MODELING AND ANALYSIS OF TWO WHEELER SUSPENSION SPRING

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ABSTRACT:
In vehicles problem happens while driving on bumping road condition. Vehicles suspension system has to perform complexity requirements, which includes road holding and equality, driving pleasure, riding comfort to occupant. The objective of this paper is to analyze the performance of shock absorber spring by varying stiffness, which is obtained by doing optimization using genetic algorithm as optimization tool to obtain maximum ride comfort. The Shock absorber which is one of the Suspension systems is designed mechanically to handle shock impulse and dissipate kinetic energy. It reduces the amplitude of disturbances leading to increase in comfort and improved ride quality. The spring is compressed quickly when the wheel strikes the bump. The compressed spring rebound to its normal height when the weight of the vehicle pushes the spring down spring resist deformation. The spring is an elastic object used to store mechanical energy. They can twist, pulled or stretched by some force and can return to their original shape when the force and is released. The compressed spring rebound to its normal dimension or normal loaded length which causes the body to be lifted. The spring goes down below its normal height when the weight of the vehicle pushes the spring down. This, in turn, causes the spring to rebound again. The spring bouncing process occurs over and over every less each time, until the up-and-down movement finally stops. The vehicle handling becomes very difficult and leads to uncomfortable ride when bouncing is allowed uncontrolled. Hence, the designing of spring in a suspension system is very crucial.

The present work is carried out on modelling, analysis and testing of suspension spring is to replaced by different material for two wheeler vehicle the stress and deflections of helical spring is going to be reduced by using the new material.

Thus in this project we designed the suspension spring for three bike models splendor, tvs and Yamaha and by applying two materials alloy steel and chromium vanadium steel analysis is carried out in ansys.

Introduction

The suspension system is one of the main parts of the vehicle, where the shock absorber is designed mechanically to handle shock impulse and dissipate kinetic energy. In a vehicle, shock absorbers reduce the effect of traveling over rough ground, leading to improved ride quality and vehicle handling.

Fig: suspension spring
While shock absorbers serve the purpose of limiting excessive suspension movement, their intended sole purpose is to damp spring oscillations. Hysteresis is the tendency for otherwise elastic materials to rebound with less force than was required to deform them. Hence, the designing of suspension system for vehicle is very crucial. In modeling the time is spent in drawing the coil spring model and the front suspension system, where risk involved in design and manufacturing process can be easily minimized. So the modeling of the coil spring is made by using SOLID WORKS. Later the model is imported to ANSYS for the analysis work.

Suspension Systems

Shock absorbers are important part of vehicle's suspension, which is fabricated to reduce shock impulse. Shock absorbers work on the principle of fluid displacement on both the compression and expansion cycle. The modern motorcycle uses suspension to accomplish several things; it provides a smooth comfortable ride absorbing bumps and imperfections in the road. It also allows the rider to fine tune the machine to give him/her better control over the machine when riding. Motorcycles with only one shock absorber are called mono shock motorcycles. When mono suspension is mentioned everyone should remember that it should be on the rear side. The performance of mono suspension motorcycles is vastly superior to twin suspension motorcycles. They are used not only in automotive industries but are also used in various other manufacturing and processing industries.

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 tuning of suspensions involves finding the right compromise. It 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.

Introduction to Shock Absorbers

Shock absorbers are important part of vehicle's suspension system, which is fabricated to reduce shock impulse. Shock absorber minimizes the effect of travelling on a rough ground. Modern vehicles are designed with strong shock absorbers to tolerate any type of bouncy conditions. If supposedly shock absorber is not used then to control excessive suspension movement, stiffer springs will be used. The shock absorbers duty is to absorb or dissipate energy. One design consideration, when designing or choosing a Shock absorber is where that energy will go. In most dashpots, energy is converted to heat inside the viscous fluid.

Shock Absorber types

There are a number of different methods of converting an impact/collision into relatively smooth cushioned contact.

4.1.1 Metal springs
4.1.2 Elastomatic shock observer
4.1.3 Hydraulic Dashpot
4.1.4 Collapsing Safety Shock Absorbers
4.1.5 Air (Pneumatic) spring
4.1.6 Self compensating Hydraulic Pressure to improve the working efficiency. They are sometime also called ‘gas shock absorber’.
Spring Suspension System

The shock absorbers duty is to absorb or dissipate energy. One design consideration, when designing or choosing a shock absorber, is where that energy will go. In most dashpots, energy is converted to heat inside the viscous fluid. In hydraulic cylinders, the hydraulic fluid will heat up, while in air cylinders, the hot air is usually exhausted to the atmosphere. In other types of dashpots, such as electromagnetic ones, the dissipated energy can be stored and used later. In general terms, shock absorbers help cushion cars on uneven roads.

Front suspension system

Motorcycle's suspension serves a dual purpose contributing to the vehicle's handling and braking, and providing safety and comfort by keeping the vehicle's passengers comfortably isolated from road noise, bumps and vibrations. The typical motorcycle has a pair of fork tubes for the front suspension. The most common form of front suspension for a modern motorcycle is the telescopic fork. Other fork designs are girder forks, suspended on sprung parallel links and bottom leading link designs. Some manufacturers used a version of the swinging arm for front suspension on their motocross designs. The top of the forks are connected to the motorcycle's frame in a triple tree clamp which allows the forks to be turned in order to steer the motorcycle. The bottoms of the forks are connected to the front axle around which the front wheel spins. On typical telescopic forks, the upper portion, known as the fork tubes, slide inside the fork bodies, which are the lower part of the forks. As the tubes slide in and out of the body they are telescoping, thus the term telescopic forks. The fork tubes must be smooth to seal the fork oil inside the fork, and typically have a mirrored finish, though some fork tubes, especially those on off-road motorcycles, are enclosed in plastic protective sleeves, known as gaiters. A shock absorber consists of springs which determine posture and cushioning buffer action and a damper which suppresses vibration. On 2-wheeled vehicles, shock absorbers are separated into the categories of the “front fork” and “rear cushion”. The front fork: Front fork serves as rigidity component just like a frame. Vehicle specific rigidity given to present run out while braking and changing the direction of a wheel though handle operations. Maintain balance of vehicle frames stability and secures straight running stability as well as rotationality of the vehicles. The front fork prevents excessive weight on the front wheel during drastic sudden applications the break, softens bumping when driving on rough road surfaces. The front fork maintains proper damping through traction with the road surface

Difference between rear suspension and front suspension

Obviously any four wheel vehicle needs suspension for both the front wheels and the rear suspension, but in two wheel drive vehicles these can
be very different configuration. For front-wheel drive cars, rear suspension has few constraints and a variety of beam axles and independent suspensions are used. For rear-wheel drive cars, rear suspension has many constraints and the development of the superior but more expensive independent suspension layout has been difficult. Four-wheel drives often have suspensions that are similar for both the front and rear wheels

**Requirements of Suspension Systems**

- Independent movement of each of the wheels on an axle
- Small, unsparing masses of the suspension in order to keep wheel load fluctuation as low as possible
- The introduction of wheel forces into the body in a manner favorable to the flow of forces
- The necessary room and expenditure for construction purposes, bearing in mind the necessary tolerances with regard to geometry and stability, ease of use
- Behavior with regard to the passive safety of passengers and other road users
- To preserve stability of the vehicle in pitching and rolling while in motion

### 5. Spring rate

The spring rate (or suspension rate) is a component in setting the vehicle's ride height or its location in the suspension stroke. When a spring is compressed or stretched, the force it exerts is proportional to its change in length. The spring rate or spring constant of a spring is the change in the force it exerts, divided by the change in deflection of the spring. Vehicles which carry heavy loads will often have heavier springs to compensate for the additional weight that would otherwise collapse a vehicle to the bottom of its travel (stroke).

#### 5.1 Mathematics of spring rate:

Spring rate is a ratio used to measure how resistant a spring is to being compressed or expanded during the spring's deflection. The magnitude of the spring force increases as deflection increases according to Hooke's Law. Briefly, this can be stated as

\[ F = -kx \]

where

- \( F \) is the force the spring exerts
- \( k \) is the spring rate of the spring
- \( x \) is the deflection of the spring from its equilibrium position (i.e., when no force is applied on the spring)

Negative sign indicates direction of applied force and forces exerted by spring are opposite. Spring rate is confined to a narrow interval by the weight of the vehicle, load the vehicle will carry, and to a lesser extent by suspension geometry and performance desires.

Spring rates typically have units of N/mm (or lbf/in). The spring rate of a coil spring may be calculated by a simple algebraic equation or it may be measured in a spring testing machine. The spring constant \( k \) can be calculated as follows:

\[ k = \frac{d^4G}{8ND^3} \]

Where \( d \) is the wire diameter, \( G \) is the spring's shear modulus (e.g. about 12,000,000 lbf/in² or 80 GPa for steel), \( N \) is the number of wraps and \( D \) is the diameter of the coil.

**Applications**

Shock absorbers are an important part of automobile and motorcycle suspensions, aircraft landing gear, and the supports for many industrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility
of structures to earthquake damage and resonance. A transverse mounted shock absorber, called a yaw damper, helps keep railcars from swaying excessively from side to side and are important in passenger railroads, commuter rail and rapid transit systems because they prevent railcars from damaging station platforms. The success of passive damping technologies in suppressing vibration amplitudes could be ascertained with the fact that it has a market size of around $4.5 billion.

**Other application**

Shock absorbers are designed to absorb shocks. They are used not only in automotive Industries but are also used in various other manufacturing and processing industries.

Some of the other applications of the shock absorbers can be summarized as follows:

1. Automotive robotics
2. Foundry–conveyor line
3. Rolling Door
4. Air cylinder
5. Printing:
6. Packaging machinery
7. Overhead crane

**Advantages and Disadvantages**

**A. Advantages**
- To absorb impact load caused by irregularities of road surface.
- To provide safety for passenger & driver.
- To prevent rebounding effect.

**B. Disadvantages**
- Maintenance is required.
- It increases sprung weight.
- Cost is high

**Design procedure of Two wheeler Suspension Spring**

For designing the Suspension spring the following procedure has to be follow

**Spring Specifications**

<table>
<thead>
<tr>
<th>Type</th>
<th>Wire diameter (d)</th>
<th>Coil outer diameter (D)</th>
<th>Coil free height (h)</th>
<th>No. of active coils (n)</th>
<th>Pitch (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1 For splender plus</td>
<td>=8 mm</td>
<td>=40 mm</td>
<td>=200 mm</td>
<td>=12</td>
<td>=15 mm</td>
</tr>
<tr>
<td>9.2 For Yamaha</td>
<td>=8 mm</td>
<td>=40 mm</td>
<td>=200 mm</td>
<td>=12</td>
<td>=15 mm</td>
</tr>
<tr>
<td>9.3 For TVs Motor</td>
<td>=8 mm</td>
<td>=40 mm</td>
<td>=200 mm</td>
<td>=10</td>
<td>=15 mm</td>
</tr>
</tbody>
</table>

**Introduction To Solidworks**

Solidworks mechanical design automation software is a feature-based, parametric solid modeling design tool which advantage of the easy to learn windows™ graphical user interface. We can create fully associate 3-D solid models with or without while utilizing automatic or user defined relations to capture design intent.

Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Numeric parameters can be associated with each other through
the use of relations, which allow them to capture design intent.

Design procedure of suspension spring

For designing the suspension spring the following procedure has to be follow

\[
\text{Wahl's Stress Factor (K_i) = } \frac{4c - 1}{4c - 4} + \frac{0.615}{5}
\]

\[
K = 1.3105
\]

Maximum Shear Stress \( \tau = \frac{KXWD}{\pi d^3} \)

\[
1.3105 \times 8 \times 100 \times 0 \times 0 = \frac{\pi(8)^3}{8} \times \frac{26.07733 \text{ Mpa}}{150 \text{ N}}
\]

Deflection of Spring \( d' = \frac{W_{WC} n}{Gd} \)

\[
\frac{8 \times 100 \times (8)^3 \times 2}{87500 \times 8} = 1.714285 \text{ mm}
\]

AT LODE=150 N

Maximum Shear Stress \( \tau = \frac{KXWD}{\pi d^3} \)

\[
1.3105 \times 8 \times 150 \times 0 \times 0 = \frac{\pi(8)^3}{8} \times \frac{39.10851 \text{ Mpa}}{150 \text{ N}}
\]

Deflection of spring \( d' = \frac{W_{WC} n}{Gd} \)

\[
\frac{8 \times 150 \times (8)^3 \times 2}{87500 \times 8} = 2.571428 \text{ mm}
\]

AT LODE=200 N

Maximum Shear Stress \( \tau = \frac{KXWD}{\pi d^3} \)

\[
1.3105 \times 8 \times 200 \times 0 \times 0 = \frac{\pi(8)^3}{8} \times \frac{52.143152 \text{ Mpa}}{200 \text{ N}}
\]

Deflection of spring \( d' = \frac{W_{WC} n}{Gd} \)

\[
\frac{8 \times 200 \times (8)^3 \times 2}{87500 \times 8} = 3.4285714 \text{ mm}
\]

AT LODE=400 N

Maximum Shear Stress \( \tau = \frac{KXWD}{\pi d^3} \)

\[
1.3105 \times 8 \times 400 \times 0 \times 0 = \frac{\pi(8)^3}{8} \times \frac{104.28630 \text{ Mpa}}{400 \text{ N}}
\]

Deflection of spring \( d' = \frac{W_{WC} n}{Gd} \)

\[
\frac{8 \times 400 \times (8)^3 \times 2}{87500 \times 8} = 6.8571428 \text{ mm}
\]

AT LODE=600 N

Maximum Shear Stress \( \tau = \frac{KXWD}{\pi d^3} \)

\[
1.3105 \times 8 \times 600 \times 0 \times 0 = \frac{\pi(8)^3}{8} \times \frac{156.4294 \text{ Mpa}}{600 \text{ N}}
\]

Deflection of spring \( d' = \frac{W_{WC} n}{Gd} \)

\[
\frac{8 \times 600 \times (8)^3 \times 2}{87500 \times 8} = 15.64294 \text{ Mpa}
\]

Therefore, finally the suspension spring will be modeled by above steps and procedure

9.4 Theoretical calculations of spring

AT LODE=100 N

Spring Index, \( (C) = \frac{D}{d} = \frac{4c}{8} = 5 \)
\[ (d') = 10.285714 \text{ mm} \]

AT LODE=800 N

Spring Index, \( (C) = \frac{D}{d} = \frac{40}{8} = 5 \)

Wahl’s Stress Factor \( (K) = \frac{4c-1}{4c-4} + \frac{0.615}{c} \)

\[
\frac{4(5) - 1}{4(5) - 4} + \frac{0.615}{5} = 5
\]

\[ (K) = 1.3105 \]

Maximum Shear Stress \( (\tau) = \frac{KXWWD}{\pi d^3} \)

\[
= \frac{1.3105X8X800X40}{\pi X(8)^3} \\
(\tau) = 208.57255 \text{ MPa}
\]

Deflection of Spring \( (d') = \frac{6d}{8X800X(5)^3X12} \)

\[
= \frac{87500X8}{X} \\
(d') = 13.714 \text{ mm}
\]

**Anslysis introduction**

ANSYS 14.5 delivers innovative, dramatic simulation technology advances in every major Physics discipline, along with improvements in computing speed and enhancements to enabling technologies such as geometry handling, meshing and post-processing. These advancements alone represent a major step ahead on the path forward in Simulation Driven Product Development. But ANSYS has reached even further by delivering all this technology in an innovative simulation framework, ANSYS Workbench14.5. The ANSYS Workbench environment is the glue that binds the simulation process; this has not changed with version 14.5. In the original ANSYS Workbench, the user interacted with the analysis as a whole using the platform’s project page: launching the various applications and tracking the resulting files employed in the process of creating an analysis. Tight integration between the component applications yielded unprecedented ease of use for setup and solution of even complex multiphysics simulations.

**Meshing:**

The software uses the Finite Element Method (FEM). FEM is a numerical technique for analyzing engineering designs. FEM is accepted as the standard analysis method due to its generality and suitability for computer implementation. FEM divides the model into many small pieces of simple shapes called elements effectively replacing a complex problem by many simple problems that need to be solved simultaneously.

**SIMULATIONS**

Simulations is done on three different bike suspensions springs

- Splendor bike
- TVs victor bike
- Yamaha bike

**Fixed support**

**Load force applied**
Meshing:

Simulations on Splendor Bike Suspension System
Material – Alloy Steel
LOAD – 700N
Maximum stress

Material – Chromium Vanadium Steel
LOAD – 700N
Maximum stress
Maximum shear stress

Material - Chromium Vanadium Steel

Maximum principal stress

Material - Alloy Steel

Maximum principal strain

Simulations on TVs victor bike suspension system

Total deformation

Material - Chrominum Vanadium Steel

Maximum Stress

Strain

Max shear stress
Simulations on Yamaha bike suspension system
Material – Alloy Steel
Maximum stress

Maximum principal stress
Maximum principal strain

Material – Chromium Vanadium Steel

Maximum principal stress

Total deformation

Maximum strain

Max shear stress

Results:

### Splendor plus

<table>
<thead>
<tr>
<th>Material</th>
<th>Stress</th>
<th>Total deformation</th>
<th>Strain</th>
<th>Shear stress</th>
<th>Maximum principal stress</th>
<th>Maximum principal strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy steel</td>
<td>414.96</td>
<td>26.86</td>
<td>0.0020507</td>
<td>239.4</td>
<td>217.48</td>
<td>0.0013899</td>
</tr>
<tr>
<td>Chromium vanadium steel</td>
<td>414.92</td>
<td>27.06</td>
<td>0.0020507</td>
<td>239.37</td>
<td>217.89</td>
<td>0.0014023</td>
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</table>

### TVs victor

<table>
<thead>
<tr>
<th>Material</th>
<th>Stress</th>
<th>Total deformation</th>
<th>Strain</th>
<th>Shear stress</th>
<th>Maximum principal stress</th>
<th>Maximum principal strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy steel</td>
<td>368.27</td>
<td>15.883</td>
<td>0.0017949</td>
<td>211.98</td>
<td>188.46</td>
<td>0.0012048</td>
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<tr>
<td>Chromium vanadium steel</td>
<td>368.29</td>
<td>16.007</td>
<td>0.0017951</td>
<td>211.99</td>
<td>189</td>
<td>0.0012159</td>
</tr>
</tbody>
</table>

### Yamaha

<table>
<thead>
<tr>
<th>Material</th>
<th>Stress</th>
<th>Total deformation</th>
<th>Strain</th>
<th>Shear stress</th>
<th>Maximum principal stress</th>
<th>Maximum principal strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy steel</td>
<td>299.48</td>
<td>7.5042</td>
<td>0.0014682</td>
<td>172.41</td>
<td>153.69</td>
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<tr>
<td>Chromium vanadium steel</td>
<td>299.49</td>
<td>7.5027</td>
<td>0.0014684</td>
<td>172.42</td>
<td>155.06</td>
<td>0.00097635</td>
</tr>
</tbody>
</table>
CONCLUSION:

- Modeling and analysis of suspension spring is done
- Modeling of suspension spring is done in solidworks by using various commands
- Suspension spring for splendor, TVs and Yamaha with various dimensions is done.
- Thus the geometry is saved to igs files to import in ansys work bench
- Structural analysis is carried out in ansys workbench with two different materials alloy and chromium vanadium steel at load 700N
- Maximum shear stress, max principle stress, normal stress, strain, max principle strain, normal strain total deformation are noted
- From the analysis results we can conclude that alloy steel is showing best results in three vehicles (among three for Yamaha alloy steel got the least stress)
- Thus alloy steel is preferable compared to chromium vanadium steel.

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