DOUBLE WISHBONE SUSPENSION SYSTEM

B. Rohith Raju
Department of Mechanical Engineering, K.L University, Green Fields, India

K.P.V.S. Raja Rao
Department of Mechanical Engineering, K.L University, Green Fields, India

V.V Suraj
Department of Mechanical Engineering, K.L University, Green Fields, India

P. Ratna Prasad
Department of Mechanical Engineering, K.L University, Green Fields, India

ABSTRACT
Suspension system plays a crucial role in the handling of the vehicle. It helps the driver to maneuver the vehicle. The main function of suspension is to make sure that the driver feels comfortable while riding the car and the forces are damped to prevent chassis from getting damaged. Suspension helps to keep the tires in contact with ground when they encounter any bump on their way. Thus suspension is used in automobiles. This paper mainly concentrates on the design of the suspension for a formula car, modifying the mounting points, analyzing of the forces which are to be damped by the suspension.

Key words: Pushrods, Rocker Arms, Sprung Masses, Unsprung Masses


1. INTRODUCTION
In any automotive system, suspension plays a crucial role in providing comfort to the people in the automobile and protects the important parts from the shocks or the forces that act when it encounters an obstacle on its way. Suspension is a very basic system and can provide comfort to the passenger in many ways. Having sufficient pressure of air in the tires of the automobile, cushioning of the seats, padding of few components such as steering wheel provides certain resistance to the shocks that are generated. But this is not close enough to a considerable extent of
damping the shock generated. Hence other components such as springs are used to damp the
majority portion of the shocks generated.

The suspension consists of spring, dampers and links that connect the tires to the springs and
dampers. When the tire hits a bump or an obstacle on road, it would be subjected to some forces,
which would get transferred to the chassis if they are not damped. These forces would cause chassis
a permanent damage resulting in the breakage of the metal. The loads transferred strictly depend
on the sprung and unsprung mass of the vehicle. The larger the ratio of sprung mass to that of the
unsprung mass, the more stable the vehicle would be.

The main functions of the suspension system are as follows:
1. It helps to keep the tires in contact with the road.
2. Prevents damage to the chassis if any sudden forces are encountered.
3. Provides comfort to the driver
4. Supports the weight of the vehicle.

2. SELECTION OF THE SUSPENSION SYSTEM
Since the suspension we are about to design is used for formula1 cars, out of many suspensions,
we choose double wishbone suspension system. The below are the following reasons for which
double wishbone suspension system is selected:
1. It provides a less ride height which is an essential feature for a formula car.
2. Flexibility ( in terms of wheel alignment i.e., setting of camber angle)
3. Less cost
4. Load bearing capacity of the system.
5. Availability of components in local market.

3. MATERIAL SELECTION
The most important part in designing and manufacturing of any component is the selection of the
material. As this car is fabricated as per the rules mentioned in the rule book, we must follow few
regulations laid by SAE. After the designing of the suspension system (geometry) the material
selection is done. Few factors that are to be considered in the selection of material are as follows:
1. Availability
2. Cost of the material
3. Density of the material
4. Yield strength of the material
5. Bending strength of the material
6. Weight of the material etc.

In the rule book it is mentioned that the material used must be LESS WEIGHT and MORE
STRONG. Hence chromoly can be selected as the best material for use. Each and every part of the
suspension system is made up of different materials. The following gives the details of the material
used in different components of the suspension system:
1. The rocker arms are made up of aluminum.
2. Push rods are made up of mild steel
3. Springs are made up of chrome steel
4. Caps are made up of aluminum
5. Adjustable column is made up of aluminum

Few important properties of different materials available in market are mentioned in the table 1.1:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Chromoly 4130</th>
<th>1018 steel</th>
<th>T6 6061 aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength(ksi)</td>
<td>63.1</td>
<td>53.7</td>
<td>40</td>
</tr>
<tr>
<td>Bending stiffness(lb x in$^2$)</td>
<td>829898.26</td>
<td>829898.26</td>
<td>279430</td>
</tr>
<tr>
<td>Bending strength(lb x in)</td>
<td>3526.369057</td>
<td>3001.07</td>
<td>2237.13</td>
</tr>
<tr>
<td>Density(g/cm$^3$)</td>
<td>7.85</td>
<td>7.87</td>
<td>2.70</td>
</tr>
<tr>
<td>Cost per feet</td>
<td>162Rs/ft</td>
<td>60Rs/ft</td>
<td>200Rs/ft</td>
</tr>
</tbody>
</table>

The table 1.1 is made by considering the material dimension of 1 inch X 0.095 inch.

4. RATING OF THE MATERIAL

Generally a rating is given to any material depending on various parameters for the selected material. The overall rating is for 25 points. The above 3 materials are rated in the table 1.2:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Chromoly 4130</th>
<th>1018 steel</th>
<th>T6 6061 Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield strength</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Manufacturability</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Bending strength</td>
<td>5</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>weight</td>
<td>3</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>cost</td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>21</td>
<td>20</td>
<td>15</td>
</tr>
</tbody>
</table>

As rated in the table 1.2, chromoly and 1018 steel are almost close, but with a minor difference in bending strength. Hence, we consider chromoly 4130 for the fabrication of A-arms of the suspension system.

The next important factor which we need to consider while fabricating is the selection of the thickness of the material. The following graphs show different factors for different thickness of the materials:
Double Wishbone Suspension System

Figure 1.1 Graph showing bending stiffness vs. thickness

The above graph fig: 1.1 shows the bending stiffness of chromoly 4130 at different cross sections and at various thicknesses.

Figure 1.2 graph showing weight vs. thickness

The above graph fig: 1.2 shows density of chromoly 4130 at variable thickness and at various diameters.

Figure 1.3 graph showing bending strength vs. thickness
The above graph Fig: 1.3 shows the bending strength of the material chromoly 4130 at different thickness and at different diameters.

5. ANALYSING THE MASSES
After the selection of materials the next important task is the analyzing the weights on the suspension components. The masses in the system can be divided into 2 types. They are:

- Sprung masses and
- Unsprung masses.

Sprung masses: sprung masses can be defined as the mass of the components of the body that are supported by the springs of the system.

Unsprung masses: unsprung masses are the masses that move with the body (i.e. while travelling over bumps or any irregular surface). Generally these include the weights of tires, hubs, uprights etc.

Generally the components that are considered to be on the sprung masses are protected from sudden shocks and loads. These are considered not to take any shocks or minimum shocks. Components like frame of the body, drive train and its components etc. can be considered as sprung masses.

The sprung masses are more important when it comes to stability. As the sprung mass increases, the stability of the vehicle increases. Hence when we try to divide the masses, we almost try to maximize the sprung mass so that the vehicle would be as stable as possible.

For the suspension system we are about to create, the masses are as follows:

- Sprung Mass front = 96kg
- Sprung Mass rear=144kg

These masses include the masses of all the components that are supported by the springs.

6. DESIGN OF THE COMPONENTS
After deciding the sprung and unsprung masses, the next task comes to the design of the components. The designing of the components is done by following few rules and regulation that are described in the rule book.

Among all the rules that are mentioned in the rule book, the important rule that we consider in designing is that there must be a jounce and rejounce of spring that must be maximum of 1 inch. Few other rule about ground clearance, wheel base etc., are considered.

The main components of the suspension are:

- A-Arms
- Push rods
- Rocker arms
- Springs with dampers

As we all know the mechanism, if the automobile faces any sudden load (bump on the road), then the load is transferred to A-arms from tires, then to push rods, to rocker arms and finally to the damper where the shock will be damped. The design of all the components should be in such a way that they take up the loads without getting failed.
Double Wishbone Suspension System

We use solid works software, for the modeling of the components. Solid works is one of the famous modeling software that is used in the designing process. The designed components of the suspension system are as follows:

6.1. A-Arms
A- Arms can be termed as the starting part of the suspension system, from where the load transferring takes place. These components hold the wheels of the automobile and are attached to the chassis. When the automobile is subjected to any sudden obstacles, these will the first component which is used to transfer the shock to the damping system.

The following are the designed components of suspension system:

6.2. Spring
Spring is one of the main components in the suspension system. Without these, the suspension will be incomplete. Springs take the forces that are generated and damp them. The spring material is made up of chrome silicon. The following are the details of the springs:
- Spring Material=Chrome Silicon
- Spring Stiffness=30N/mm²
- Spring wire diameter (d) =4.4mm
- Spring outer diameter (D) =65mm
- Pitch=12mm
- Total Length I to I=11inch
- Number of Active coils=8

The Fig: 3.0 represent a model of spring which is used in the suspension system designed.

Spring is not a single component. It is an assembly which consists of different parts. One of the most important components is damper. The spring is mounted on the damper and is fixed with the caps. The below diagrams shows the design of damper.
Fig 3.1, Fig 3.2, Fig 3.3, describes the components which are used for the mounting of springs and shock absorbers.
Double Wishbone Suspension System

Here the damper travel is considered to be 5cms.

**Figure 3.4** shock absorber

Fig: 3.4 represent a shock absorber.

**Figure 3.5** spring with caps on both sides

Fig: 3.5 represent a spring with caps installed on both sides of it.

**Figure 3.6** final assembly of spring

Fig: 3.6 represent the entire spring assembly.

Without push rods, the transmission of the shock doesn’t takes place. Push rods and rocker arms are the two important components that are used in transmitting the forces from one axis to another. Push rod transmits the force that is created at the tires to the rocker arm and to spring system. The motion ratio of the push rod is as follows:
Motion Ratio
Front=0.728
Rear=0.968

Figure 3.7 push rod

Fig: 3.7 represent a model of push rod.

_A-Arm specifications:_
Material=Mild Steel AISI 1018
Outer diameter=0.8 inch.

Figure 3.8 front lower A-Arm

Fig: 3.8 represent the A-Arms used.

Rocker arm is the component on which the spring system is mounted on. This can be termed as the main component which transfers the force that is generated in an axis to another. The forces that are transmitted from the push rods are transferred to the springs by changing the direction (or can be termed as axis) of its action.
Double Wishbone Suspension System

**Figure 3.12** rocker arm

Fig: 3.12 represent the rocker Arm used.

**Figure 3.13** final assembly of the suspension system

Fig: 3.13 represent the final assembly of the suspension system.

As shown in the Fig: 3.14 the final rear assembly is done in such a way that the maximum space is allocated for engine, battery and fuel tank. Consideration has been taken that if any load applied, it won’t be transmitted to chassis.

**Figure 3.14** rear assembly of suspension (rear view)

Fig: 3.14 represent the final rear assembly (rear view).
Fig: 3.15 represent the front assembly system.

The front assembly system as shown in Fig: 3.15 are installed in such a way that it accommodates steering, brakes and a perfect ergonomic position for the driver’s cabin.

Fig: 3.16 represent rear assembly system (top view).

7. ANALYSIS OF THE DESIGNED COMPONENTS

ANSYS is one of the most powerful tools which are used to perform analysis on the modeled objects. We used ANSYS work bench for the analysis process. Few operations such as meshing, application of loads, stresses developed and total deformation of the object can be done by using this software.

7.1. Analysis of rocker arm

Rocker arm is the component which is used to transfer sudden loads or shocks from road to springs and dampers. The analysis of the component is as follows:
Double Wishbone Suspension System

![Figure 4.0 stresses developed in rocker arm](image)

The above diagram (Fig: 4.0) mentions the total stresses developed in the rocker arm.

![Figure 4.1 total deformation of rocker arm](image)

The above diagram (Fig: 4.1) indicates the total deformation that takes place in the rocker arm.

**7.2. Analysis on brackets**

Brackets can be generally attached on the A-Arms for supporting of the push rods. Here, the analysis of the brackets is done.
The above diagram (Fig. 4.2) indicates the total deformation of the brackets.

The above diagram (Fig. 4.3) indicated the direction of the loads applied.
Figure 4.4 stresses developed in the brackets

The above diagram (Fig: 4.4) indicates the stresses developed within the brackets.

7.3. Analysis on the assembly of A-Arms and brackets

Since the assembly of A-Arms and brackets are the one that transfer any loads or shocks from tire to the springs and dampers, the analysis of the assembly is done.

Figure 4.5 applications of loads on the brackets connected to A-Arms

The above diagram (Fig: 4.5) indicates the loads applied on the assembly of A-Arms and brackets.
Figure 4.6 total deformations occurred in the brackets and A-Arms

The above diagram (Fig: 4.6) indicates the total deformation that occurs.

Figure 4.7 stresses developed in brackets and A-Arms

The above diagram (Fig: 4.7) indicates the total stresses that are developed in the assembly.

8. ANALYSIS OF THE SPRING AND ITS MOUNTING POINTS

After completion of the designing and analysis of the components, the next part is to fix the mounting points for all the components. As mentioned earlier, the entire design is done based on few rules and regulations. It will need a tremendous amount of man work if we keep on changing the mounting points until the required point is obtained and the obtained point should be according to the rule.

To avoid this we use LOTUS SHARK SUSPENSION ANALYSIS, which provides us the exact dimensions where the mounting points must be installed. By using LOTUS, much iteration can be done. If there is any failure of the system, then we will be able to observe that and change the mounting points.
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The following is the design of the suspension system with the mounting points included in it:

![Double Wishbone Suspension System Design](image)

**Figure 5.0** final mounting points of the suspension system

Fig: 5.0 represent the final mounting points on the vehicle.

9. CONCLUSION

Thus by the usage of double wishbone suspension system, we can obtain required ground clearance, caster and camber angles. Hence we can rate this as the best suspension system which can be used in majority of formula cars.

REFERENCES


[7] FSAE forums
