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A REVIEW PAPER ON MODELLING AND ANALYSIS OF UPRIGHT AND HUB FOR FORMULA STUDENT VEHICLE

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Abstract - The upright or knuckle attaches the wheel, brake rotor, hub, brake caliper, Steering arm, upper and lower control arm. The design of the upright or knuckle determines the geometry on the outboard side of the suspension. The mount points on the chassis and wishbones/links form the inboard side of the suspension, and provide their own contribution to the overall geometry of the suspension and that affects the dynamics of the vehicle. Initially suspension is designed using lotus shark software and by using that hard points upright is modelled using Solid works software. While modelling various parameters like hub diameter, brake caliper mounts, bolt size, rim spacing is taken into consideration. The model is meshed using ANSYS and analyzed based on the loads calculated using analytical method using formulae of various manures possible. The results from the analysis are taken and considered as input for the iterations on the model and the model which offers better factor of safety and less weight is considered for manufacturing.

***Key Words*:** Upright, Lotus shark, Solid Works, ANSYS.

1.INTRODUCTION

1.1 Suspension system

Suspension is the part of automobile that negates the most of the forces that the car gets from driving on the road making sure the cabin stays still. It can be small rocks on the road to big potholes, suspension deals with them all. This is a normal understanding we have that the job of a suspension is to only provide a cushion when a bump or a crack appears on the road. It does much more than that. It makes it easier to drive a car.

Fig -1: Suspension system

The suspension works on the principle of force dissipation which involves converting force into heat thus removing the impact that force would have made. It uses springs, dampers and struts to achieve this. A spring will hold the energy while a damper will convert into heat.

There are few important parts in the suspension system, discussed below.

1.1.1. SPRING

The job of a spring in a suspension system is to store the energy that is generated when the car goes through a bump. A spring or a coil stores energy by compressing its size thus making any type of force into energy. The amount of energy spring can hold depends on a multitude of factors. Including and not limited to the length, the material of the spring and the coefficient of spring. The material is included because some springs might be able to hold more energy but with a non-durable material, the spring might falter.

There are two types of springs used for suspension a coil spring and a leaf spring. A coil spring is a common one which most you might have seen. A leaf spring is used on a solid axle so basically in trucks and has very high energy storing capacity compared to a coil spring.

Fig -2: Leaf spring

Fig -3: Coil spring

Spring is good for providing a cushion however your car will keep on bouncing around giving you absolutely no control over it which is not a good thing. When you speed up your car or when you take a corner having only springs in your car will make it keep on moving back and forth.

1.1.2. DAMPER

The energy stored by the springs need to go somewhere else it will be released by the springs again with some minor transfer loss and your car will keep on jumping around at every crack in the road. After the spring stores the energy, the dampers or shock absorbers start working. Inside a damper is a piston with small holes in it and some Pressurized oil. When the spring transfers the energy to the damper the piston moves through the pressurized oil by using the energy of the spring. Passing through the oil generates heat, successfully converting the energy of the bump in the road into heat energy and negating any energy left which would have caused the car to jump.

Fig -4: Spring-damper setup

1.1.3. A-ARMS

In suspension, a A-arm, also known as control arm, is a hinged suspension upright or hub that carries the wheel. The inboard (chassis) end of the control arm is attached by a single pivot in double shear, usually bushings either rubber or steel ones. It can control the position of the outboard end in only single degree of freedom, the single bushing does not control the arm from moving back and forth. This motion is constrained by a separate link or radius rod.

Fig -5: Double wishbone setup

1.1.4. TYRES

Tyres is important for the suspension to keep the road wheel in contact with the road Surface as much as possible, because all the road or ground forces acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different because of it effects the dynamics of the vehicle and basically the front tires are relatively smaller due this set up provides less roll center.

1.1.4. UPRIGHT

The upright or knuckle attaches the wheel, brake rotor, hub, brake caliper and steering arm to the vehicle. The upright also locates these components in space.

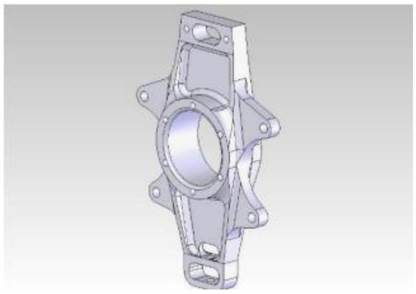

Fig -6: Upright of formula student vehicle

1.2 SUSPENSION USED IN FORMULA STUDENT VEHICLE

For formula student vehicle performance and handing are prioritized. The vehicle is expected to suffer large cornering forces and high –g cornering forces so the suspension plays a key role in keeping tire in contact with the ground. And the suspension must maintain the motion ratio (spring travel/wheel travel). So, the double wishbone suspension is not suitable for this purpose, because to maintain the motion ratio in 1:1 ratio the spring and damper must be aligned in 90 degrees which is not optimum for the formula student vehicle which causes ride height, mounting issues.

To maintain the motion ratio to 1, a pushrod and rocker arrangement is used. The push or pull rod is mounted on the upright and a rocker is mounted on the frame the push or pull rod actuates the rocker arm.

The pivot lengths of rockers are adjusted to produce the motion ratio to 1.

1.2.1. DOUBLE WISHBONE – PUSH ROD SUSPENSION

In a push-rod suspension system, there is an upper and lower control arm, similar in design to a double-wishbone frame, which provides a structurally integral connection between the wheel hubs and the chassis. These arms are able to pivot inwards towards the center of the vehicle, meaning that as the wheels experience shocks from the ground, they move up and down.

Between these two wishbone control arms, the wheel hubs connect to a rigid 'push rod'. Here, as the wheels move longitudinally, this rod will push upwards against an oscillating rocker arm, creating a see-sawing motion that transfers latitudinal forces from the ground into longitudinal forces inwards towards the chassis.

Fig -7: Double-wishbone pushrod suspension

1.3 SOFT WARES

Various soft wares are used for modelling and analysis, i.e.

1. Lotus shark for Designing of suspension
2. Solid works for modelling of Modelling of Upright
3. Ansys for analysis and optimization of upright

1.3.1 Solid works

Solid works is one of the most commonly used CAD programs today. It is a mechanical design automation application that lets designers create structural models quickly and precisely. When you want to sketch ideas, experiment with features and dimensions, and produce models and drawings. It lets you visualize how your design will look after manufacturing. Additionally, any changes you make to a part will reflect in all associated drawings. Solid works includes all familiar Windows functions, such as dragging and resizing windows in its interface for easier use. Many of the same icons, including open, save, cut and paste, and print is also included in the application. Solid works also allows collaboration between workspaces allowing other designers to see your progress and offer feedback.

1.3.2 Ansys

Ansys develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics or machine components to the simulate strength, toughness, elasticity, temperature distribution. Electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests. For example, Ansys may simulate how a bridge will hold up after years of traffic, how to best process salmon in a cannery to reduce waste, or how to design a slide that useless material without sacrificing safety.

1.3.3 Lotus shark

Lotus shark is suspension design software offered by Lotus Corporation. It consists pre- defined models that can be iterated according to our requirements. It offers different suspension parameters to iterate like camber, caster, toe, and king pin inclination.

1.4 Suspension parameters

There are different parameters that are considered while designing suspension that affects the vehicle in dynamic condition and that also shapes the upright.

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They are as follows.

1.4.1 Camber Angle

A wheel alignment adjustment of the inward or outward tilt on the top of the wheel when viewed from the front of the vehicle. Tipping the top of the wheel center line outward produces positive camber. Tipping the wheel Centre line inward at the top produces negative camber. When the camber is positive, the tops of the tires are further apart than the bottom. Correct camber improves handling and cuts tire wear.

Camber is of two types, positive camber and negative camber.

If the tire is viewed from the front, if the tire leans too much inwards then its negative camber. If the tire leans outwards then it is positive camber.

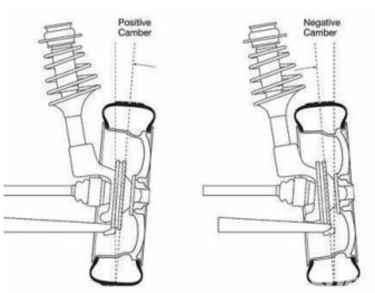
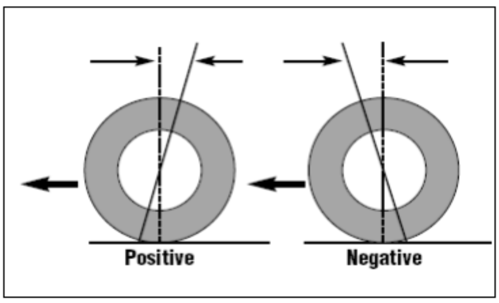


Fig -8: Positive and negative camber

1.4.2 CASTER

The caster angle or castor angle is the angular displacement of the steering axis from the Vertical axis of a steered wheel in a car, motorcycle, bicycle, other vehicle or a vessel, As seen from the side of the vehicle. The steering axis in a car with dual ball joint Suspension is an imaginary line that runs through the center of the upper ball joint to the Center of the lower ball joint, or through the center of the kingpin for vehicles having a Kingpin. Caster causes a wheel to align with the direction of travel, and can be accomplished Either by caster displacement or caster angle. Caster displacement moves the steering axis ahead of the axis of wheel rotation.



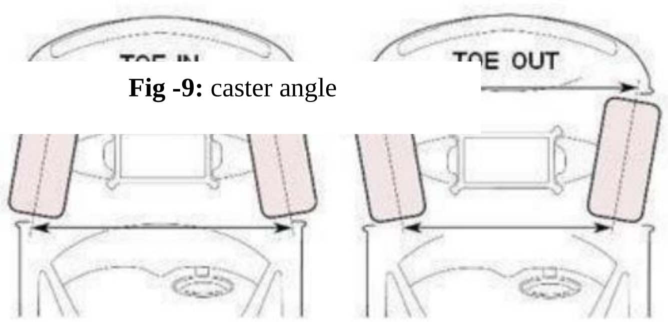


Fig -9: caster angle

1.4.3 Kingpin inclination

The kingpin inclination is the angle, measured in degrees, that forms the line passing through the kingpin and the perpendicular to the ground, looking at the vehicle from the front. The kingpin angle has an important effect on steering, making it tends to return to the straight ahead or center position because the straight-ahead position is where the suspended body of the vehicle is at its lowest point. Thus, the weight of the vehicle tends to rotate the wheel about the kingpin back to this position. The kingpin inclination also contributes to the scrub radius of the steered wheel, the distance between the center of the tire0 contact patch and where the kingpin axis intersects the ground. If these points coincide, the scrub radius is zero.

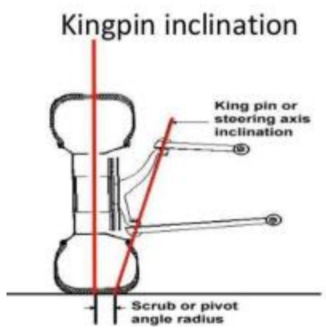


Fig -10: King Pin inclination

1.4.4 Toe

In automotive engineering, toe, also known as tracking is the symmetric angle that each wheel makes with the longitudinal axis of the vehicle, as a function of static geometry, and kinematic and compliant effects. This can be contrasted with steer, which is the ant symmetric angle, i.e. both wheels point to the left or right, in parallel (roughly). Negative toe, or toe out, is the front of the wheel pointing away from the centerline of the vehicle. Positive toe, or toe in, is the front of the wheel pointing towards the centerline of the vehicle. Historically, and still commonly in the United States, toe was specified as the linear difference (Either inches or millimeters) of the distance between the two front-facing and rearfacing tire Centerlines at the outer diameter and axle- height; since the toe angle in that case depends on the tire diameter, the linear dimension toe specification for a particular vehicle is for Specified tires.

2. LITERATURE SURVEY

Tune to Win by **Carroll Smith**, 1978. Covers the development and tuning of race car by clearly explaining the basic principles of vehicle dynamics and relating these principles to the input and control functions of the racing driver. It gives better insights in determining the important p[illegible]k covers the concepts like lateral load transfer and longitudinal load transfer that helps in determining the track width and wheel base of the car. The book covers the dynamics of the suspension which directly affects the performance of the vehicle. Those parameters are taken into consideration in designing of the suspension system and steering.

Fig -11: Toe-in and Toe-out

Race Car Vehicle Dynamics by **Douglas L. Milliken**. To find the load transfer and breaking calculations in dynamic conditions this book contain experimental results and the book goes into great detail about all aspects considered when building a race car. This book covers about the tyre dynamics, slip angles and g-g diagrams which give information about the tyre under different conditions like roll, maximum cornering etc. that help in selecting the tyre to initiate the suspension design.

Fundamentals of Vehicle Dynamics by **Thomas D. Gillespie**. This book provides a foundation of engineering principles and analytical methods to explain the performance of an automotive vehicle, with chapters focusing on acceleration performance, braking performance, aerodynamics and rolling resistance, ride, tires, steady state cornering, suspensions and steering systems and roll over. Acceleration, braking, Turning and ride are among the most fundamentals properties of a motor vehicle. To understanding the vehicle as system, it is necessary to acquire knowledge of all these modes. Motion is the common denominator of these modes.

Anshul dhakar and rishav ranjan, Forces are generated at the tire contact patch during various maneuvers of the car and transferred to the chassis through the suspension links. Calculating the forces on every link is important to design the suspension system as all the forces from wheel to the chassis are transferred by the suspension linkages. These forces have been calculated for all the links of double wishbone Suspension geometry. The load paths and FBD have been drawn and axial stress in the all the linkages are calculated that helps in choosing the right material and dimensions for the A-Arms.

Badih A. Jawad and Jason Baumann, 2002. This paper will cover the suspension geometry and their component, which include the control arm, uprights, spindles, hubs, and pull rods and cover the key points in the design and analysis of different components and calculates the forces on uprights and calculation on the forces of the wishbones as that forces are transferred on the upright that are further used for the analysis of knuckle. This paper mainly focuses on the types of suspension geometries suitable for Formula student vehicles, thus helps in choosing the vehicle suspension system.

Detailed design report of design of Upright and hubs, by **Zubair & Karthik**, 2016. This research points the important parameter for the designing of the upright and hubs of the automobile like Material, Load paths etc. This paper gives a brief idea about the designing of the Hubs and upright and considerations while designing the wheel assembly system. This paper also concentrates on the fatigue analysis of the upright in cyclic loadings. This paper guided us in analysis of the upright and the application of the static forces on the upright.

Design and optimization of Formula SAE suspension system, by **Ashish Avinash Vadhe**, 2018. This research paper discusses about the types of suspension systems suitable for the FSAE vehicle and compares the pushrod and pull rod suspension system. This paper contains the details analytical calculations on the force on the wishbones by resolving the forces form vehicle and upright thus helps in analysis of the upright and it also concentrate on the calculation of forces on the bolts on the upper and lower ball joints of the Upright thus helps in determining the suitable bolts for the upright.

Design of Suspension system for a Formula Student race car, **Y. Sumanth Saurabh, Santosh Kumar**, 2016. In this work, presented in detail the design procedure of the front double A arm push rod suspension system for a formula student race car. The type of suspension systems used generally is reviewed. The CAD models of the components in the suspension system are made using Solid works. The Finite element analysis of the components is done using ANSYS Workbench. Both kinematic and dynamic analysis of the designed suspension system is performed. The results of vibration or ride analysis and roll steer analysis are also presented for the designed suspension system. The method for spring design is elucidated. This work emphasizes the method for designing and analyzing the suspension system for a race car in various aspects.

Car Suspension design. This gives insights on the suspension parts and how to design suspension in consideration to the external parts and also gives the overview of the wheel assembly and focuses on the design of knuckle including determining the different values like camber angle, caster angle etc.

3. CONCLUSIONS

- The model is developed in solid works using the points extracted in lotus shark
- The weight of the model (obtained from CAD data) is relatively less than the previous model which is modelled using AL-6061. The weight of the material is got reduced by around 20%.
- The upright is able to sustain the given loading condition and has good factor of safety.
- Considering the objective to design an optimum upright for a formula student car keeping rules in mind. The design goals are achieved by iterating several models and analyzed with the load transfer calculations. It is observed that the upright can sustain any kind of loading and provides a factor of safety of around 2.5 which is preferable for the mechanical components and the upright does fit in the rim space provided clearances between rim and the upright. And there is negligible deformation is observed in the upright under different loading condition.

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