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Articulated Suspension System

Mr. Sahil Darekar, Mr. Vinay T., Mr. Swapnil Kendre, Dr. N. K. Nath
Department of Mechanical Engineering
JSPM's Rajarshi Shahu College of Engineering, Pune, Maharashtra, India

Abstract: *The Suspension system is one of the most important aspects of a vehicle, since it fulfils all the shock absorbing functions and requirements. The findings of this research provide a useful design system to improve the absorbing performance of suspension system. This paper present design and development of suspension system that will be based on the functional movement of human knee joint implementing Biomimicry and Utilization torsional spring.*

Keywords: Suspension system

I. INTRODUCTION

Meaning of Suspension system

Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems must support both road holding/handling and ride quality, which are at odds with each other. The first suspension to be introduced is from horse-drawn carriages in the 19th century, it is still under the process of development. This development is regarding:

1. Cost
2. Efficiency
3. Maintenance
4. Weight
5. Shock Absorber

Problem Statement

The conventional and common type of the front suspension used in motorcycle is Telescopic forks. But this system has some problems such as uneven vibration, leakage of oil, changing of wheelbase, uneven compression of shock absorbers etc. Due to uneven vibrations the rider experience discomfort and this leads to medical issues to the rider. The heating causes wear and tear of the shock absorber.

Why Articulated Suspension System

The advantages of articulated suspension system over telescopic suspension system are as follows:

1. Input action for system is in vertical and horizontal direction.
2. Torsion spring is used which is good in restoring forces.
3. The design is integrated and simple.
4. The weight is less.
5. The nose dive is less

II. LITERATURE REVIEW

Development of a New Suspension System Using a Knee-joint Mechanism.

(Technical Solution to Alternative Transportation Problem SP-1189)

The Development of new suspension system carried out by emphasizing the imitation and utilization of the movement of the knees as a natural shock absorber.

Design and Analysis of Shock Absorber (ISSN: 3219-*1163)*

Design of a 3D model of a shock absorber after doing structural and model analysis of considering various structural loads and human load on different materials of springs.

Material Optimization of Automotive Shock Absorbers.
(ISO 3297: 2007 Vol.5 Issue 12, December 2016)

The report follows a detailed design and methodology as well as the factors affecting the criteria for selection of best material for shock absorbers. It encompasses several iterations for various materials to establish a reasoning for the most suitable material.

Design and analysis of Front Mono Suspension in Motorcycle.
(ISSN: 2320-334X Vol.2 Ver.VI 2015).

Design of Mono Front Suspension to eliminate the torque to the swing arm and provide more consistent handling and braking, to reduce stress and make it easier to adjust the shock absorber.

Vibration Analysis of a Two-Wheeler.
(Analytically) (ISO 3297: 2007 Certified Organization.)

The Mathematical Model is analysed by analytical method for vertical vibrations responses of the rear seats to vertical input (sinusoidal) applied to wheels.

III. CONSTRUCTION

The suspension system based on the articulation of knee and its impact dampening capability is constructed by mimicking its structure based on the human knee where the Upper arm represents the thigh bone whilst the lower arm represents the shin bone.

The upper arm and lower arm are attached via a bushing coupled with a torsion spring where the spring is attached to the main part of the arm through an internal bore which holds the end of the spring.

The integrity of spring is maintained by providing a shaft through the spring in between the coils; such that when exerted to impact the spring would not leave its body due to sudden load differential.

The damper is attached to the upper and lower arms respectively for absorbing the Impact of the quick reaction of torsion spring's restoring force; The measured distance is 1/3rd of total length of the upper arm and 2/3rd distance from the total length of lower arm starting from spring/pivot point.

The arms are provided with a curvature of 8R to handle the impact and its construction is hollow from inside leading to a crisscross patterned truss such that it retains its rigidity and integrity.

Parts in the assembly:

- Upper arm
- Lower arm
- Torsional Spring
- Damper
- Shaft pin

IV. WORKING

Working of the Suspension System

- The Human Knee Joint (Articulated) Suspension system is an acute representation of what it would be like to mimic the property of the part of a human body.
- The mechanism works by splitting and converting the original fork suspension system into two different arms; representing a Knee.
- The arms represent the Bone in the human thigh whilst the spring acts as Muscle and the damper acts as Tendons which hold and forces the muscles in arm to contract and expand in controlled manner.
- When the suspension system travels on the uneven road surface the Tire maintains the road contact and whilst returning the impact/force is absorbed by the spring which springs back to its original state quickly, to prevent such action (such quick uncomforting motion) damper is placed between two arms such that the returning motion is compensated to accomplish comfort yet at the same time performance.

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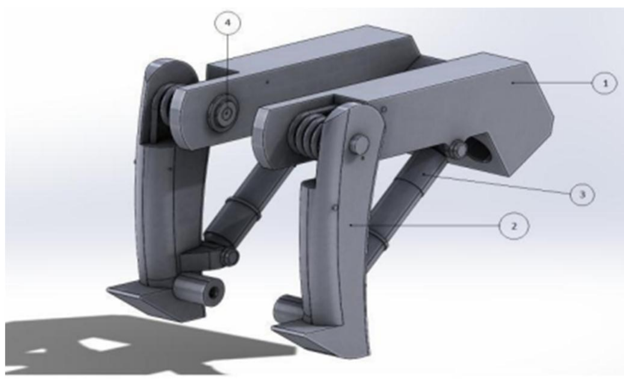
- When the tyre is in contact to the road surface and waves/bumps are created the spring absorbs the shock experienced by the tire from its sudden displacement the spring contracts radially and expands releasing its stored energy from compression, the released energy should not be exerted rapidly to avoid shock to the rider hence

Damper are mounted on each side of the arm to provide cushioning effect as well as a lenient way for the arms to stay stable during banking/cornering. The Arm should not fall to the subjected force of the bike with the weight of rider hence the arms are given a curved profile to enhance its strength as well as its Aesthetics.

The point of making such changes to a pre-existing suspension system is that there is no balancing effect on the front suspension system when cornering/banking, here the articulated system helps by distributing the load from back of the front wheel to its centre.

V. METHODOLOGY

Based on the Knowledge attained from the research, literature Survey conducted and general information available on social media, following steps were followed to get the desired outcome:
Detailed drawing is generated showing how in general we can assemble the mechanical components together, which will also give a general idea about the mechanism we need to install:



Detailed diagram of the suspension system

Component Specifications as marked in the above diagram.

1. Upper Arm: L-385mm_W-100mm_T-80mm
2. Lower Arm: L-297mm_W-100mm_T-60mm
3. Damper (3.4.1.2. Damper)
4. Steering shafts distance - 205mm
5. Link shaft: D - 20mm

5.1 Material Selection

Upper and Lower Link

The material used for upper and lower link is AHSS (Advanced High Strength Steel). Properties of AHSS (Advanced High Strength Steel)

- Low weight
- High Strength
- Optimised Formability
- High Stiffness
- Yield Strength more than 550 MPa.

Torsional Spring

The material used for torsional spring is Beryllium Copper.
Properties of Beryllium Copper:

- High Strength
- Sustain High temperature

- Wear resistance
- Fatigue resistance

Damper

The material used for damper body is steel and for the rod material is Chrome plated steel Properties of damper:

- Durable
- Shock Resistance
- During the operation damper gets less heated.

Calculation of Spring Constant

Spring terms:

- Inside diameter (Di):40mm
- Outside diameter (Do):60mm
- Mean diameter (Dm):50mm
- Length of spring (L):73.71mm
- No. of active coils (Na): 4
- Wire diameter (d): 10mm
- Leg length (a): 25mm
- Spring force (F): 2501.55N

Calculation:

Moment = F×a =2501.55×25

(M) =62538.75N-mm

Spring Index (C)= Dm/d =50/10

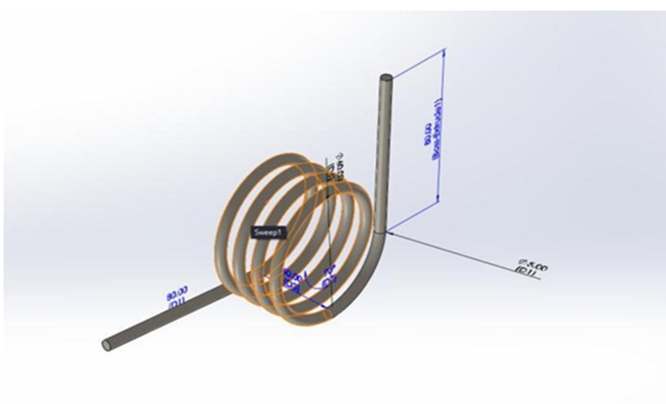
(C)=5

Spring Constant (S)

S=32M/ (π×d) ×4c^2-c-1/4c(c-1)

=32×62538.75/ (π×10) × (4×(5)^2-5-1)/4×5×(5-1)

S= 764.417N/mm²



Torsion Spring Specifications

Motion Analysis

Assumption of a simple model of motor vehicle as a bike that can vibrate in the vertical direction while travelling over rough road. Vehicle has mass of 192 kg (including weight of passenger). The suspension system has a spring constant of 764.417 N/m (Calculated by online spring stiffness calculator) and a damping ratio of ε = 0.577 for vehicle speed 20, 40, 60 Km/Hr. the road surface varies sinusoidal with an amplitude of Y = 0.05 m and wavelength here I consider 6 m,

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Spring Stiffness calculation: as on the basis of dimensions measured from shock absorber
Wire diameter (d) = 10 mm, no of active coils (n) = 4, Outer diameter of spring coil = 70 mm, Mean diameter of spring coil = 60 mm, Force on spring = 2501.55N.

Damping Coefficient(C):
$C = WD/ (\pi\times w\times X) = 300/ (\pi\times 17.44\times 0.0124)$
C =441.57 Ns/m
Critical Damping (Cc):
$Cc= 2mWn= 2\times 192\times 1.992$
Cc= 764.928

Damping ratio:
€= C/Cc= 0.577
Frequency $(\omega) = 2\pi f= 2\pi\times (V\times 1000/3600\times 6)$
$\omega= 0.29089 \times V$ rad/s

Natural Frequency (ωn) = 1.995 rad/s
For V1 = 20km/hr, ω = 5.8178 rad/s
For V2 = 40km/hr, ω = 11.64 rad/s
For V3 = 60km/hr, ω = 17.45 rad/s

Frequency Ratio (r)
(r) 20km/hr= 2.91
(r) 40km/hr = 5.832
(r) 60km/hr = 8.748

For 20 km/hr,
Amplitude Ratio is:
(X1/Y) =√1+(2∗€𝑟)2(1−𝑟2)2+(2€𝑟)²
= ✓ (1+ (2×0.5×2.91)^2)/ ✓(1-2.91^2)^2 +(2×0.5×2.91)^2)
(X1/Y) 20 km/hr = 0.384

Displacement Amplitude of vehicle at different road amplitude:
$X1 = 0.384 \times 0.05 = 0.0192$m
$X1 = 0.384 \times 0.1 = 0.0384$m
$X1 = 0.384 \times 0.15 = 0.0576$m
$X1 = 0.384 \times 0.2 = 0.0768$m

Acceleration: -
$\ddot{X}1 = -\omega^2 X1 = - (5.8178)^2 \times 0.0192 = 0.649$m/s
$\ddot{X}1 = - (5.8178)^2\times 0.0384 = 1.299$m/s²
$\ddot{X}1 = - (5.8178)^2 \times 0.0576 = 1.95$m/s²
$\ddot{X}1 = - (5.8178)^2 \times 0.0768 = 2.599$m/s²

For 40Km/hr,
Amplitude Ratio is:
(X2/Y) = √1+(2∗€𝑟)2(1−𝑟2)2+(2€𝑟)²
(X2/Y) 40km/hr = 0.177

Displacement Amplitude of vehicle at different road amplitude:
X2= 0.177 × 0.05 = 0.00885m
X2= 0.177 × 0.1 = 0.0177m
X2= 0.0177 × 0.15 = 0.02655m
X2= 0.0177 × 0.2 = 0.0354m

Acceleration
$\ddot{X}2 = -(11.64)^2 \times 0.00885 = 1.199 m/s^2$
$\ddot{X}2 = -(11.64)^2 \times 0.0177 = 2.398 m/s^2$
$\ddot{X}2 = -(11.64)^2 \times 0.02655 = 3.597 m/s^2$
$\ddot{X}2 = -(11.64)^2 \times 0.0354 = 4.796 m/s^2$

Similarly,
For 60Km/hr,
Amplitude ratio is:
(X3/Y) 60Km/hr = 0.2857

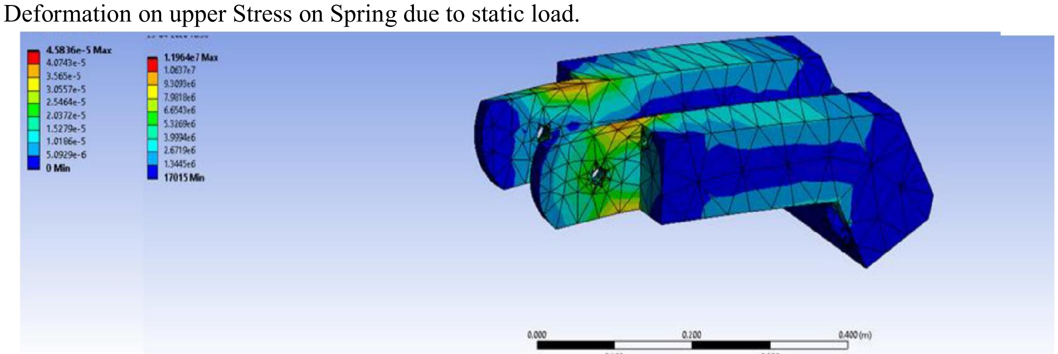
Displacement Amplitude of vehicle at different road amplitude:
X3 = 0.2857×0.05 = 0.0142m
X3 = 0.2857×0.1 = 0.02857m
X3 = 0.2857×0.15 = 0.04285m
X3 = 0.2857×0.2 = 0.05714m

Acceleration:
$\ddot{X}3 = -\omega^2 X = -17.45^2 \times 0.0142 = 4.32 m/s$
$\ddot{X}3 = -17.45^2 \times 0.02857 = 8.69 m/s$
$\ddot{X}3 = -17.45^2 \times 0.4285 = 13.04 m/s$
$\ddot{X}3 = -17.45^2 \times 0.05714 = 17.39 m/s$

Speed (km/hr)	Road one 0.05m/s²	Road two 0.10m/s²	Road three 0.15m/s²	Road four 0.2m/s²
20	0.649	1.299	1.95	2.599
40	1.199	2.348	3.597	4.796
60	4.32	8.69	13.04	17.39

The acceleration is to be measured with assumption of different road conditions and at two different speed:

Ansys Analysis
Maximum Deformation on upper Stress on Spring due to static load.



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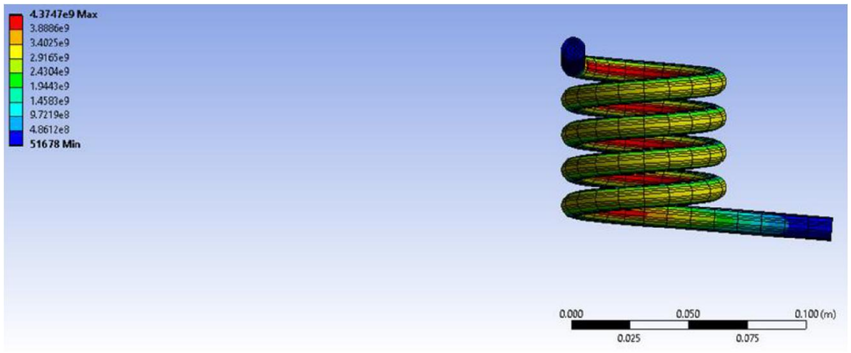
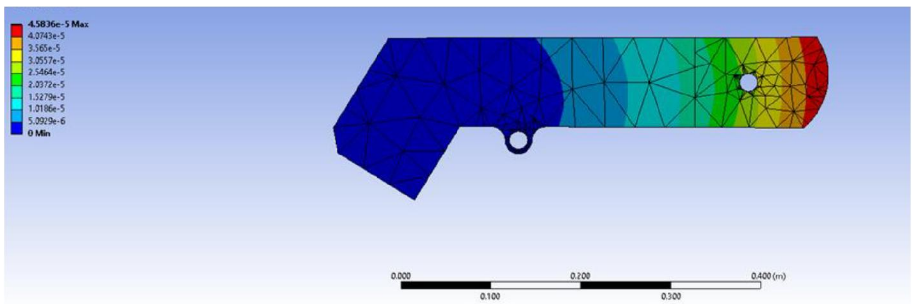
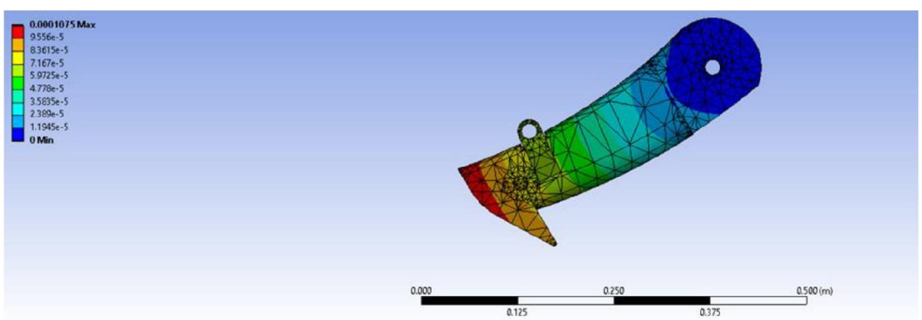
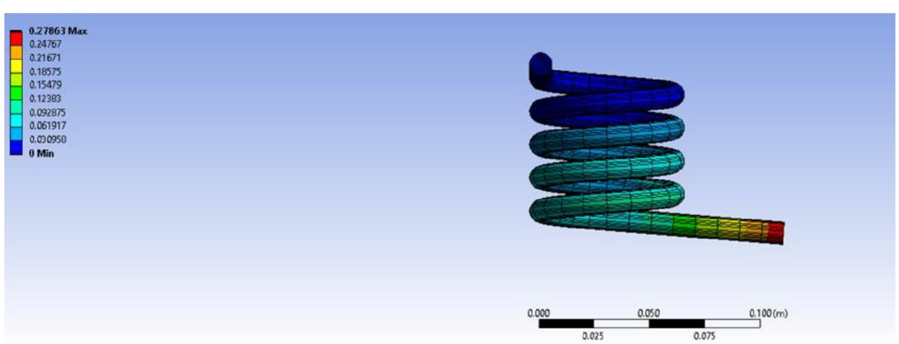




Stress on Upper link from static load.

Maximum stress on lower





Spring Deformation under maximum load

Comfort level reference

ISO standards with respect to the vibration exposure and its effects on health of rider/driver.			
Exposure duration in Hrs	International standard		
	ISO 2631-1,1997 Average RMS acceleration limits in m/s2		
	Likely health risk	Caution zone	Comfort level
8	0.8	0.5	0.315
12	0.7	0.4	0.315

Iso standards with respect to Vibration exposure and its effects on rider.
The reference comfort range is in between 0.218m/s2 to 0.315m/s2.

VI. RESULTS

From the following ANSYS Calculation:

1. The maximum displacement on upper arm: 4.5836e-5m.
2. The maximum displacement on lower arm: 0.0001075m.
3. The maximum displacement on spring:0.27863m.
4. The maximum stress on spring: 4.3747e9 Pa.
5. The maximum stress on upper arm:1.1964e7 Pa.

VII. APPLICATIONS

Following are some Applications:

1. Used for Prosthetic Leg.
2. This system used for all terrain vehicles.
3. Used for Robotic Legs.

VIII. CONCLUSION

- It is found that the new system provides better comfort to rider.
- The articulated suspension system provides the suitable comfort level and has a different Aesthetic for the future generation of two-wheeler vehicles.

IX. FUTURE SCOPE

In future we are planning to perform Dynamic analysis to the Articulated suspension system and implement the system in medical field such as Prosthetics. Also, in the field of robotics.

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