

Suspension Optimization of Student Formula Race Car

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ABSTRACT

The main objective of this paper is to design and analyze the entire double wishbone for improving the stability, handling, safety of the racing car. The actual concept is focused on designing the wishbone considering the dynamics of the vehicle along with minimizing the sprung mass. It also focuses on wishbone angle and its mounting point on tubular space frame chassis regarding roll centre position and % of anti-squat and anti-dive.

Keywords

Roll centre characteristics, anti-dive and anti-squat characteristics, wishbone configuration, weight transfer, Ansys, stress and Factor of safety.

Notations

α -angle made by the line passing through instantaneous centre and tire – ground contact patch at front wheel.

β - angle made by the line passing through instantaneous centre tire-ground contact patch at rear wheel.

L- perpendicular distance between ground and point where anti-dive %line cuts the COG line.

H- centre of gravity height.

l- perpendicular distance between ground and point where anti-squat % line cuts the COG line.

1. INTRODUCTION

There is different kind of suspension system, in racing cars wishbone configuration is used. The wishbone performs multiple tasks such as maintaining the proper gap between tire and chassis, providing angles to the tires like camber, caster, toe angle. In this paper we have tried to optimize student formula car suspension parameters and analyze the wishbones locally and globally.

1.1 Software used

Lotus suspension-simulation of wishbone

Catia v5- part and assembly designing

Ansys- analysis and optimization

Microsoft excel- formulation and calculation

Wishbone configuration is designed on the basis of roll centre height and the percentage of anti-squat and anti dive to achieve best results.

2. Roll center

Determination of roll center plays very important role in deciding the geometry of wishbones. Roll center and ICR is determined because it is expected that all the three elements upper wishbone, lower wishbone and tie rod should follow same arc of rotation during suspension travel. This also means that all the three elements should be displaced about same center point called ICR .initially the wishbone length is decided on the basis of track width and chassis mounting, but these two are limiting factors for wishbone length. Reasons of locating roll center

- Height of roll center (above or below) the ground affects the camber change characteristics.
- The position (left or right) of the centerline of the car will determine how the suspension will react to the dynamic forces which will influence the handling of car while cornering.

3. Calculation

All the calculations are done with the help of string calculation and lotus suspension software. The graph shown below represents wishbone angle with horizontal plane Vs roll center position as % of COG height. Depending on the % of roll center height you distribute how much force goes through the wishbones and how much through the spring/dampers. The range between 15 - 30% of roll centre height compare to COG is the most common place to locate. Anti-dive and anti squat calculation.

$$\% \text{anti-dive} = \tan \alpha / (H/L) * 100$$

$$= \tan 18.410 / (279.4/930) * 100 = 9.99\% \approx 10\%$$

$$\% \text{anti-squat} = \tan \beta / (H/l) * 100$$

$$= \tan 47.97 / (279.4/620) * 100 = 49.9\% \approx 50\%$$

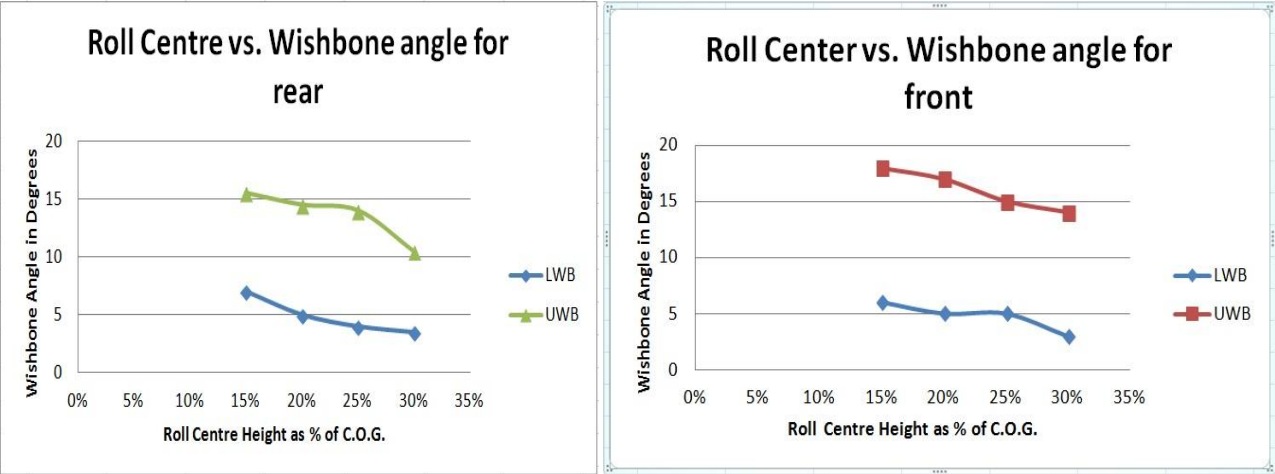


Fig1: Relation between wishbone angle and roll center height

2.1 Lotus analysis of Front suspension

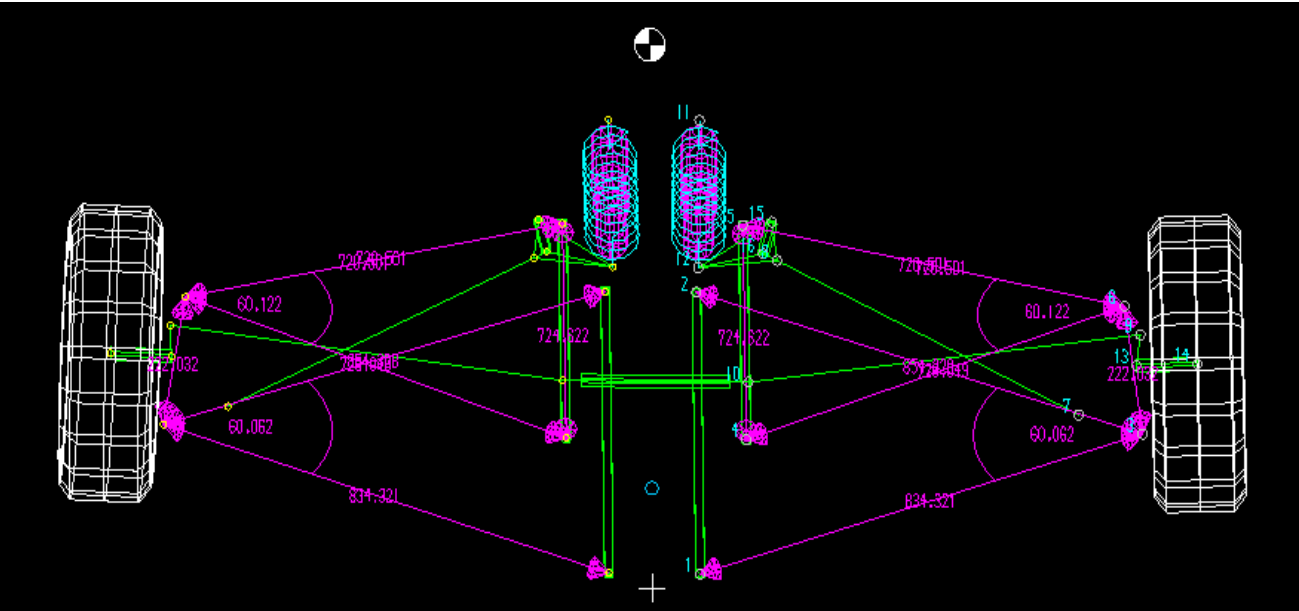


Fig 2: Isometric view of front suspension (wishbone, suspension & damper assembly) in lotus suspension.

INCREMENTAL SUSPENSION PARAMETER VALUES

Bump Travel (mm)	Anti Dive (%)	Anti Squat (%)	Roll Centre Height {to Body} (mm)	Roll Centre Height {to Grnd} (mm)	Half Track Change (mm)	Wheelbase Change (mm)	Damper1 Travel (mm)	Spring1 Travel (mm)
60.00	0.72	0.00	3.03	-56.97	-1.47	-3.37	-42.77	-42.77
40.00	3.50	0.00	6.30	-33.70	-0.46	-2.14	-27.84	-27.84
20.00	5.85	0.00	9.63	-10.37	0.03	-1.02	-13.61	-13.61
0.00	7.92	0.00	13.06	13.06	0.00	0.00	0.00	0.00
-20.00	9.81	0.00	16.63	36.63	-0.55	0.91	13.08	13.08
-40.00	11.61	0.00	20.41	60.41	-1.63	1.69	25.69	25.69
-60.00	13.38	0.00	24.49	84.49	-3.23	2.34	37.89	37.89

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LOTUS SUSPENSION ANALYSIS v5.01

Fig3: Numerical summarization of front suspension properties

through the springs. When this happens there is no suspension deflection due to braking and no visible brake dive. There is still load transfer onto the wheels, but the chassis does not pitch nose down.

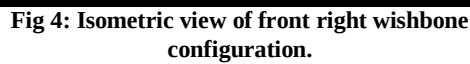


Fig 6: %Anti-dive Vs spring travel

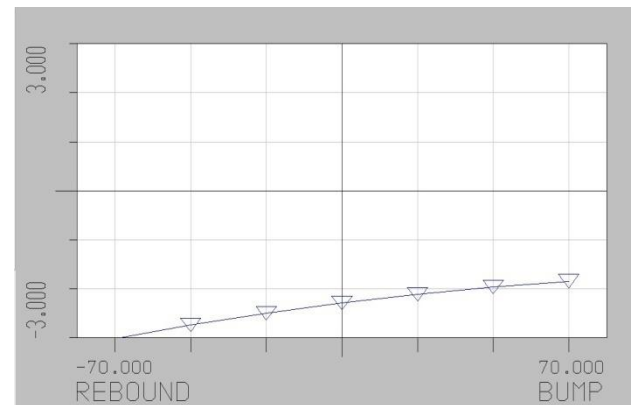


Fig 7: Camber angle Vs wheel travel

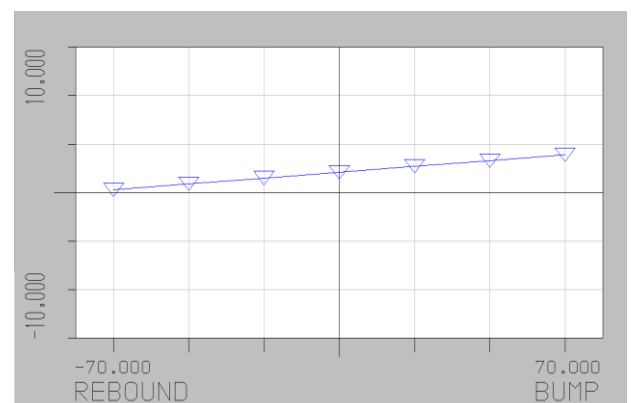


Fig 8: caster angle Vs wheel travel

2.2 Lotus analysis of rear wishbone

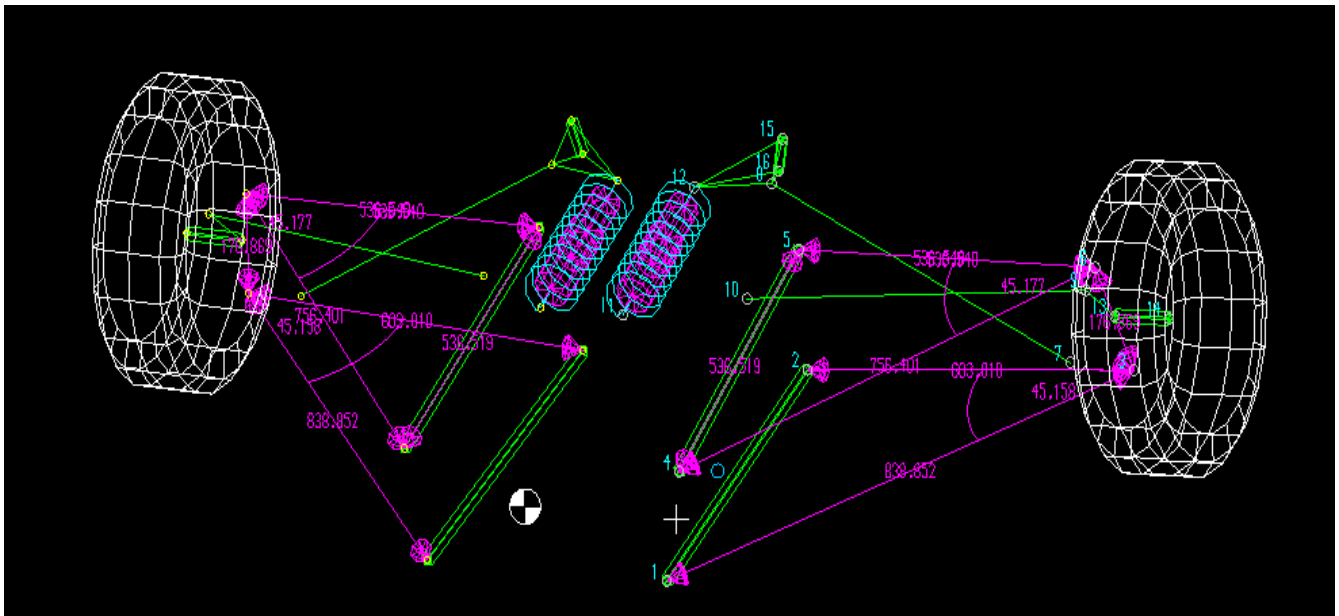


Fig 9: Isometric view of rear suspension (wishbone, wheel and damper assembly) in Lotus suspension

INCREMENTAL SUSPENSION PARAMETER VALUES

Bump Travel (mm)	Anti Dive (%)	Anti Squat (%)	Roll Centre Height {to Body} (mm)	Roll Centre Height {to Grnd} (mm)	Half Track Change (mm)	Wheelbase Change (mm)	Damper1 Travel (mm)	Spring1 Travel (mm)
60.00	44.74	71.88	-32.73	-92.73	-3.93	3.45	49.38	49.38
40.00	39.98	63.29	-30.26	-70.26	-2.12	2.27	31.87	31.87
20.00	36.02	56.11	-27.65	-47.65	-0.81	1.11	15.36	15.36
0.00	32.66	49.97	-24.89	-24.89	0.00	0.00	0.00	0.00
-20.00	29.77	44.64	-21.99	-1.99	0.30	-1.07	-13.87	-13.87
-40.00	27.24	39.93	-18.93	21.07	0.09	-2.11	-25.68	-25.68
-60.00	25.00	35.71	-15.69	44.31	-0.64	-3.09	-34.43	-34.43

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Fig 10: Numerical summarization of rear suspension properties

After summarizations we have achieved best percentage of anti-squat and anti-dive. Anti-squat is chosen to stop the moment of pitch centre. Under acceleration there is a natural tendency for weight to transfer at rear axle. And at the time of braking the weight gets transferred at front. With the help of Lotus suspension software we calculated %anti-squat variation for 60mm bump and jounce is 71.88 to 35.71%. At initial condition (0 mm) bump travel the value of anti-squat is 50%. Just like anti-dive in the front suspension, there can be anti-lift in the rear suspension that reduces rebound travel under 'braking.

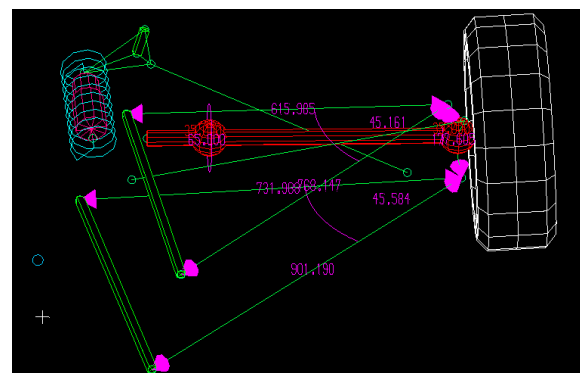


Fig 11: Side view of rear wishbone configuration.

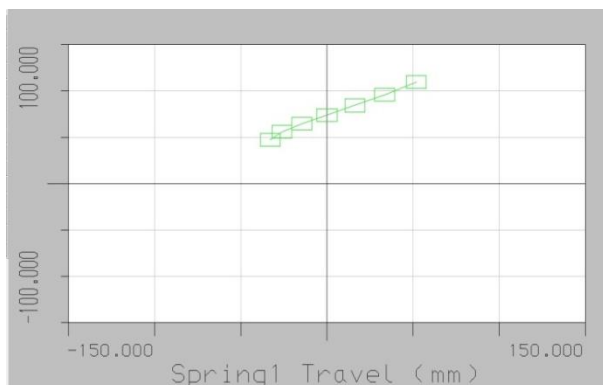


Fig 12: % anti-squat Vs spring travel

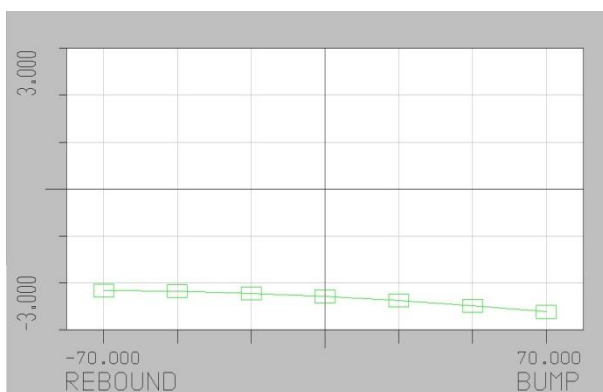


Fig 13: Camber angle Vs wheel travel

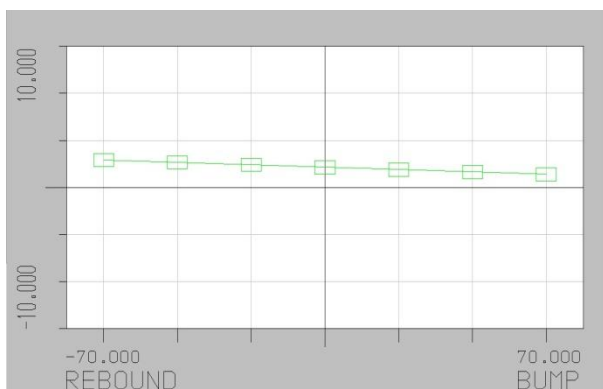


Fig 14: caster angle Vs wheel travel

5. DESIGN AND ANALYSIS

Material selection

Material	Youn g's modu lus	Density	Ultimate tensile strength	yield strengt h
Chromoly 4130	20GP a	7.8g/cm ³	559.85N/mm ²	<u>450.90</u> <u>N/mm²</u>

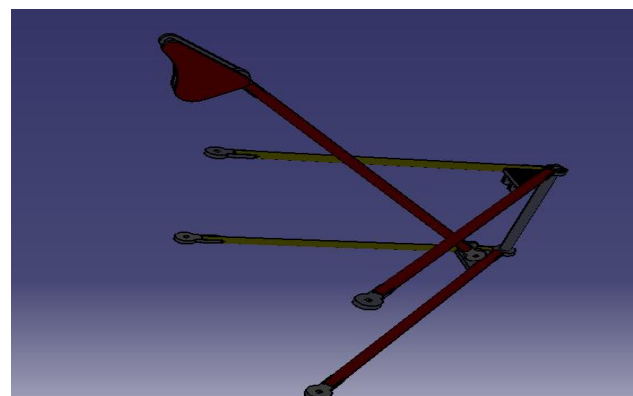


Fig 15: Catia Assembly (wishbone, pushrod, rockerarm, ball joints)

Loading condition on FSAE vehicle

Vehicle weight	3000N
Cornering load	1.3g = 3900N
Braking force	1.4g = 4200N

5.1 Local analysis of wishbone

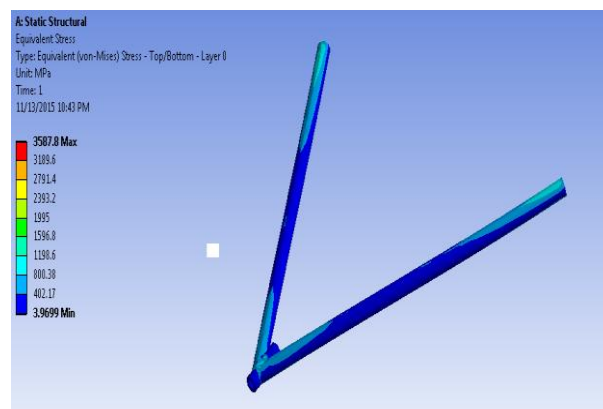


Fig16 equivalent stress analysis of front wishbone

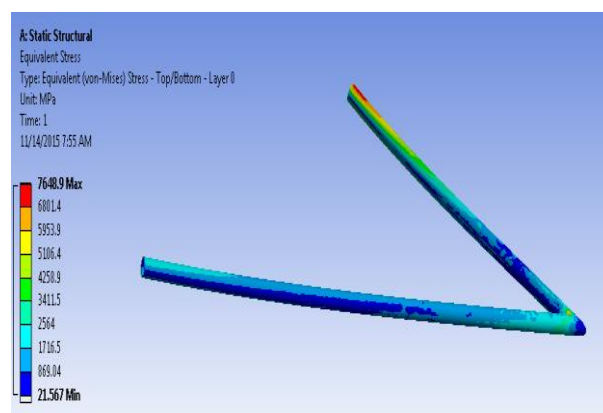


Fig17: equivalent stress analysis of rear wishbone

Results

Part	Maximum Stress(MPa)	Maximum deformation(mm)
Front wishbone	1115	22
Rear wishbone	1005	21

5.2 Global Analysis of wishbone assembly

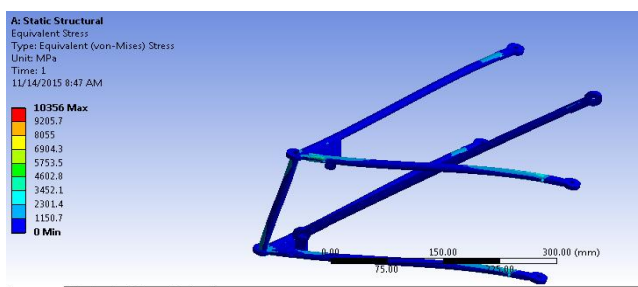


Fig 18: stress analysis of wishbone assembly

Max stress = 732 Mpa , FOS= 1.6, maximum deformation = 11mm

6. Conclusion

Finally we gave prominent importance to stability of wishbone with heavy load carry position and achieved the better optimum configuration for student formula race car competition. In future we work on weight optimization with use of carbon and glass fiber composites and modal analysis and vibration analysis due to wheel frequency. The current structure of our suspension design is on the conservative side . The reported stresses are well below the allowable stresses. The use of shock absorbers will absorb the undue energy transferred to our tubular space frame chassis

7. Acknowledgement

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8. REFERENCES

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