DESIGN ANALYSIS AND SIMULATION OF VEHICLE SUSPENSION SYSTEM

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ABSTRACT

The purpose of this project is to design and stimulation analysis of the vehicle suspension system by controlling the load inputs, spring stiffness, effectiveness and the damper rate. And this performance will be compared with passive suspension system. The main parameters that are focused in this project are sprung mass, stiffness of the spring. The suspension system is a mechanical device which is designed for a vehicle to smooth out or damp the shock impulse, and dissipate the kinetic energy. The purpose of the suspension system in vehicle is to absorb or dissipate the energy. Generally, in a vehicle, it reduces the effect of travelling over rough ground, leading to improved ride quality, and increase in comfort due to substantially reduce the amplitude of disturbances. The stages in the design of a suspension system are selecting the appropriate vehicle level targets, choosing the location of hard points, analysing the loads in the suspension, designing the spring rates, designing the characteristics of the suspension system, analysing the vehicle dynamics of the resulting design. The software's used for the designing are CATIA, ANSYS. The analysis is done by providing different loads and then calculate the deflection in suspension and the change in the characteristics of the suspension on application of loads. And required stimulation analysis is done to the suspension system by using ADAMS software. The stimulation analysis is done to achieve significant improvements in the ride quality and road handling. The analysis and the stimulation process are done by taking AISI 4130 material.

KEY WORDS: Suspension system, catia, ansys, adams, AISI 4130

INTRODUCTION

Suspension system is the term given to the system of springs, shock absorbers and linkages that connect a vehicle to its wheels. When a tire hits an obstruction, there is a reaction force and the suspension system tries to reduce this force. The size of this reaction force depends on the unsprung mass at each wheel assembly. In general, the larger the ratio of sprung weight to unsprung weight, the less the body and vehicle occupants are affected by bumps, dips, and other surface imperfections such as small bridges. A large sprung weight to unsprung weight ratio can also impact vehicle control. The automobile chassis is mounted on the axle, not direct but through some form of springs. This is done through isolate the vehicle body from the road shocks which may be in the form of bounce, pitch, roll, or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame and body. All the parts which perform the function of isolating the automobile from the road shocks are collectively called a suspension system. Broadly speaking, suspension system consists of spring and a dumper. The energy of road shocks causes the spring to oscillate. These oscillations are restricted to a reasonable level by the dumper, which is more commonly called as shock absorber.

The job of car suspension is to maximize the friction between the tires and the road surface, to provide the steering stability with good handling and to ensure the comfort of the passenger. for perfectly flat, with no irregularities, suspension would not be necessary but they are not therefore these imperfection interact with the wheels of a car and apply some force on them. A bump in the road causes the wheel to move up and down perpendicular to the road surface. The magnitude depends on the whether the wheel is striking a gaint bump or a tiny speck. either way the car wheel experiences a vertical acceleration it passes over imperfection.

TYPES OF SUSPENSION SYSTEM

Suspension systems can be broadly classified into two subgroups: dependent and independent. These terms refer to the ability of opposite wheels to move independently of each other.

DEPENDENT SUSPENSION SYSTEM:

Dependent systems may be differentiated by the system of linkages used to locate them, both longitudinally and transversely. Often both functions are combined in a set of linkages. Examples of location linkages include:

Satchell link
Panhard rod
Watt's linkage
WOBLink
Mumford linkage

INDEPENDENT SUSPENSION SYSTEM: The variety of independent systems is greater and includes: 3 DESIGN ANALYSIS AND SIMULATION OF VEHICLE SUSPENSION SYSTEM Swing axle Sliding pillar MacPherson strut/Chapman strut Upper and lower A-arm (double wishbone) Multi-link suspension Semi-trailing arm suspension Swinging arm o Transverse leaf springs when used as a suspension link, or four quarter elliptics on one end of a car are similar to wishbones in geometry, but are more compliant. Examples are the front of the original Fiat 500, the Panhard Dyna Z and the early examples of Peugeot 403 and the back of the AC Ace and AC Aceca. Because the wheels are not constrained to remain perpendicular to a flat road surface in turning, braking and varying load conditions, control of the wheel camber is an important issue. Swinging arm was common in small cars that were sprung softly and could carry large loads, because the camber is independent of load. Some active and semi-active suspensions maintain the ride height, and therefore the camber, independent of load. In sports cars, optimal camber change when turning is more important.

SEMI-INDEPENDENT SUSPENSION SYSTEM:

In a semi-independent suspensions, the wheels of an axle are able to move relative to one another as in an independent suspension but the position of one wheel has an effect on the position and attitude of the other wheel. This effect is achieved via the twisting or deflecting of suspension parts under load. The most common type of semi-independent suspension is the twist beam.

METHODOLOGY FOR DESIGNING OF SUSPENSION SYSTEM: Suspension can be carried by a mechanical element which deflects under action of the load and then returns to its original shape when load is removed. Hence springs are most preferred. When a vehicle is on the road, it suffers jerk due to cracks/bumpers and while loading/unloading the vibrations in the system are increased due to more unbalanced force and hence these sudden jerks can be handled by springs.

Now for finding the kind of spring for a particular system, we will search for its property K(spring index; constant for a material) and that will give the required spring arrangement. Follow below points:

Chose a spring with a particular "spring index"(i.e. "c"; c=D/d, where (D) is spring overall mean diameter and (d) is coil/wire diameter). You must be knowing the material of spring to be used which will give you an idea of permissible shear stress of that material. Now this value will be used in following equation(includes torsional and direct shear stresses)"shear stress(t)=K((8*P*c)/(3.14*d^2)): (P is the load acting; c = spring index; k= (Wahl factor)where "K" is equal to ----(K)=((4*c-1)/(4*c-4))+(0.615/c), where "c" is already taken by you hence find (d) and then corresponding to it find (D), giving you the required spring dimension which will help you in designing your model.

1. Next is to find the particular spring index required to do the job. To get this we have a formula (F=S*x), F is the load(maximum), S is (spring index), x is the (deflection)..........knowing the maximum force on the spring x(defection) can be given by"x"=((8*P*(D^3)*N)/(G*d^4)), where "G" is torsional rigidity(fixed for a material and can be found) which will give value of (x) and hence a value of S can be found out using the spring equation. This will complete your search for a particular type of spring.
2. Now you can use this spring index to choose your spring which will do the job for suspension system..Try series or parallel arrangement methods to find out number of spring required if you dont have a spring of particular spring index, because using these methods of parallel and series arrangement will help you with increasing spring index of a particular spring by putting them in required arrangements.

LITERATURE REVIEW

1) Rishi dhar,saurabh singh states that :Damping is an influence within or upon an oscillatory system that has the effect of reducing, restricting or preventing its oscillations. In physical systems, damping is produced by processes that dissipate the energy stored in the oscillation.Main design and functionality of dampers depends on type of fluid, material of spring, etc. Dampers of shocks are one of the pivotal components of a shock critical in the suspension system. Some basic concepts that should be known to determine the damper force absorption phenomenon.

2) Savan thacker, anthriskh bhatt explains Double wishbone designs allow the engineer to carefully control the motion of the wheel throughout suspension travel. 3-D model of the Lower Wishbone Arm is prepared by using CAD software for modal and stress analysis. The forces and moments are used as the

boundary conditions for finite element model of the wishbone arm. By using these boundary conditions static analysis is carried out. Then making the load as a function of time; quasi-static analysis of the wishbone arm is carried out. A finite element based optimization is used to optimize the design of lower wishbone arm. Topology optimization and material optimization techniques are used to optimize lower wishbone arm design.

DESIGNING OF SUSPENSION SYSTEM

For the design the design of suspension system we have used CATIA system software. Firstly the line diagram is designed to get the different hardpoints of the suspension system. The following steps are used for the designing of the suspension.

MECHANICAL DESIGN:

Decide type of suspension system

Decide basic dimensions- wheelbase, track width, centre of gravity, height, tyre, wheels and other suspension parameters.

Design wishbones and knuckles.

Design springs.

SELECTING TYPE OF SUSPENSION SYSTEM:

It is very important to choose your suspension type according to the use of vehicle. Considering the use of this vehicle on roads in cities double wishbone suspension was selected. This is an independent suspension system; so it increases the ride comfort, traction, stability of vehicle and also reduces the un-sprung mass. Also double wishbone suspension system is light, offers easy packaging with high degree of freedom in design of suspension geometry. Non parallel unequal arms were selected over parallel unequal arms to reduce the height of roll centre. In this vehicle initially double wishbone independent suspension was designed and then was suitably modified to replace the upper
„A" arm according to space constrains and driver ergonomics.

With the premise of introduction of suspension in chapter 1, the design of front suspension for the vehicle is described in this chapter.

After reviewing various types of suspension geometries the "Double 'A' arm" setup was preferred as it met many of our criteria which were:

- Adjustability.
- Ability to package in a small space.
- Simpler construction.
- Lightweight yet robust construction.

Main components of the suspension system (front):

- Wishbones or "A" arms
- Uprights or Knuckles
- Hubs
- Stub Axles
- Mounting tabs
- Shock absorbers

A standard double "A" arm or double wishbone geometry consists of two links that are used to connect the chassis to the upright. The two links namely, upper wishbone and lower wishbone each of which is provided with two revolute joints at the chassis end and one rotational joint at the upright. The design of suspension earlier was done using paper doll-models connected with threads to verify the motion, but in a more sophisticated way the design has been done using various computer software's that provide better accuracy and analysis.

THE BASIC DIMENSIONS:

The next step of designing is to decide the various basic dimensions of the system. The dimensions are as:

1. Wheel track = 137cm (54inch).
2. Wheel base =147 cm (58 inch).
3. Camber Angle = -3 degree(FRONT),-2 degree(rear).
4. Toe angle = toe-in- front :5-8 degree, rear:0 degree.
5. Castor angle = -7 degree(front),0 degree(rear).
6. Kingpin angle = -8 degree(front), 1 degree (rear).
7. Sprung weight = 243 kg
8. Weight bias = 45:55 (front : Rear)

For tyre and wheel selection a decision matrix was made as a result of which it was decided that 56cm (22 inch) diameter wheel package (tyre and tube) should be preferred over 51 cm (20 inch). The various considerations in selection include mass moment of inertia, ground clearance, tire availability, upright packaging, chassis impact, wheel availability, cost and mass effect, etc. The 22 inch package offers better moment of inertia, lesser weight and a good ground clearance while the 20 inch package lacks is providing adequate traction and its load baring capacity is also low. So 22 inch package was selected. Now the width needs to be decided. Wider tyre increases the overall traction but also increase the rotating mass that needs to be accelerated. So a balance between the traction and weight of tyre is made while deciding the width. Accordingly the width of tyre was selected as 3.8 cm (1.5 inch). Obtained is 49.36mm (1.94 inch). This is the minimum variation of the roll centre distance from centre of gravity of vehicle. The wishbones have unequal length. The upper wishbone is replaced by a single arm of adequate cross section to bear the induced forces and stresses. Its length is shorter than the lower wishbone. The advantage of having different lengths is that when the car takes a turn a negative camber is induced which increases the stability.

The unequal lengths also result in a negative camber of -3 degrees. The specifications of wishbones are as:
Upper arm length= 174 mm

Upper arm outer diameters =12.7mm (0.5 inch)

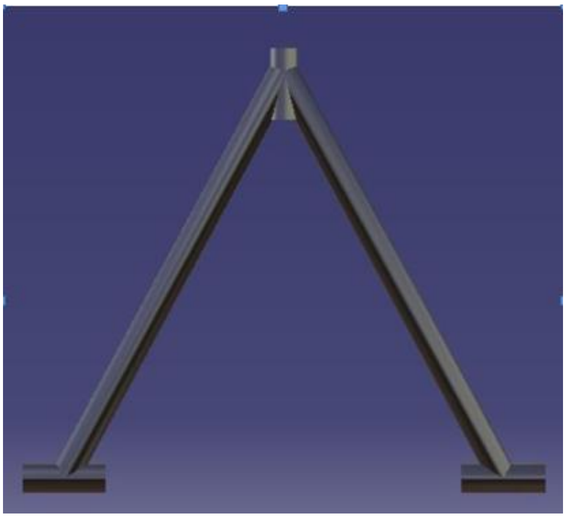
inner diameter =9.5mm (0.374 inch)

Upper arm angle with horizontal = 23 degree Lower arm length= 225 mm (axial) Lower arm outer diameter =12.7mm (0.5 inch)

inner diameter =9.5mm (0.374 inch)

Angle between two links of A arm = 60 degrees

Lower arm angle with horizontal = 22 degree



The spring is mounted on the lower wishbone and the knuckle is attached to the wishbone by rod-end bearings. The knuckle design was aimed to give stability to the wheel and dimensions were decided from the above finalised geometry of system. Aluminium was used to reduce its weight. Both wishbones and knuckle were tested on Ansys Workbench.

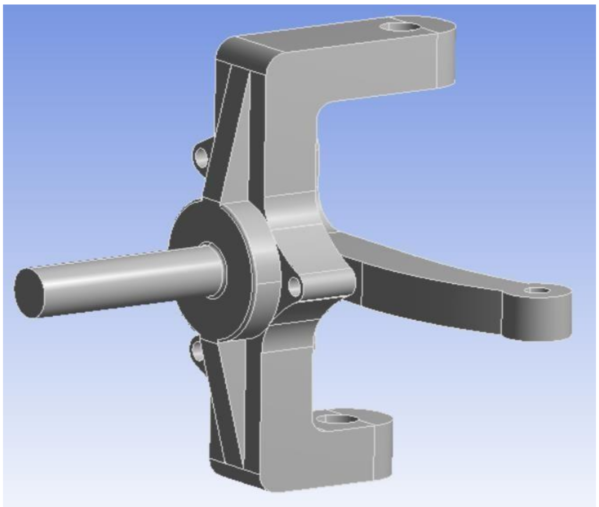
After studying various design, the finalized design was make it out of a single tube by bending into a parabola.

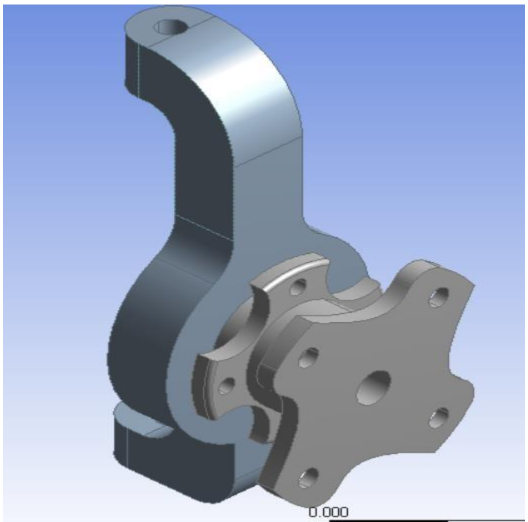
Reasons for selection of the design

1. Easy to fabricate
2. Consumes less time in production
3. Sophisticated jig not required
4. Less number of welds hence low heat effected areas.
5. Easy correction in design by opening and closing of bend.

DESIGN OF KNUCKLE or UPRIGHT:

Before designing of any components there are various parameter that are to be included in it. Irrespective of other details the main design parameters determine mostly the performance, adaptability with the environment, mates with the sub-component in an assembly, space occupancy etc. They are Special consideration and often are the constrains which are to be met.





Material Selection:As it was mentioned above in design parameters, weight consideration was the main objective that dictated the choice of material for the suspension components. Also as mentioned earlier the preference of low unsprung mass in the vehicular system, it was necessary to opt the material which could bear the forces induced during the motion as well be light.

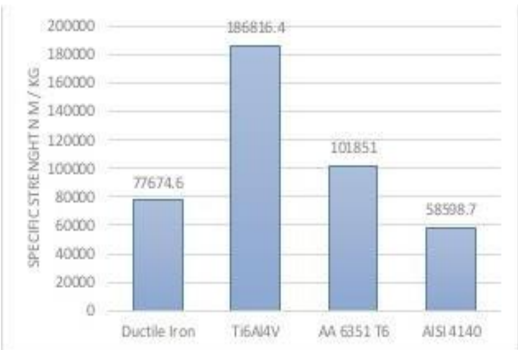
Market survey revealed the local availability of the following suitable material candidate for the component. 1. Cast Ductile Iron

2. Titanium Alloy Ti 6Al-4V

3. Aluminum Alloy AA 6351 T-6

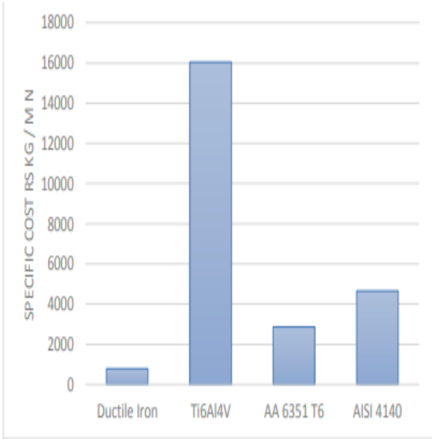
4. Alloy Steel AISI 4140

Specific Strength comparison It is the strength to weight ratio of the material. Strength here can be tensile or yield strength. A higher ratio dictates the material has appreciable strength compared to its weight.



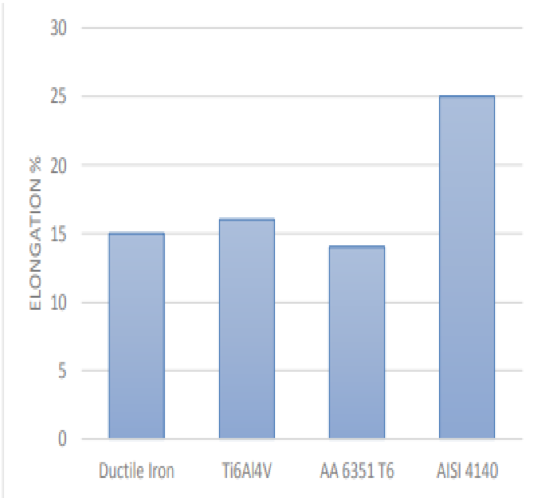
usage of titanium alloy

The above graphs shows the usage of Titanium alloy to be most apt choice for the component. Nevertheless other factors also have be considered before material selection is to be made.



cost of titanium vs other materials

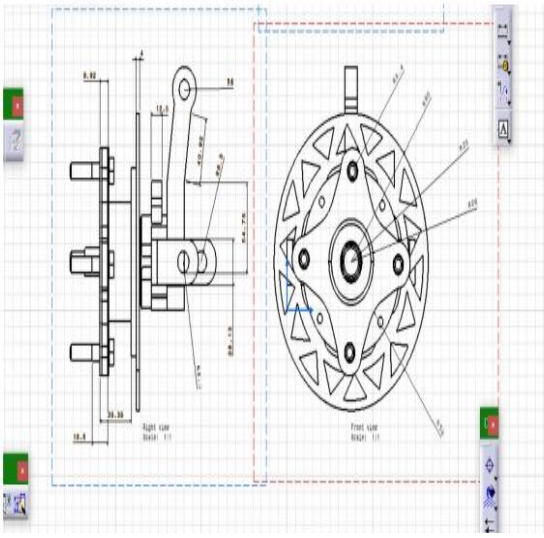
Ductility is Defined as the percentage elongation under stress before the material ruptures. This property is important as it gives a clear warning before the metal breaks down.



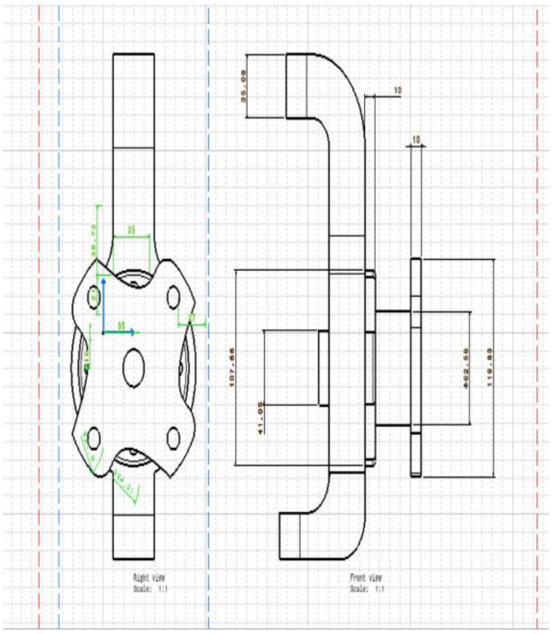
elongation of different materials

DESIGN OF HUB:

The design of wheel hub is important thing in reduction of weight of vehicle. The improvement in technology causes weight or mass reduction for this technology used are material selection, design analysis and optimization method. The whole mass or weight of vehicle is transfer to wheel by hub. Hub is attached to motor shaft which transfer the motion into wheel. The vehicle which required large speed such as sport car, it is require that their mass or weight should be



minimum. It is mandatory for a Designer to have knowledge of the product design and analysis, versatile optimization techniques, physical material selection



Fox suspension

Main design and functionality of dampers depends on type of fluid, material of spring, etc. Dampers of shocks are one of the pivotal components of a shock critical in the suspension system.

Some basic concepts that should be known to determine the damper force absorption phenomenon are

Type of Damping fluid used and all its properties

Proper equations governing the dimensions of a shock. Material selection for damper:
For Dampers -> Aluminium (Galvanized and its alloy) For Fluid-> Nitrogen and air
Damper values:

Damping Coefficient: 0.35 for rear and front.

Spring Constant : 17 Kn/m for front and 27Kn/m for Rear Mass under consideration(in front) : 320 kgs Damping is an influence within or upon an oscillatory system that has the effect of reducing, restricting or preventing its oscillations. In physical systems, damping is produced by processes that dissipate the energy stored in the oscillation.

As we saw, the unforced damped harmonic oscillator has characteristic equation, with $m > 0$, $b \geq 0$ and $k > 0$ $s^2 + bs + k = 0$ with characteristic roots.
There are three cases depending on the sign of the expression under the square root:

1. b2 < 4mk (this will be under damping, b is small relative to m and k).
2. b2 > 4mk (this will be over damping, b is large relative to m and k).
3. b2 = 4mk (this will be critical damping, b is just between over and under damping.

Mathematically, the easiest case is over damping because the roots are real. However, most people think of the oscillatory behavior of a damped oscillator. Since this is connected to under damping we start with that case.

Case-1: Under damping (non-real complex roots) If b2 < 4mk then the term under the square root is negative and the characteristic roots are not real. In order for b2 < 4mk the damping constant b must be relatively small. First we use the roots (2) to solve equation (1) Let The general real solution is found by taking linear combinations of the two basic solutions, that is: sinx(t) = c1e sin(ωd t)

Case-2: Overdamping (distinct real roots) If b2 > 4mk, then the term under the square root is positive and the characteristic roots are real and distinct. In order for b2 > 4mk the damping constant b must be relatively large. One extremely important thing to notice is that in this case the roots are both negative. You can see this by looking at the formula . The term under the square root is positive by assumption, so the roots are real. Since b2 − 4mk < b2 the square root is less than b and therefore the root −b + √b2 − 4mk < 0. The other root is clearly negative. Now we use the roots to solve equation

Case-3: Critical Damping (repeated real roots) If b2 = 4mk then the term under the square root is 0 and the characteristic polynomial has repeated roots, −b/2m, −b/2m. Now we use the roots to solve equation (1) in this case. We have only one exponential solution, so we need to multiply it by t to get the second solution.

Basic solutions: e−bt/2m, te−bt/2m. x (t) e −bt/2m = (c1 + c2t).

As in the overdamped case, this does not oscillate. It is worth noting that for a fixed m and k, choosing b to be the critical damping value gives the fastest return of the system to its equilibrium position. In engineering design this is often a desirable property. This can be seen by considering the roots, but we will not go through the algebra that shows this. Hence with the given values of b, k and m; the damping can be classified as under-damped.

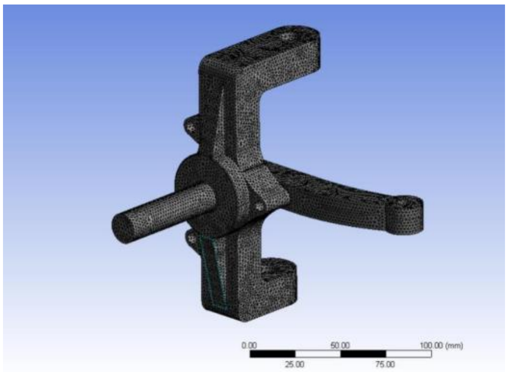
Design of the suspension system with the vehicle assembly

Front full assembly

Rear full assembly

ANALYSIS OF SUSPENSION SYSTEM

DETAILS	Suspension system 1	Suspension 2
Type of suspension system	Three step adjustable suspension	5 way adjustable nitrox suspension
Material	Structural steel	Chrome vanadium
Material specification	ASTM A227	ASTM A231
Young's modulus (EX)	207000 Mpa	79300 MPa
Poisson's ratio (PRXY)	0.25	0.25
Density	0.000007860kg/mm^3	0.000007860kg/mm^3



Analysis of vibration using ANSYS can be used to predict the failure of springs in suspension system. Moreover, Structural analysis approach using CREO and ANSYS would be used to reduce design cycle time, number of prototypes and more importantly, testing time and its associated costs.

ANALYSIS OF KNUCKLE

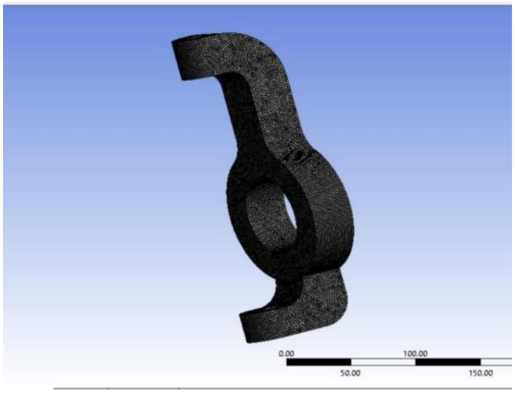
Mild steel EN24

Density 7.857 g/cc
Hardness, Rockwell =248 HB
Tensile Strength, Ultimate 850 MPa
Tensile Strength, Yield 680 MPa
Modulus of Elasticity 250 GPa

Poisson's Ratio 0.29

Result of ANSYS of knuckle: front knuckle

Max Stress= 198.27N/mm2



Max Deformation = 0.19 mm(front), 0.031095mm(rear)

Factor of Safety = 5(front), 2(rear)

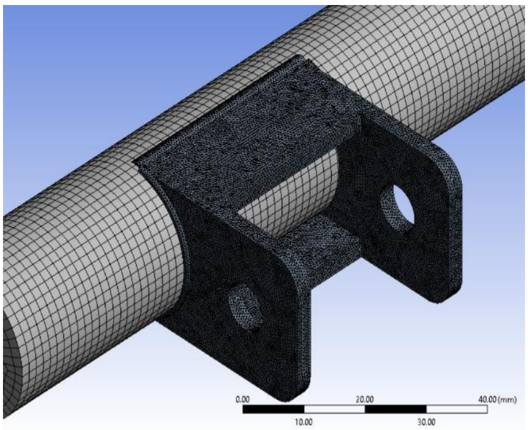
MESH TYPE	TETRAHYDRONS
MESH SIZE	2MM
CONSTRAINTS	TOP AND BOTTOM A-ARM POINTS
LOADS	10,000
FACTOR OF SAFETY	2.2

ANALYSIS OF HUB

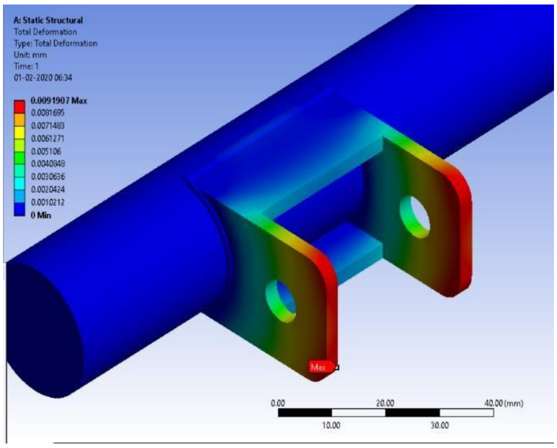
After getting the final optimization results and final geometry generation analysis of hub is done using ANSYS software.Meshing is done by keeping the element size as 2mm. The element size is selected according to the theory of meshing which suggests that on a smallest part of the model at least 2 elements should be present. Here the smallest hole diameter is 6mm.So we have taken the element size as 2mm.

MESH SIZE	2MM
MESH TYPE	TETRA HYDRON
LOADS	5000N LOADS WAS APPLIED ON HOLES
CONSTRAINTS	STUB-AXLE WAS FIXED
EQUIVALENT STRESS	0.02MPA
TOTAL DEFORMATION	0.07MM

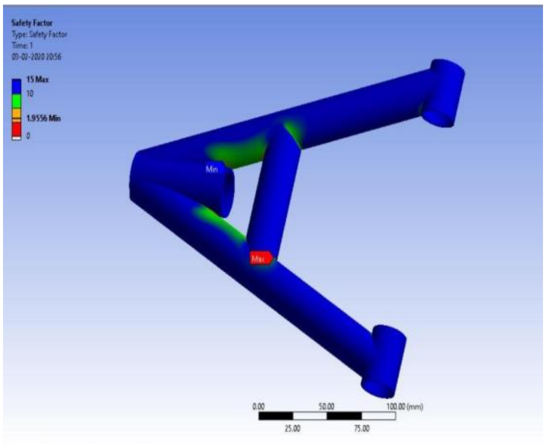
ANALYSIS OF WISHBONES



Meshing Of Wishbones/Arms



Analysis For Total Deformation



Analysis Of Wishbone For Factor Of Safety

Following forces will act on wishbones –

1) Wheel Reaction- The wheel exerts an upward normal reaction on the knuckle. This is the total sprung mass distributed as per the mass distribution of the vehicle. The value is found out to be 580N.

2) Spring force- The spring will exert a downwards force on the brackets. This force is calculated to be 1937N. The above force is calculated by considering the dynamic factor found out in Analysis of A-arm:

Image 4.3 shows the FEA analysis of front upper wishbone. As it can be observed from the image the component shows stress concentration near bearing sleeves, though the force at which the red zone has occurred it is a very critical section where failure can occur hence, in manufacturing extra care is been taken to avoid any possibility for defect occurrence. Image 4.3 shows the possible deflection in the upper wishbone due to same force as applied for the stress distribution analysis

After the analysis of the suspension system the following results are obtained:

Position of Center of gravity and roll center obtained from vehicle for better stability and comfortable ride for driver.

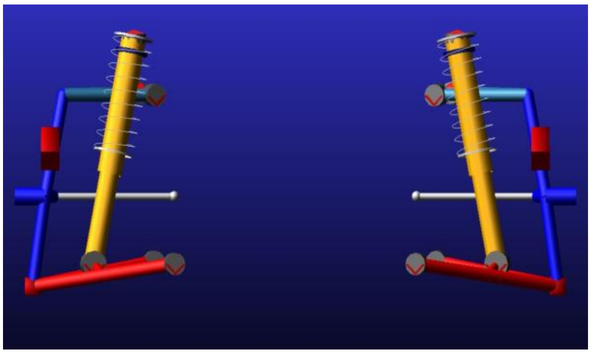
Distance from ground level hv= 12" Roll center at front = 12"

Roll center at rear = 17"

SIMULATION

PARAMETER	**FRONT** Max	Min	Static	**REAR** Max	Min	Static
Camber Angle	0.5	-1.3	-1.2	3.1	-4.5	-0.5
Caster Angle	10.3	10.2	10.2	10.9	10.1	-1
Static Toe	1.3	-0.5	0.5	0.745	-1.02	-1
Kingpin Angle	10.9	8	-8.7	-10.2	-10.4	-10.1
Scrub Radius	1.5 in	1 in	1.25cm	6.6cm	5.0cm	5.6cm
Roll Center	12 inch			17 inch		
Wheel Rate	18.1N/mm			18.9N/mm		
Stiffness	12.56N/mm			21.7N/mm		
Motion Ratio	0.7			0.76		

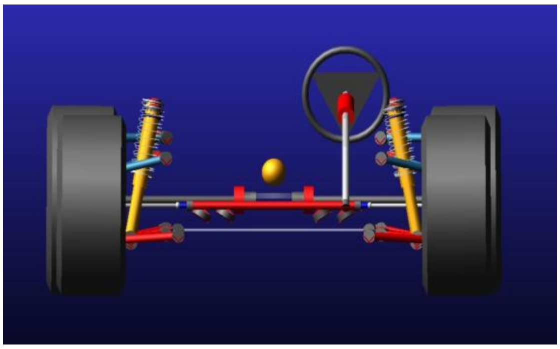
SIMULATION USING ADAMS:



ADAMs is an interactive motion simulation software for analyzing the complex behaviour of mechanical assemblies. ADAMs allows virtual testing of prototypes and optimize designs for performance, safety, and comfort, without building the physical prototypes. Building a solid model of the mechanical system from major CAD systems. Apply joints and constraints while creating articulated mechanisms of virtual prototypes. Various vehicle modules prepared in ADAMS system are:

a) Front Suspension System: Modelling of vehicle consists following subsystems; body, front suspension, steering, rear suspension, tire, powertrain and brakes. The vehicle used for this study is having double wishbone with coil spring type front suspension. Modelling of suspension system is begun with plotting hard points.

b) The hard point coordinates for front suspension are as per table 1, these points belongs to right hand side of the suspension. As the suspension is symmetrical about the vertical center plane of the vehicle, the left hand side hard points are found out by putting negative valve for the y- coordinate.



Assembly Subsystem .MDI_Demo_Vehicle_tilt.TR_Front_Suspension

	loc_x	loc_y	loc_z	remarks
hpl_drive_shaft_inr	267.0	-200.0	255.0	(none)
hpl_lca_front	67.0	-400.0	180.0	(none)
hpl_lca_outer	267.0	-750.0	130.0	(none)
hpl_lca_rear	467.0	-450.0	185.0	(none)
hpl_lwr_strut_mount	267.0	-600.0	180.0	(none)
hpl_subframe_front	-133.0	-450.0	180.0	(none)
hpl_subframe_rear	667.0	-450.0	180.0	(none)
hpl_tierod_inner	467.0	-400.0	330.0	(none)
hpl_tierod_outer	417.0	-750.0	330.0	(none)
hpl_top_mount	307.0	-500.0	680.0	(none)
hpl_uca_front	367.0	-450.0	555.0	(none)
hpl_uca_outer	307.0	-675.0	555.0	(none)
hpl_uca_rear	517.0	FRONT [illegible]	[illegible]	ne)
hpl_wheel_center	267.0	-760.0	330.0	(none)

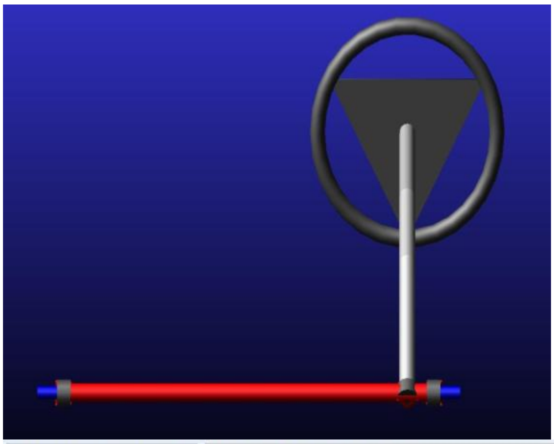
Front assembly stimulation

Assembly Subsystem .MDI_Demo_Vehicle_tilt.TR_Rear_Suspension

	loc_x	loc_y	loc_z	remarks
hpl_drive_shaft_inr	2875.0	-125.0	350.0	(none)
hpl_lca_front	2627.0	-400.0	240.0	(none)
hpl_lca_outer	2827.0	-750.0	190.0	(none)
hpl_lca_rear	3027.0	-450.0	245.0	(none)
hpl_lwr_strut_mount	2827.0	-600.0	200.0	(none)
hpl_subframe_front	2427.0	-450.0	235.0	(none)
hpl_subframe_rear	3227.0	-450.0	250.0	(none)
hpl_tierod_inner	3027.0	-400.0	350.0	(none)
hpl_tierod_outer	2977.0	-750.0	350.0	(none)
hpl_top_mount	2867.0	-500.0	700.0	(none)
hpl_uca_front	2927.0	-450.0	575.0	(none)
hpl_uca_outer	2867.0	-675.0	575.0	(none)
hpl_uca_rear	3077.0	-490.0	580.0	(none)
hpl_wheel_center	2827.0	-797.0	350.0	(none)

Rear Assembly

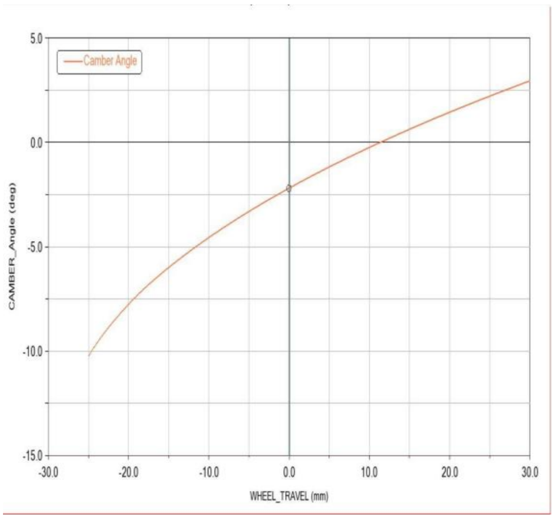
Steering System: The steering inputs required to vehicle are applied as motion or torque inputs at this joint. The steering rack part is connected to the vehicle body by a translational joint and connected to the tie rod by a universal joint. The translation of the rack is related to the rotation of the steering column by a coupler statement that defines the ratio.



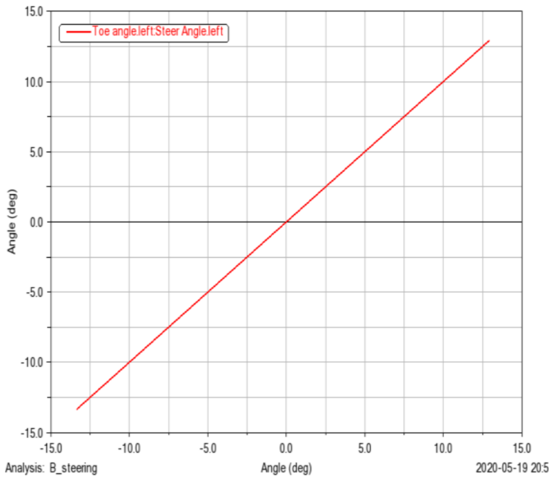
Assembly Subsystem .MDI_Demo_Vehicle_tilt.TR_Steering

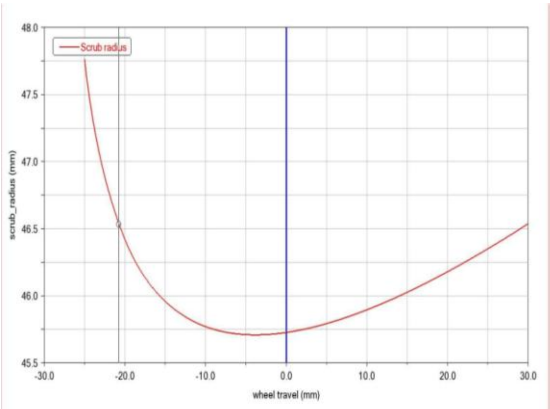
	loc_x	loc_y	loc_z	remarks
hpl_rack_house_mount	467.0	-350.0	330.0	(none)
hpl_tierod_inner	467.0	-400.0	330.0	(none)
hps_intermediate_shaft_forward	667.0	-300.0	530.0	(none)
hps_intermediate_shaft_rearward	817.0	-300.0	630.0	(none)
hps_pinion_pivot	467.0	-300.0	330.0	(none)
hps_steering_wheel_center	1167.0	-300.0	730.0	(none)

SIMULATING KINEMATIC AND COMPLIANCE ANALYSIS & MEASURING ITS CHARACTERISTICS:



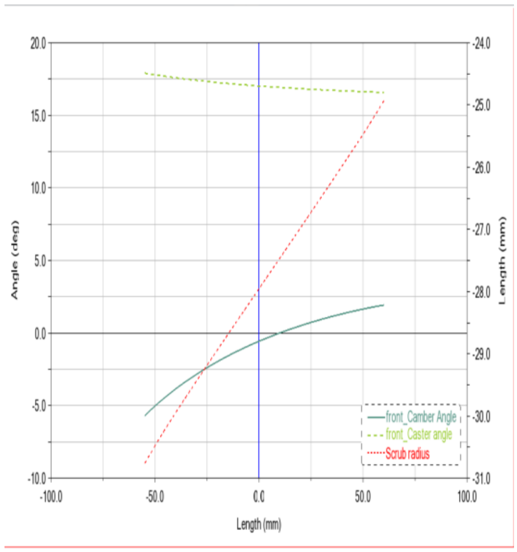
RESULTS



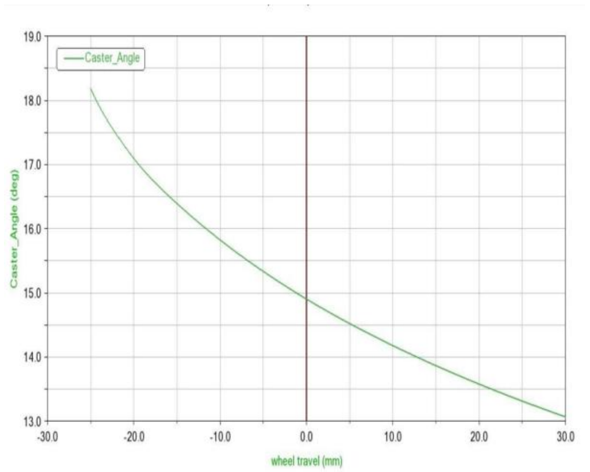


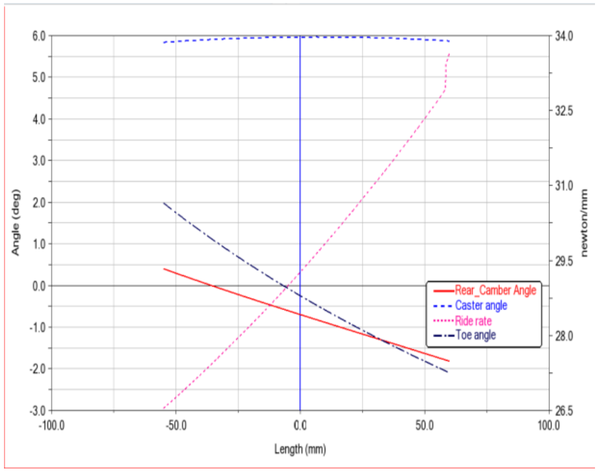
Toe angle
camber angle
Caster angle
scrub radius

FRONTASSEMBLYSIMULATIONGRAPHS:



REAR ASSEMBLY SIMULATION GRAPHS:





RESULT

PARAMETER	FRONT			REAR		
	Max	Min	Static	Max	Min	Static
Camber Angle	0.5	-1.3	-1.2	3.1	-4.5	-0.5
Caster Angle	10.3	10.2	10.2	10.9	10.1	-1
Static Toe	1.3	-0.5	0.5	0.745	-1.02	-1
Kingpin Angle	10.9	8	-8.7	-10.2	-10.4	-10.1
Scrub Radius	1.5 in	1 in	1.25cm	6.6cm	5.0cm	5.6cm
Roll Center	12 inch			17 inch		
Wheel Rate	18.1N/mm			18.9N/mm		
Stiffness	12.56N/mm			21.7N/mm		
Motion Ratio	0.7			0.76		

CONCLUSION

With the advent of automobiles, the importance of suspension and steering systems can never be underestimated; this fact is recognized by the designers of automobiles around the world. The suspension and steering systems play an integral role in allowing the vehicle to perform its basic functions. The suspension and steering system go all the way ahead to ensure the vehicle's safety during operation, on our part we made an intensive approach in studying the system in a way to understand and design.

We have made a tedious effort to reduce the unsprung weight which led us to design most of the assemblies on our own, which while being a gargantuan task was an experience of learning like no other, the division of phases, project planning has lead us to understand the atmosphere in a tight work environment.

The design process was first divided into design of links backed by kinematics, design of steering system backed by theory of steering by Ackerman, the process proceeded in design of components that incorporated the geometries obtained by the previous calculations. The design of components had to be approached in a way that incorporated machine design, stress-strain analysis and design of life of a component, the component also involved simulation, both static and dynamic, involved destructive testing, selection of bearings, material selection and failure analysis.

The fabrication has taught us the world of machining, where workmanship, the skill to operate the machines, CNC part programming is learnt and applied.

The final manufactured components which needed heat treatment were heat treated accordingly before assembly. The assembly process included the tolerance and types of fits, use of allen or hex bolts, torque wrech etc.To conclude the project, we feel we have achieved our objectives, fabricated innovative one of a kind ultra light weight components.

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