPa

Bending Strength =460*10^6{3.14[(Ro)^4-(Ro-0.00157) ^4]}/2*12.7
>387 N/m

Bending stiffness = 205*10^9*{3.14[(Ro)^4-(Ro-0.00157) ^4]}/2
>2758 Nm^2

So, we have chosen O.D of 29.4mm as per calculation and market availability.

Table7.1: Design Parameters Of Roll Cage

Material used	AISI 1018 or Steel alloys	AISI 4130
Max. Vehicle width (inch)	64	54
Max. Vehicle length (inch)	108	62
Vertical distance of S.I.M. From seat (inch)	8-14	10
F.B.M. angle	Less than 45°	
Vertical distance between seat and R.H.O. (inch)	Greater than 41	46
Firewall thickness (mm)	20	
Tube outer diameter (mm)	29.4	
Thickness of tube (mm)	1.64	

VIII. CONCLUSIONS

The design, development and fabrication of the roll cage is carried out successfully. The roll cage is used to build an ATV by integrating all the other automotive systems like transmission, suspension, steering, brakes and other miscellaneous elements. The Aim of this paper was to determine the Perfect Selection of Material for Chassis and Determination of cross section which has been done successfully.

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