Design and Analysis of Multi-Link Structure for Rear Independent Suspension of Heavy Vehicle

G.S.V.V.N. BHARGAVI, M.Tech in MECHANICAL ENGINEERING Specialization in MACHINE DESIGN from Kakinada Institute of Engineering & Technology, JNTU, Kakinada, Andhra Pradesh, India

Mr. K. HARI KRISHNA. Assistant professor, Kakinada Institute of Engineering & Technology, JNTU, Kakinada, Andhra Pradesh, India

ABSTRACT

In this thesis, a multi link structure for rear independent structure of heavy vehicle is designed and modelled in 3D modelling software Creo 2.0. Two models are done by varying the pitch value of spring 12.6mm and 18.5mm. Finite element analysis is performed on the structure by varying materials Chromoly 4130, Alloy Steel 1018, Aluminium alloy 6061. Static, Modal and Random Vibration analysis are done to determine displacements, stresses and frequencies. Analysis is done in Ansys.

INTRODUCTION TO 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 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. The design of front and rear suspension of a car may be different.
Fig:-Suspension system

Types of suspension systems in a vehicle
Well, the type of suspension to be used depends on the type of vehicle. Broadly, there are 2 types of suspension systems:

a) Rigid Axle Suspension
b) Independent Suspension
c) Wishbone arm system
d) Trailing link system
e) Sliding pillar Type

MULTI-LINK SUSPENSION

A multi-link suspension is a type of vehicle suspension design typically used in independent suspensions, using three or more lateral arms, and one or more longitudinal arms. A wider definition considers any independent suspensions having three control links or more multi-link suspensions. These arms do not have to be of equal length, and may be angled away from their "obvious" direction. It was first introduced in the late 1960s on the Mercedes-Benz C111 and later on their W201 and W124 series.

Fig:-Rear view

<table>
<thead>
<tr>
<th>Weight of the car (W)</th>
<th>Total load=4905+981=5886N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction due to gyroscopic couple</td>
<td>ωw = V/2W = 88.88 rad/sec</td>
</tr>
<tr>
<td>Angular velocity of precession</td>
<td>ωp = V/R=0.2222rad/sec</td>
</tr>
<tr>
<td>Reaction due to four wheels:</td>
<td>CW = 4IW × ωP = 0.2396m</td>
</tr>
<tr>
<td>Reaction of ground on each outer wheel and inner wheel</td>
<td>P/2=CW/2x = 0.0739N</td>
</tr>
<tr>
<td>Reaction due to rotating parts of the engine</td>
<td>CE=IE.ωE×ωP = 575.94N-m</td>
</tr>
<tr>
<td>Reaction of ground on each front and rear wheel</td>
<td>F/2=CE/2b = 106.48N</td>
</tr>
<tr>
<td>Reaction due to centrifugal couple</td>
<td>Mc = [M×V2÷R] ×h = 1925.5N-m</td>
</tr>
</tbody>
</table>
Reaction on ground on each outer wheel and inner wheel

\[
\frac{Q}{2} = \frac{C_0}{2x} = 594N
\]

Wheel rate: Front Wheel & Rear Wheel:

\[
R_1 = \frac{W_1}{2} + \frac{P}{2} - \frac{F}{2} - \frac{Q}{2} = 2253.44N
\]

\[
R_2 = \frac{W_1}{2} - \frac{P}{2} - \frac{F}{2} - \frac{Q}{2} = 1064.49N
\]

Design calculation for spring

Wahl stress factor: 
\[
K_S = 4C - \frac{1}{4}C + 0.615/C = 1.2525
\]

Shear stress:
\[
\tau_{\text{max}} = 16 \times T \times K / \pi d^3
\]
\[
\tau = 480 \text{ N/mm}^2
\]

\[
C = D/d
\]

\[
D = 54 \text{mm}
\]

Wire diameter = 9mm

Deflection of spring : (y) \( Y = 8pc3n/Gd = 36.05 \text{mm} \)

Solid length: \( LS = dn + 2d = 90 \text{ mm} \)

Free length of the spring (Lf): \( Lf = LS + Y = 126.05 \text{mm} \)

Pitch of the coil: (p) \( P = Lf - LS/nt + d Nt = n+2=10 \text{ P} = 12.60 \text{mm} \)

Helix angle : (\( \alpha \))

\[
\alpha = \tan^{-1}[\text{pitch} / \pi \times D] = 4.24^\circ
\]

**LITERATURE REVIEW**

D.S.Balaji, [1], The car model is generated in a virtual representation with the suspension system and the analysis was done by ANSYS. Using modelling software, 3-D models were generated, and the simulation was performed using ANSYS to estimate the value. The analytical values are calculated using vehicle dynamic values and they are entered in the ADAMS software. The construction of track ride analysis is done by road builder. The results of the theoretical values are validated with the values from the finite element analysis.

Dhamodharan.P, [2], In particular, an optimal dimensional synthesis of a five link suspension mechanism in terms of length of the five links and positions of the ten spherical joints, which are installed on the vehicle chassis and wheel carrier, is presented. In this paper, the influence of the complaint joints on the dynamic behaviour of the suspension system is approached, considering the axle guiding linkage used for an off-road vehicle. This optimisation has been carried out by using mat lab optimisation tool box with the aim to obtain a body motion of the wheel carrier with respect to the vehicle chassis as close as possible to a vertical translation. The simulation of the multi-link suspension is performed by using the MBS environment ADAMS of MSC software.

Ernesto ROCCA, [3], A multilink suspension analysis aimed to improve the performances in terms of car handling or comfort, by acting on the components of the suspension itself. In particular the analysis focuses on the effects produced on the suspension characteristic curves.
by some modifications in rods length. The technique can be adopted in the design phase of a multilink suspension to obtain a desired characteristic, in terms of camber or steering, by optimizing the proper length of each single rod.

**MODELING OF MULTI-LINK STRUCTURE**

For modelling of multi-link structure for rear independent suspension of heavy vehicle in reference is taken from “Design and Analysis of A Suspension Coil Spring For Automotive Vehicle” By N.Lavanya.

Spring pitch – 12.60mm

![Spring](https://example.com/spring.png)

Fig: - Spring

![Final model](https://example.com/model.png)

Fig: Final model of multi link structure with spring of pitch 12.6mm

**ANALYSIS OF MULTI-LINK STRUCTURE**

**STATIC STRUCTURAL, MODAL AND RANDOM VIBRATION ANALYSIS**

**PITCH** – 12.60mm

**MATERIAL** – Chromoly 4130
Fig: -Imported Model of multi link structure with 12.6mm pitch

Fig: -Meshed Model of multi link structure with 12.6mm pitch

Fig: -Fixed Supports are applied on the base and top supports
Fig: -Force is applied on the spring piston

Fig: - Total Deformation in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.

Fig: - Stress in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.

Fig: - Strain in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.
Fig: - Total Deformation 1 in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.

Fig: - Total Deformation 2 in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.

Fig: - Total Deformation 3 in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.

Right Click on Random Vibration > Insert > PSD Displacement > Give Required data.
RESULTS & DISCUSSIONS

Fig: - Tabular Data

Fig: - Directional Deformation in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.

Fig: - Shear Stress in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.

Fig: - Shear Strain in Multi-Link Structure with Pitch of 12.60 mm for Chromoly 4130.
STATIC STRUCTURAL ANALYSIS

Pitch - 12.60mm

<table>
<thead>
<tr>
<th>Materials</th>
<th>Deformation (mm)</th>
<th>Stress (MPa)</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromoly 4130</td>
<td>14.881</td>
<td>310.83</td>
<td>0.014125</td>
</tr>
<tr>
<td>1018 steel</td>
<td>15.253</td>
<td>310.83</td>
<td>0.14481</td>
</tr>
<tr>
<td>6061 aluminium</td>
<td>45.621</td>
<td>312.49</td>
<td>0.042142</td>
</tr>
</tbody>
</table>

Pitch – 18.5mm

<table>
<thead>
<tr>
<th>Materials</th>
<th>Deformation (mm)</th>
<th>Stress (MPa)</th>
<th>Strain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromoly 4130</td>
<td>10.336</td>
<td>305.85</td>
<td>0.013808</td>
</tr>
<tr>
<td>1018 steel</td>
<td>10.594</td>
<td>305.85</td>
<td>0.014153</td>
</tr>
<tr>
<td>6061 aluminium</td>
<td>31.671</td>
<td>305.98</td>
<td>0.041052</td>
</tr>
</tbody>
</table>

By observing the static structural analysis results, the deformation, stress and strain are reducing by increasing the pitch value. The deformation value is less for Chromoly 4130. The stress values for all materials are less than their respective yield stress values. The stress values are reducing by increasing the pitch value. The stress value is reducing by about 0.5% for both Chromoly 4130 and 1008 Steel when compared with Aluminium 6061 with pitch value of 12.6mm. The stress value is reducing by about 0.042% for both Chromoly 4130 and 1008 Steel when compared with Aluminium 6061 with pitch value of 18.5mm. By using Aluminium 6061 material is better due to its less weight.

MODAL ANALYSIS

Pitch - 12.60mm

<table>
<thead>
<tr>
<th>Material</th>
<th>Total Deformation 1 (mm)</th>
<th>Frequency 1 (Hz)</th>
<th>Total Deformation 2 (mm)</th>
<th>Frequency 2 (Hz)</th>
<th>Total Deformation 3 (mm)</th>
<th>Frequency 3 (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromoly 4130</td>
<td>38.016</td>
<td>17.409</td>
<td>36.977</td>
<td>18.273</td>
<td>29.001</td>
<td>30.391</td>
</tr>
</tbody>
</table>
By observing the modal analysis results, the deformation values are increasing by increasing the pitch value. The deformation value is more for Aluminium 6061. The frequency values are increasing by increasing the pitch value. The frequencies are less when 1018 Steel is used.

**RANDOM VIBRATION ANALYSIS**

**Pitch – 12.6mm**

<table>
<thead>
<tr>
<th>Materials</th>
<th>Directional Deformation (mm)</th>
<th>Shear Stress (MPa)</th>
<th>Shear Strain (mm/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromoly 4130</td>
<td>36.982</td>
<td>5.9184e-12</td>
<td>0.16699</td>
</tr>
<tr>
<td>1018 steel</td>
<td>36.796</td>
<td>5.9184e-12</td>
<td>0.16588</td>
</tr>
<tr>
<td>6061 aluminium</td>
<td>21.899</td>
<td>3.3554e-12</td>
<td>0.12973</td>
</tr>
</tbody>
</table>
Pitch – 18.5mm

<table>
<thead>
<tr>
<th>Materials</th>
<th>Directional Deformation (mm)</th>
<th>Shear Stress (MPa)</th>
<th>Shear Strain (mm/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromoly 4130</td>
<td>65.625</td>
<td>2.2139e-13</td>
<td>0.26965</td>
</tr>
<tr>
<td>1018 steel</td>
<td>64.965</td>
<td>2.2139e-13</td>
<td>0.2681</td>
</tr>
<tr>
<td>6061 aluminium</td>
<td>60.583</td>
<td>1.6169e-13</td>
<td>0.20833</td>
</tr>
</tbody>
</table>

By observing the random vibration analysis results, the directional deformation is increasing and shear stress value is decreasing by increasing the pitch value. The directional deformation value is less for Aluminium 6061. The shear stress value is reducing by about 43% for Aluminium 6061 when compared with other two materials with pitch value of 12.6mm. The shear stress value is reducing by about 27% for Aluminium 6061 when compared with other two materials with pitch value of 18.5mm.

**CONCLUSION**

By observing the static structural analysis results, the deformation, stress and strain are reducing by increasing the pitch value. The deformation value is less for Chromoly 4130. The stress values for all materials are less than their respective yield stress values. By using Aluminium 6061 material is better due to its less weight.

By observing the modal analysis results, the deformation values are increasing by increasing the pitch value. The deformation value is more for Aluminium 6061. The frequency values are increasing by increasing the pitch value. The frequencies are less when 1018Steel is used.

By observing the random vibration analysis results, the directional deformation is increasing and shear stress value is decreasing by increasing the pitch value. The directional deformation value is less for Aluminium 6061. The shear stress value is reducing by about 43% for Aluminium 6061 when compared with other two materials with pitch value of 12.6mm. The shear stress value is reducing by about 27% for Aluminium 6061 when compared with other two materials with pitch value of 18.5mm.

So it can be concluded that using Aluminium 6061 is better at pitch value 18.5mm.

**REFERENCES**

[1] D.S.Balaji, S Prabhakaran, K.Umanath,Design and analysis of the double wishbone suspension system,


