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Design and FEA Model of Double Wishbone Suspension for StudentFormula Prototype Vehicle

Vipul Patil[1], Prathamesh Sawant[2], Sidhant Shinde[3], Nitin Chavan[4] and Viraj Pasare[5]

1,2,3,4 Students, D.Y. Patil College of Engineering and Technology, Kolhapur, Maharashtra.
5 Assistant Professor, D.Y. Patil College of Engineering and Technology, Kolhapur, Maharashtra.

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ABSTRACT- One of the important aspects considered in a car design is the suspension system of the car. Vehicle performance is mostly dependent on suspension systems; hence a robust and reliable suspension system is necessary to achievesignificant vehicle performance. Vehicle performance is a crucial part, especially it comes to a formula one car. The main aim of this paper is to design and develop an efficient suspension system for a racecar that has a perfect balance between ride and handling.The Suspension system is made up of wishbones, a spring damper, and an upright. Hence, there's an impact of those elements on the overall performance of the vehicle. Hence, designing wishbone arms and upright in detail and testing them thoroughly to avoid any anomalies is our main focus.So, this paper highlights the design process and Finite Element Analysis of suspension parts of formula one prototype vehicle as per the rule book of SUPRA SAEINDIA (2020). To make this suspension system robustit is necessary to analyze and assess all the possible failures which may adversely affect the suspension system and ultimately the vehicle performance. So, there is a need to evaluate all the components of the suspension system thoroughly to avoid failure of any kind, and this constitutes the main aim of this paper.Here, SUPRA SAEINDIA 2021 car is taken for example.

Keywords – suspension, upright, wishbones, spring rates, roll center

I. INTRODUCTION

When formula one car racing is considered, we know that the suspension of the car is at its crux. Double wishbone suspension with either a pull rod or push rod is normally used in racing cars, abiding to ease of design and lighter components. Numerous combinations of pull rod and push rod suspension are used in the front and rear of the vehicle. Supra is a competition, where students are expected to brainstorm, plan, construct and compete with other cars. The sub-system of the suspension is enlisted in this research paper those are uprights, wishbones, pull rods, etc. Safety, durability, and weight are important parameters in the design ofsuspension systems.

II. OBJECTIVE

The objective of the paper is to define the location of various points of the suspension geometry, Like C.G. points, and Roll Centers. The main focus of the paper is selecting suitable material for wishbone arms by comparing its mechanical properties and design analysis on ANSYS software.

III. LITERATURE REVIEW

1]Hiremath Iel-al, in this paper, they have designed a kind of front suspension structure for a Formula racing car, and by using the ADAMS/Car, the front suspension kinematics model is established and simulated, in order to optimize the wheel alignment parameters.[1]

2]Santosh el-al, in this paperwork, anticipated values for the suspension stiffness and damping are captured for great handling and comfort conditions.[2]

3] Vadheel-al, the purpose of this thesis project is not only to design and manufacture the suspension system for the car but also to provide an in-depth study of the process taken to arrive at the final design.[3]

IV. FLOW-CHART

Process Steps:

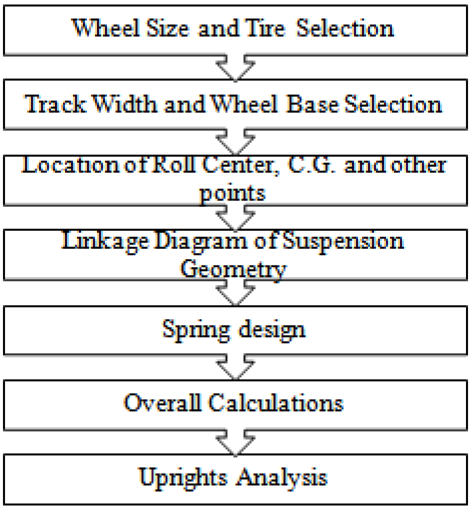

Fig.1. Process Steps

V. GENERAL PARAMETERS

The main reason for using this suspension framework is to permit the race vehicles to control the movement of the wheel all through the suspension travel, controlling the boundaries for camber, caster, roll focus and scour range. The tire keeps better contact with the street surface, dealing with friction.

TABLEI. OVERALL VEHICLE PARAMETERS

Parameter	Value(unit)
Wheelbase	1880 mm
Width of front	1300 mm
Width of rear	1240 mm
Self-weight of car	310 kg
Power (Est)	20 KW
Longitudinal length	2500 mm
Vertical length	1200 mm

ROLL CENTER LOCATION AND MOVEMENT OPTIMIZATION

Certain boundaries were then fixed which expected us to sort out the weight move experienced during different increasing speeds and learn ride and roll rates. [4,5]

A.Roll Center

The roll center of a vehicle is an imaginary point at which a body rolls, due to high lateral forces.

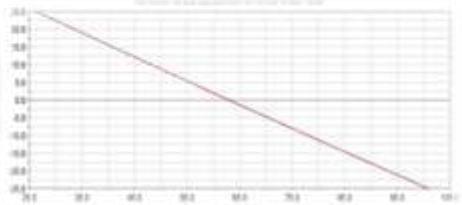

Fig.2.Optimization study for roll center vertical position with wheel travel

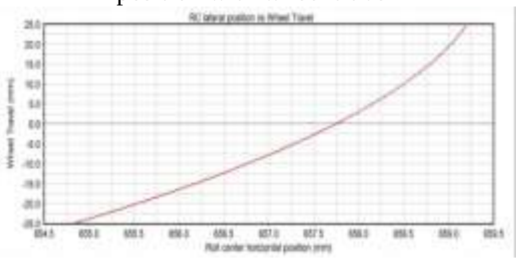

Fig.3. Optimization study for roll center horizontal position with wheel travel

B. Roll Gradient

As per calculations, the roll gradient is 1.00 deg/g.

C. Roll Stiffness

The roll stiffness (KØ) is described as the roll moment per degree of chassis roll and KØ = 449.89 Nm /deg.

D. Roll Stiffness Distribution

The roll distribution was lightlytending towards the rearat 47:53.

E. Ride Rate

As per calculations, the front ride rate is viewed to be 14.8 N/mm

VI. SUSPENSION GEOMETRY:

If the roll angle stiffness is extra significant, the handling and stability will be enhanced, and the corresponding ride comfort might be less. Otherwise, the vehicle will tend to roll according to its roll axis.[6]Suspension Geometry was created by using linkage diagrams and the principles of kinematics and dynamics of machinery. The kinematic and dynamic instantaneous centers helped us determine various suspension parameters.

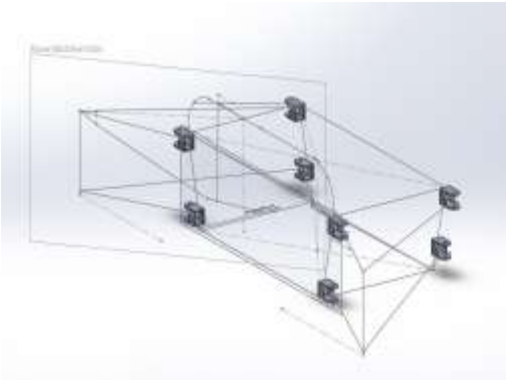

Fig.4.3D Geometry

A. Wishbone:

The two wishbones, upper and lower form the mechanism that connects the wheels to the chassis structure.The suspension arm can be joined close to the even concerning the ground improving aerodynamics [3]. Depending upon the factors like carbon content and material properties, we have chosen two materials AISI1018 and ST35 and compared them. As per tensile test results,ST35 is more suitable by means of cost, manufacturing cost, yield stress, and the ratio of yield stress and ultimate tensilestress.Here, werepresent the 2D CAD drawing modelof wishbones.

Wishbone material- ST35
Dimensions
Outer diameter: 12 mm
Inner diameter: 6 mm
Material Properties
Density: 7.8 g/cm3
Ultimate tensile strength: 607 MPa
Yield tensile strength: 517 MPa
Modulus of elasticity: 200 GPa
Poisson ratio: 0.29

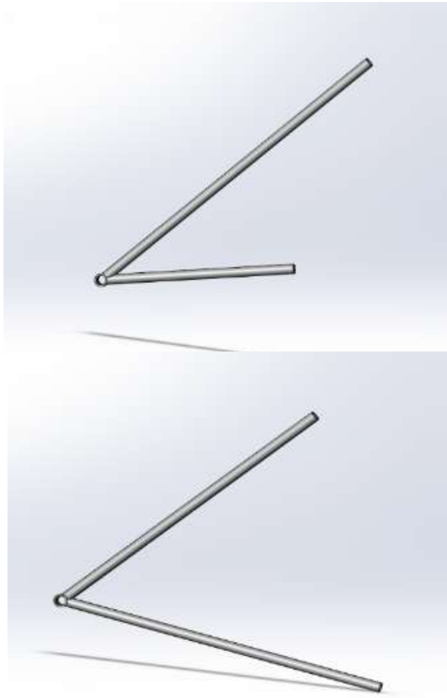

Fig.5. 3D CAD model of(Rear and Front) Wishbone

The wishbone arm is examined in ANSYS software.

Boundary Conditions: The side of the wishbone arm which is connected to the chassis is fixed with cylindrical support and another side of the wishbone which is connected to theupright is provided with a vertical force in the z-direction.

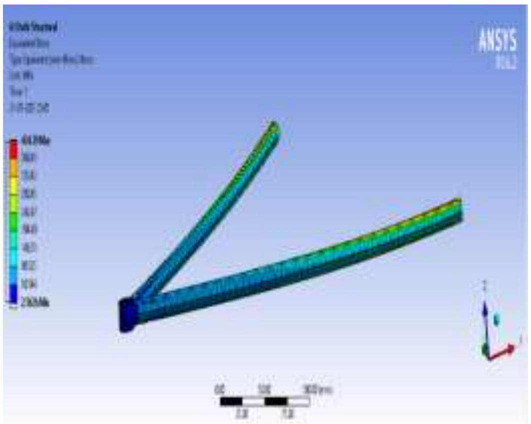

Fig6.Equivalent (Von-Mises) Stress(Front Wishbone)

As considered from the above result the maximum stress in the arm is 434.3 MPa which is less than the allowable stress of 517 MPa. For this reason, the design structure is safe under loads.

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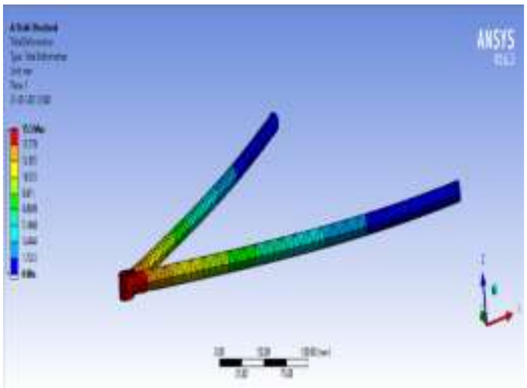

Fig 7. Total Deformation (Front Wishbone)

VII. SPRING DESIGN

Designing of spring is an important aspect to achieve comfort and safety of occupants. Slight errors during the design may lead to many problems such as reduction in ground clearance, generation of unwanted forces, mislaying of CV joints, and many other undesirable conditions.In the study by changing the diameter of the spring wires in addition to studying the change in the type of materials used in the springs. [7]

TABLE II. SPRING DIMENSIONS

PARAMETERS	FRONT	REAR
Wire Diameter	7	8
Outer Diameter	50	58
Inner Diameter	36	42
Active Coils	5	8
Total Coils	7	10
Solid Height	49	80

A. Installation Ratio:
The Installation ratio is found to be IR = 0.83

VIII. WHEEL ASSEMBLY

A. UPRIGHTS:
An upright is one of the most vitalcomponentsof a suspension system. Upright connects all components of the suspension system.The uprights interface the upper and lower ball conjunctures of the control arm and also provides a mounting point to the brake calipers. [8]

B. STRESS ANALYSIS:
The forces on the upright were also imported from ANSYS. As there were many components assembled in the upright, there was a need to do a Fatigue Analysis and Contact Stress analysis. The results are:

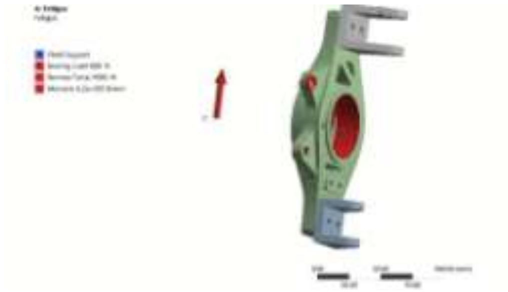

Fig.8. Boundary Conditions

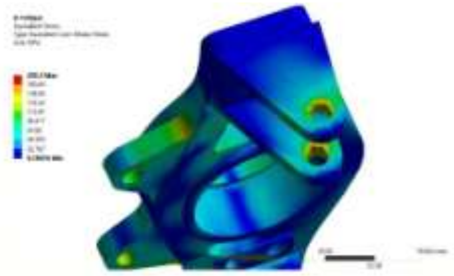

Fig.9. Equivalent (Von-Mises) Stress (Including Stress Concentration Effect)

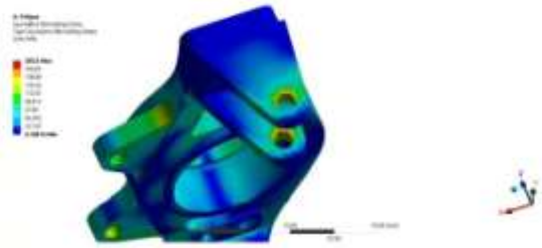

Fig.10. Equivalent Alternating Stress

IX. CALCULATIONS

A.
Wheelbase = 1600 mm
Body Bounce Frequency
Fnf = 2.2 to 2.5 Hz
Fnr = 2.0 to 2.2 Hz
Front Trackwidth tf = 1.3m
Rear Trackwidth tr = 1.245m
Weight = Mass of vehicle = 310 kg
Weight distribution = 47/53
Front corner mass
Unsprung mass (mu) = 13 kg
Sprung mass (ms) = 60 kg
Total (Mtotal) = 73 kg
Rear corner mass
Unsprung mass (mu) = 12.4 kg
Sprung mass (ms) = 70 kg
Total (Mtotal) = 82.4 kg
Tire Stiffness
Front tire Stiffness (ktf) = 100 N/mm
Rear tire Stiffness (ktf) = 125 N/mm
B.
Wheel Bump travel = 20 mm

Travel due to weight transfer (due to cornering) = 20 mm
Total Travel = 20+20 = 40 mm
Rolling moment resisted at front = M
C.
Ha = distribution between CG and RC
M = F x ha = ms x dy xha
To find ha,
15:1600 = X:912
X = 8.55 mm
Center of Gravity Height (CG) = 310 mm
ha = 310 - (60 +8.55)
ha = 241.45 mm
M = ms x dy x ha
M= 260 x (1.25 X 9.81) x 241.45
M = 769802.96 Nmm
D.
Assume roll couple distribution as 50:50.
Weight transfer due to roll = M x 0.5 /tf
Δwf=296 N
Required front ride rate (KRf)
KRf = $\Delta wf \div$ wheel travel due to cornering
= 296 N ÷ 20 mm
KRf = 14.8 N/mm
E.
Wheel center rate (kw) = Vertical axle rate
1/KRf = 1/kw + 1/kt
Kw = 17.35 N/mm
Front corner sprung mass-related frequency
Fns front =$1 \div 2\pi \times (14800 \div 60)$
Fns front = 2.5 Hz
Now,
Kw = 17.30 N/mm
Body roll front angle = $\tan^{-1}(20/650)$
Body roll front angle = 1.76° =0.03 radian
Lateral acceleration = 1.25 g and 1.5g
For 1.25 g
Roll gradient = 1.76/1.25 = 1.4 deg/g
For 1.5 g
Roll gradient = 1.76/ 1.5 = 1.17 deg/g
Rolling
Wheel travel (ΔZw)
$\Delta Zw = 0.5\ M \div t \times KRf$ = 20 mm
Roll rate = Rolling moment resisted × roll angle =437.64 Nm/deg
Factor of safety=571/435.8 = 1.31

X. CONCLUSION:

We have designed the geometry as per the supra rule book considering standard values of wheelbase, track width, and self-weight. After assessing the materials, the yield stress for AISI 1018 material was 0.684 KN/mm2 and the yield/UTS ratio was 0.995. And for ST35 material yield stress was 0.571 KN/mm2 and the yield/UTS ratio was 0.941. This clearly indicates that ST35 material has an upper hand and hence we have selected this materialafter its calculations, the factor of safety for the selected Material was 1.31.

Acknowledgment
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