RESEARCH ARTICLE OPEN ACCESS

"Design and Analysis of Springs and Anti Roll Bar For Formula Student Car"

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ABSTRACT
The safe load of the spring with different materials by using Ansys workbench. This also includes modelling of springs in Catia. The suspension system is used to observe the vibrations from shock loads due to irregularities of the road surface. It performs its function without impairing the stability, steering (or) general handling of the vehicle. Generally, for formula vehicles coil springs are used as suspension systems. The present work attempts to analysis Anti-roll bar as part of a Formula vehicle suspension system which limits body roll angle. This U-shaped metal bar connects opposite wheels together through short lever arms and is clamped to the vehicle chassis with rubber bushes. Its function is to reduce body roll while cornering, and also enhances safety and comfort during driving. Anti-roll bar is chosen based on rolling stiffness and total deformation test by using Ansys workbench and designed in Catia.
Keywords - coil springs, anti roll bar, modeling, static analysis, Ansys

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I. INTRODUCTION

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed.Spring is use to cushion, absorb or control energy due to either shock or vibration as in car springs, railway buffers, air-craft landing gears, shock absorbers and vibration It is additionally use to maintain the contact between two component Also to apply forces, as in brakes, clutches and spring-loaded valves. To control the motion by maintaining contact between two elements as in cams and followers. To measure forces, as in spring balances and engine indicators. To store energy, as in watches, toys, etc.

In classical physics, a spring can be seen as a device that stores potential energy, specifically elastic potential energy, by straining the bonds between the atoms of an elastic material. Spring work on the hook's law of elasticity principle which states that the extension of an elastic rod is linearly proportional to its tension. Similarly, the contraction (negative extension) is proportional to the compression (negative tension).But the law actually holds only when the deformation (extension or contraction) is small compared to the rod's overall length . The Hooke's law cannot be applied beyond the elastic limit of a material . The elastic limit of a material differs from material to material .

TYPES OF SPRING

- Conical and volute springs
- Torsion springs.
- Laminated or leaf springs
- Disc or belleville springs
- Special purpose springs.
- Compression spring

ANTI ROLL BAR

The anti-roll bar itself is a simple piece of engineering. An anti-roll bar is a tube of metal that works as a spring between left and right wheels. An

anti-roll bar connects the vertical motions of the left and right wheels and works in parallel with the coil springs. During cornering, the outside wheel (be it front or rear) wants to move up in the wheel arch and the inside wheel wants to move downwards. If the two are disconnected then this would take place and the car would experience roll. With the two connected, via an anti-roll bar, the rising wheel is being held down by the falling wheel and vice versa therefore reducing the roll of the car. The bar resists twisting, or torsion, through its torsional rigidity. The stiffer the bar, the less the car leans in turns.
This is due to an anti-roll bar increasing the amount of force upon the outside tyre when cornering. Due to this, the stiffer the anti-roll bar, the more lateral load transfer that occurs across it.. When a car is cornering the roll bar will be forced to twist and become active taking effect upon the suspension system and working in parallel with the coil springs to control the car.

CALCULATION

The spring calculations are derived from optimum k tech tips,

$$\frac{\square}{A_y} = \frac{-WxH}{K\varphi R + K\varphi R}$$

Where,
$\square$=roll angle in degrees
A_y=lateral acceleration in G's
W=total weight of vehicle in newtons
H=center of gravity height in m's
$K\varphi R$=roll rate at front in newton-meter/degree
$K\varphi R$=roll rate at rear in newton-meter/degree

Here the roll angle is 1.5, lateral acceleration calculated for 30kmph speed of car taking a turn of 5m radius.

$$A_y = \frac{v^2}{r} = \frac{30*30}{5}$$

The obtained lateral acceleration is 1.41g
And the total weight expected to be 3200N.
H=0.3m.
The total roll rate ($K\varphi R + K\varphi R$ **)=902.4Nm/degree roll.**
Then the obtained roll rate is split into front and rear, the front roll rate must be greater than rear to reduce the oversteer of the vehicle.
The frontal roll stiffness=500Nm/degree roll.
The rear roll stiffness=402Nm/degree roll.
Spring rates:
To calculate spring rates=wheel rate/motion ratio^2
Spring rates at front=4*pi^2*fr^2*Msm/mr^2.
Fr=frequency at front,
Msm=sprung mass at front,
Mr=motion ratio of spring,
We considered frontal frequency=2.2,
And our frontal sprung weight=120,
Motion ratio=1,
Hence, we got our front spring rates=22.9=23N/m.
And, the rear spring rates=20.5N/m.

Force

Static condition

Total weight of our formula student car including the driver is 320kg.
The weight distribution of our car is 45:55 i.e
Weight distribution in front =45% of total weight of car
Load on front spring = 144kg
Load on each spring = 144/2
= 72 kg
In Newton = 720N
Weight distribution in rear spring =55% of total weight of car
Load on rear spring = 176kg
Load on each spring = 176/2
= 88kg
In Newton = 880N

Cornering

We know that cornering force = lateral load transfer
W = w*h*a/t.w

$$W = \frac{320*9.81*0.3*1.5}{1.2}$$

W = 1103.625
Where w = car weight
h= centre of gravity
a_y=lateral acceleration
t.w= track width
We know front load on the spring = 720N
Load on rear spring = 880N
Now add on weight due to cornering on front spring is 45% of 1103.625 =496.25N
Rear spring is 55% of 1103.625= 606 N

- Front spring = 720+496.25
  = 1216 ≅1220N
- Rear spring = 880+606
  = 1486.66 N

Cornering and acceleration (rear spring)

Due to cornering weight on rear spring = 1486N
V=60kmph ≅ 16.00m/sec
v^-u^=2as[from kinematic equation]
16.6-0 =2*a*80
a=16.6^/2*80
a=1.75m/sec sq
longitudinal weight transfer take place from front to rear

$$W = \frac{w*h*ay}{w.b}$$

Where w = car weight
h= centre of gravity
a_y=lateral acceleration
w.b = wheel base

$$W=\frac{320*0.3*9.81*1.75}{1.5}$$

W= 1086.16N
Total load = 1486+1086.16/2
=2029N

Braking and cornering (front spring)
Cornering weight on front spring =1220N
In braking longitude load transfer take place from rear to front

$$W=\frac{w*h*a}{w.b}$$

$$W=\frac{320*0.3*9.81*2.7}{1.5}$$

W =2542/1.5
W = 1685.16
So total weight on front spring
= 1220+ 1695.16/2
= 1220+842= 2067N

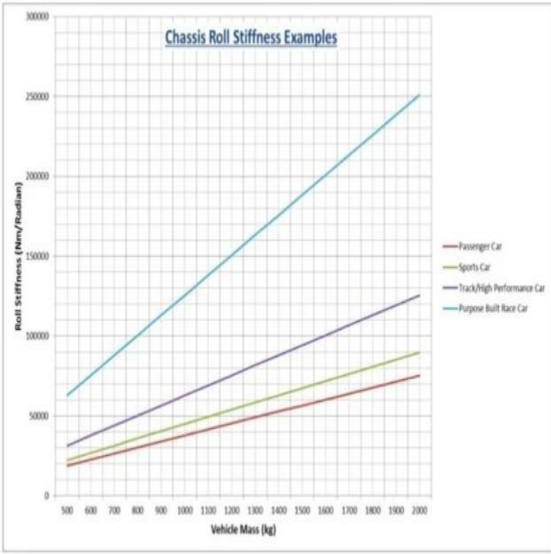
ANTI ROLL BAR
After calculating the spring rates, anti-roll bar rates are calculated based on the total rate on each axle and spring rate corresponding to roll.
We know that roll rate at front=350Nm/degree, rear roll rate=230Nm/degree
Tire stiffness is assumed to be 25kg/mm.
Additional roll rate required is given by,

$$k_{\square A}=\frac{\pi}{180}\left(\frac{K\varphi DES*KT*\left(\frac{t2}{2}\right)}{\left[KT*\left(\frac{t2}{2}\right)*\frac{\square}{180}-K\varphi DES\right]}\right)-\left(\frac{\pi*KW*\frac{t2}{2}}{180}\right)$$

K φ A = Total ARB roll rate needed (Nm/deg roll).
KW = Wheel rate (N/m).
t = Average track width between front and rear (m).
K φ DES = Desired total roll rate (Nm/deg roll).
K T = Tire rate (N/m).
By using this equation additional roll rate required is found to be=372Nm/degree
This is the anti-roll bar rate required to the car
This total rate can be divided to the front and rare of the car according to the equation,
Front anti-roll bar stiffness:

$$k_{\square FA}=\frac{K\varphi A*Nmag*MRFA2}{100}$$

K φ FA = FARB roll rate (Nm/deg twist)
KφA = Total roll rate (Nm/deg roll)
Nmag = Magic Number (%)
MRFA = FARB Motion ratio.
Note: As a baseline, use 5% higher Magic Number than the static front weight distribution.
Let the frontal weight distribution is 45% hence, magic number is assumed to be 50%.
The frontal antiroll bar rate=176Nm/degree.



The above graph is drawn between the roll stiffness and the vehicle mass. This Graph is very useful to determine the roll stiffness of our formula student car by considering the vehicle mass (including the driver)

● ***MODELLING***
The geometric model of the spring and anti roll bar is created using the CATIA software .Geometric modeling is a branch of applied mathematics and computational geometry that discusses the mathematical methods behind modeling the realistic objects for computer graphics and cad . The part design Module it is considered from most important modules, that used by the designer to get the additional advantage from cad programs, which is stereotaxic drawing or three-dimensional drawing**.**

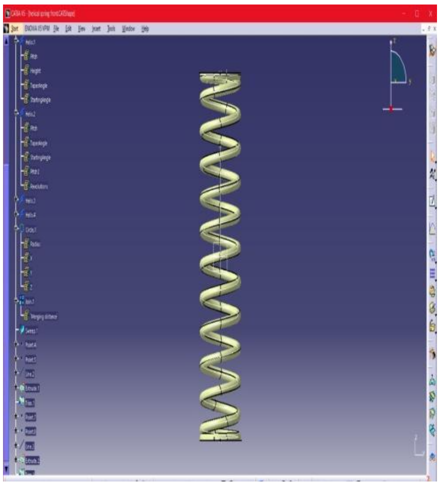


Fig: 3D diagram of the front spring

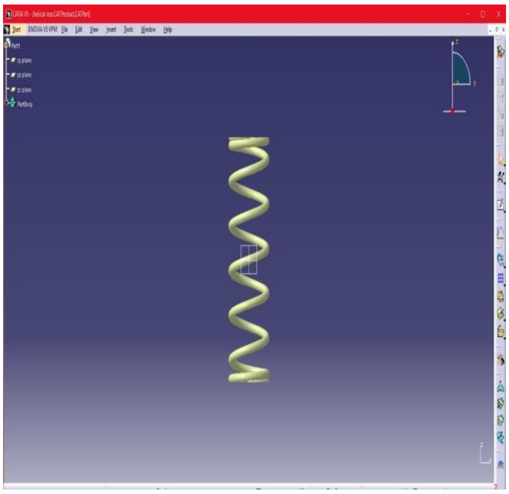


Fig: 3D diagram of rear spring

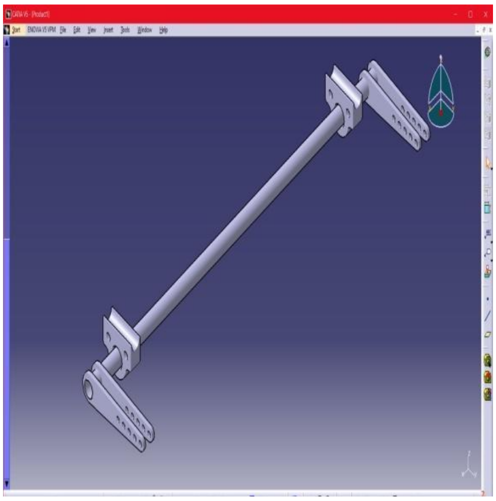


Fig: Complete assemble of the anti roll bar along with bushes

ANALYSIS

Steps Involved

1. Defining the Engineering Data
2. Importing the developed Spring and anti roll bar in STEP format file under geometry.
3. In Model analysis,
   a) Generate the mesh
   b) Applying a fixed support
   c) Apply force
   d) Insert Total Deformation
   e) Evaluating the Result
4. In Static Structural analysis, apply the boundary conditions applying gradually increasing loads and evaluating the results.

II. RESULT

For the front spring the maximum force on the spring will occur when the car is in the braking with cornering condition. So if the spring satisfies this condition then it will satisfy all the conditions.

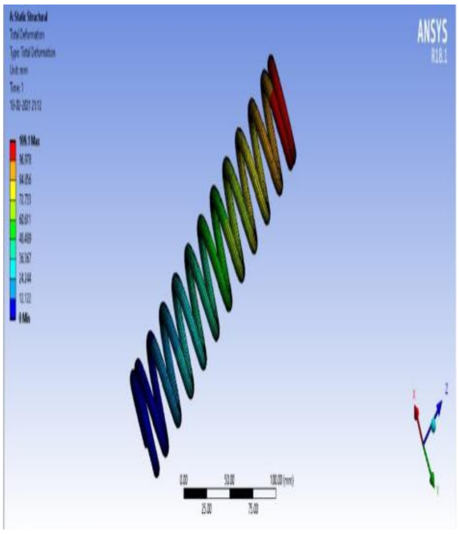


Fig: Maximum and minimum value of Total deformation of front spring

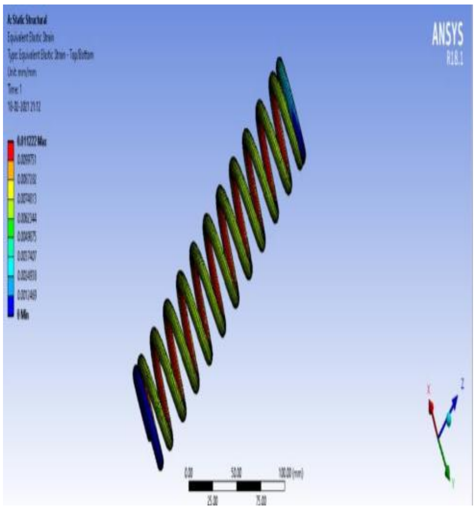


Fig: Maximum and minimum value of Equivalent elastic strain of front spring

For the front spring the maximum force on the spring will occur when the car is in the acceleration with cornering condition. So if the spring satisfies this condition then it will satisfy all the conditions.

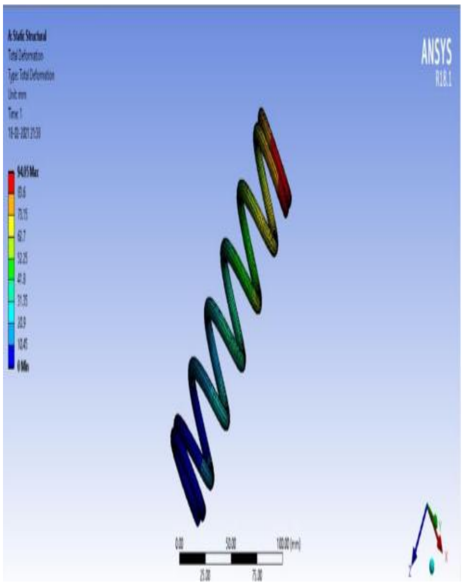


Fig: Maximum and minimum value of Total deformation of rear spring

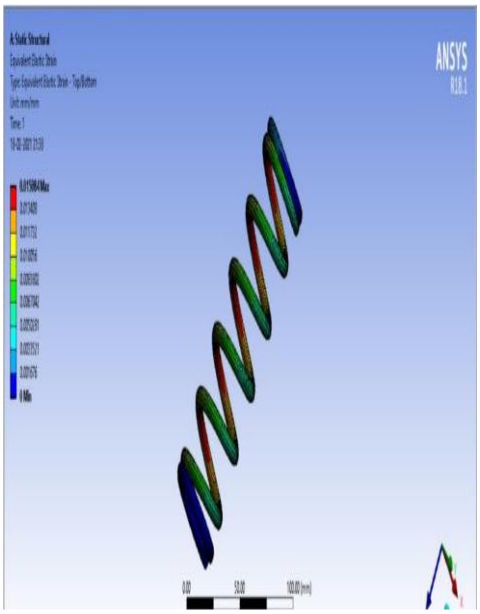


Fig: Maximum and minimum value of Equivalent elastic strain of rear spring

For the anti roll bar the maximum force on the spring will occur when the car is in the braking with cornering condition. So if the anti roll bar satisfied this condition then it will satisfy all the conditions.

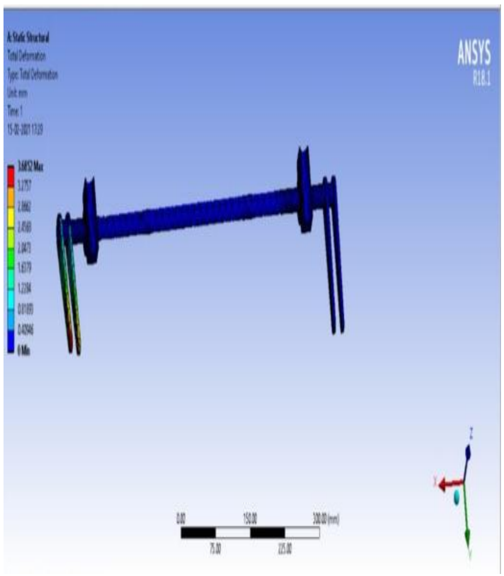


Fig: Maximum and minimum value of Total deformation of anti roll bar

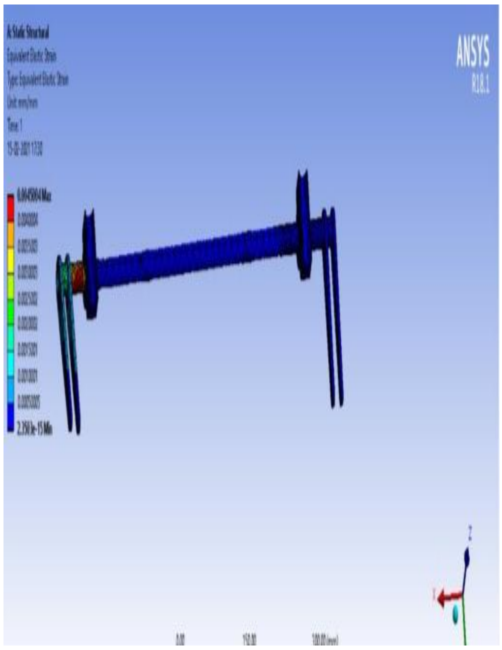


Fig: Maximum and minimum value of Equivalent elastic strain of anti roll bar

Front Spring

	Force (N)	Equivalent elastic strain	Total deformation(N/mm)	Equivalent stress (Mpa)
Static	720	0.003909	38.003	746.86
Cornering	1215	0.0066235	64.394	1265.5
Braking with cornering	1700	0.011222	109.1	2144.1

REAR SPRING

	Force (N)	Equivalent Elastic strain	Total deformation (mm)	Equivalent stress (Mpa)
Static	880	0.0065423	1253	40.791
Cornering	1485	0.011048	2115.8	68.881
Cornering With acceleration	1300	0.015084	2888.9	94.05

Anti Roll Bar

	Force (N)	Equivalent elastic	Total deformation(mm)	Equivalent stress
Cornering +Bump	1200	2.64e-003	2.16	527.37
Cornering +braking	1700	4.50e-004	3.63	896.52

III. CONCLUSION

In this project we have design and analysis the spring and anti roll bar , that we have to use in our formula student car .The theoretical calculation was carried based on the rules of the event organizer. From our calculation we find out that the more force was applied on the spring when the formula car at cornering with braking and anti roll bar it receive more force at cornering with the bump and braking. From analysis we have found out that the spring and the anti roll bar satisfied all the cases at the maximum. So in this way the spring are designing in this way.

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