DESIGN & MANUFACTURING OF DOUBLE WISHBONE SUSPENSION AND WHEEL ASSEMBLY FOR FORMULA STYLE VEHICLE

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Abstract - *This paper aims to give the methodology for design and analysis of a double wishbones suspension system and the wheel assembly for a formula styled electric vehicle. Designing the wheel assembly is one of the most critical part of the process. It is due to the reason that various forces of varying magnitude are acting on the wheel assembly. The main objective of a suspension system is contact to the road, comfort of the passenger, and control of the vehicle. Double wishbone is an independent type of suspension which uses two wishbone shaped arms to locate the wheel. The focus of this paper will be towards getting accurate results considering the dynamics of the vehicle. Part designing will be done using CATIA and SolidWorks, analysis will be done in ANSYS V16 and the simulation of the suspension system will be done using MSC ADAMS.*

Key Words: **CATIA, ANSYS, ADAMS, Suspension, Camber, Caster, Toe.**

1. INTRODUCTION

Suspension system plays an important role for the comfortable ride for passengers as well as protecting chassis & other working parts from getting damaged due to the road shocks.

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. 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.

In a Formula Student Car or in any car as such, the part that connects the main frame of the body with the wheels through suspension arms is known as the Wheel Assembly. The purpose of an upright assembly is to provide a physical mounting and links from the suspension arms to the hub and wheel assembly, as well as carrying brake components. It is a load-bearing member of the suspension system and is constantly moving with the motion of the wheel.

For the use on a high-performance vehicle, the design objective for the upright is to provide a stiff, compliance-free design and installation, as well as achieving lower weight to maximize the performance to weight ratio of the vehicle.

For a racecar, the primary goal is to achieve the best performance to weight ratio. The reduction of weight in any area will allow for better vehicle performance overall.

1.1 Problem Statement

Cornering at high speed often makes the vehicle unstable and the vehicle loses contact with the road when cornering is combined with a bump along the road. The proposal is to design and manufacture a suspension system and wheel assembly able to withstand high speed cornering at slight bumps.

1.2 Objectives

The basic goal is to design a double wishbone suspension system and wheel assembly for a formula styled electric vehicle which is able to sustain a bump and rebound of 50.8 mm in total whilst maintain perfect handling and control over the vehicle even at high speed cornering.

1.3 Methodology

• Recognition of Need:
Using the convection Mc-Person suspension is bulky.

• Definition of Problem:
The basic requirement is to design and manufacture a suspension system that can handle high speed cornering

• Synthesis:
To achieve the designing of wishbone system, first construct the system geometry using CATIA.

• Analysis and Optimization:
After the initial design the analysis is done using MSC ADAMS & ANSYS

• Evaluation:
After getting optimized results we started to manufacture the actual system.

2. BASIC PARAMETERS:

- Track width = 1270 mm (50 inch).
- Wheel base = 1574.8 mm (62 inch).
- Camber Angle = 0°.
- Toe angle = 0°.
- Kingpin Inclination angle=8°.
- Sprung weight = 350 Kg.
- Weight distribution = 40 : 60 (Front : Rear)

3. DESIGN OF SUSPENSION SYSTEM AND WHEEL ASSEMBLY

3.1 Roll Center Geometry

Roll Centre in the vehicle is the point about which the vehicle rolls while cornering. The roll centre is the notional point at which the cornering forces in the suspension are reacted to the vehicle body. The location of the geometric roll centre is solely dictated by the suspension geometry, and can be found using principles of the instant centre of rotation. Determination of roll centre plays a very important role in deciding the wishbone lengths, tie rod length and the geometry of wishbones. Roll centre and ICR is determined because it is expected that all the three elements- upper wishbone, lower wishbone and tie rod should follow the same arc of rotation during suspension travel. This also means that all the three elements should be displaced about the same centre point called the ICR.

Wishbone lengths are obtained by wheel track width and chassis mounting points. The lines of upper and lower wishbones are extended, they intersect at a certain point which is known as Instantaneous center of rotation. Then line is extended from instantaneous center of rotation to a point at which tire is in contact with the ground. The point at which this line intersects the vehicle center line is called the Roll Centre. Now by extending a line from instantaneous center of rotation to the steering arm this gives exact tie rod length.

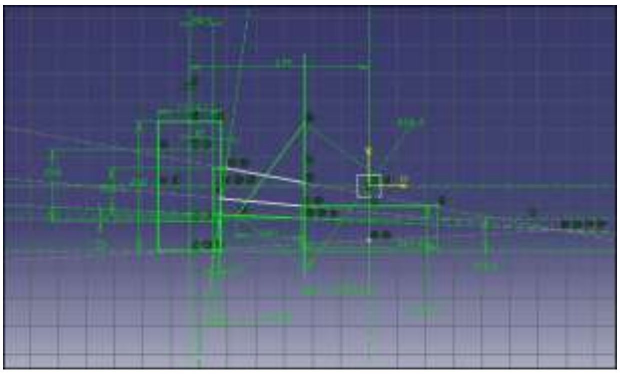

Fig-1: Roll center geometry

3.2 Design of Wishbones.

Wishbones give support to spring and help in vertical movement of the system while the Upright supports the axel of wheel. After we get the length of the wishbones from the roll center geometry we can make a 3D model of the A-Arm wishbone using SOLIDWORKS

Fig-2: CAD model of the wishbone

3.3 Design of Upright.

Upright is the non-rotating part in the wheel assembly. In an automobile, the upright is a part of the suspension system that carries the hub for the wheel and attaches to the upper and lower control arms. The wheel and tire assembly attach to the hub or spindle of the knuckle where the wheel rotates while being held in a stable plane of motion by the suspension assembly.

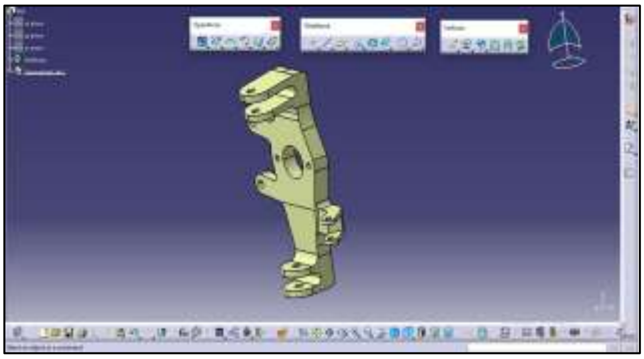

Fig-3: Isometric view of Upright.

3.4 Design of Wheel Hub

Hub is the part of wheel assembly on which the wheel and disk are mounted. Both the Wheel as well as the disk is mounted on the hub with the help of bolts. As discussed earlier the outer race of the bearing is press fitted in the hub and hence provision is made in the hub to enclose the bearing. The Hub itself is made of 2 Petal parts. One on the wheel and the other of the brake disk.

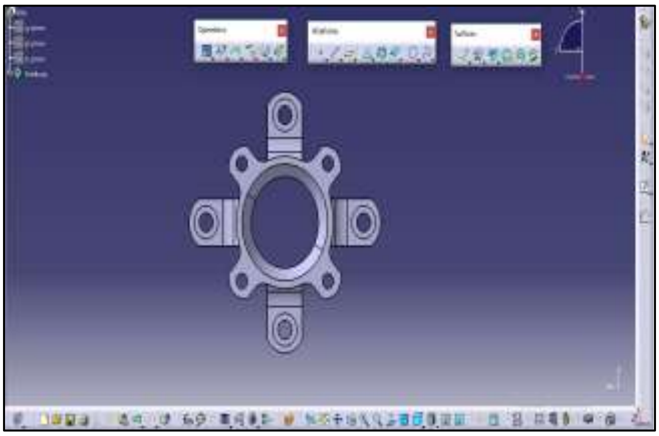

Fig-4: Front view of the Hub

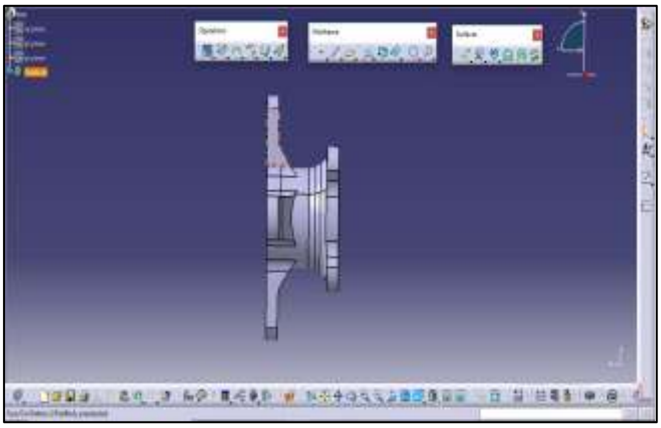

Fig-5: Side view of the Hub

3.5 Design of spring:

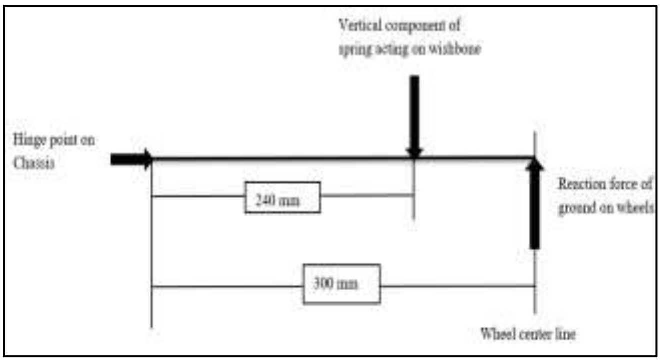

Fig -6: Forces acting on a wishbone.

Sprung mass = 350 Kg.

Mass distribution of 60 : 40 (Rear : Front)

Mass per wheel at Front = 70 Kg

Angle of inclination of the strut = 60˚

Point of attachment of strut on wishbone from chassis end = 240 mm

Distance of wheel center from hinge point of roll cage = 300 mm

Reaction force acting from the ground on the wheel = (Mass per wheel × 9.81) N

= (70 × 9.81) N

= 686.7 N.

By taking moment about hinge point on roll cage:

686.7 × 300 = Spring Force × 240

Spring Force = 858.375 N.

Considering the dynamic factor = 3

Dynamic force acting on the spring = Spring Force × Dynamic Factor

= 858.375 × 3

= 2575.125 N

As stated in the Rule book, maximum deflection allowed is 2 inches.

$$\text{Required Spring Stiffness} = \frac{\text{Spring force}}{\text{Total Deflection}}$$

$$= \frac{2575.125}{50.8}$$

= 50.6914 N/mm.

Material: Grade 4 oil hardened spring steel.

Following material details were obtained from the manufacturer.

Ultimate tensile strength = 1000 N/mm.

Modulus of rigidity = 77000 N/mm.

According to Indian Standard 4454-1981,

Shear stress = 0.5 × Ultimate tensile strength

Shear stress = 500 N/mm.

Taking spring index (C) = 5

Wahl factor K is

$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C} = 1.3105$$

$$\tau = K\frac{8PC}{\pi d^2}$$

$\therefore\ d = \sqrt{\frac{8\times1.3105\times2575.125\times5}{\pi\times500}}$

Wire diameter (d) = 9.27 ≈ 9 mm

Mean coil diameter (D) = C × d = 5 × 9 = 45 mm.

No. of active coils (N) :

$\delta = \frac{8PND^3}{Gd^4}$ $\therefore\ N = \frac{77000\times9^4\times50.8}{8\times2575.125\times45^3}$

N = 14.08 or 15 coils.

Assuming that the spring has square and ground ends.

N_t = N + 2 = 17 coils.

Solid length of spring = N_t × d = 153 mm.

Free length = Solid length + δ + (0.15 × δ) = 211.42 mm.

Pitch of coil = $\frac{\text{Free length}}{\text{Total no.of coils}} = \frac{211.42}{17}$ = 12.436 mm

Appropriate selection of material is significant for the safe and reliable functioning of a part or component. The selection of material is primarily dictated by the specific set of attributes that are required for an intended service.

4.1 Selection of Material for Wheel Assembly

Objectives of wheel assembly material:
• Light weight to maintain good performance to weight ratio of a race car.
• Optimum stiffness to maintain low system compliance and maintaining designed geometry.

Aluminium 6061, aluminium 7075 and EN24 were considered based on availability and cost in the market.

Table-2: Comparison for the various properties

Material / Properties	Aluminium 6061	Aluminium 7071	EN24
BHN	95	150	302
S_{ut}	310 MPa	572 MPa	1000 MPa
S_{yt}	276 MPa	503 MPa	680 MPa
E	68.9 GPa	71.7 GPa	207 GPa
Price	Rs 350/kg	Rs 1000/kg	Rs 100/kg

Table -1: Final Parameters of Spring Design

Parameter	Value
Material	Grade 4 oil hardened spring steel
Wire diameter	9 mm
Mean coil diameter	45 mm
Total No. of turns	17
Free length of spring	211.42 mm
Pitch of coil	12.436 mm
Solid length	153 mm
Stiffness	50.6914 N /mm

4. MATERIAL SELECTION

5. ANALYSIS OF COMPONENTS

With the objective in mind we decided to use aluminium 6061 for manufacturing the wheel assembly.

4.2 Selection of Material for Wishbone material

Objectives of wishbone material:
• The material should have high strength to with stand the loads acting on it in the dynamic conditions.

AISI 1018, AISI 1020 and AISI 4130 were considered based on availability and cost in the market.

Table-3: Comparison for the various properties

Material / Properties	AISI 1018	AISI 1020	AISI 4130
BHN	126	111	217
S_{ut}	440 MPa	394 MPa	560 MPa
S_{yt}	370 MPa	294 MPa	460 MPa
E	205 GPa	200 GPa	210 GPa
Price	Rs 350/m	Rs 250/m	Rs 500/m

With the above objective in mind we decided to use AISI 1020 for manufacturing the wishbone.

Design Analysis employs the finite element analysis method to simulate physical behavior of a product design. The FEA process consists of subdividing all systems into individual components or elements whose behavior is easily understood and then reconstructing the original system from these components. The chief purpose of the component analysis is to identify the component which is efficacious in changing behavior, if a singular component exists.

5.1 Static analysis of wheel assembly

Static analysis of hub and Upright is analysed by using ANSYS software and cad models are designed in Catia, Solidworks. Uprights are analysed by considering braking torque cornering force, longitudinal force, lateral force, reaction force, bump force.

Forces acting on the Upright are:

- Longitudinal force=1030.05 N
- Lateral force= 4408.9 N.
- Wheel Reaction= 2286 N

Forces acting on the Wheel hub are:

- Dynamic weight transfer= 968N
- Braking Force on the front axle= 2666 N
- Torque= 614 N-m
- Wheel Reaction= 2286 N

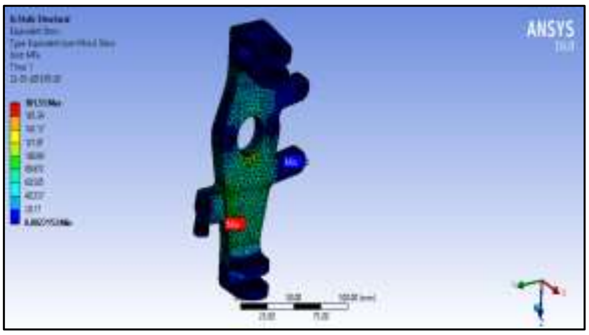

Fig -7: Equivalent Stress Analysis of Upright.

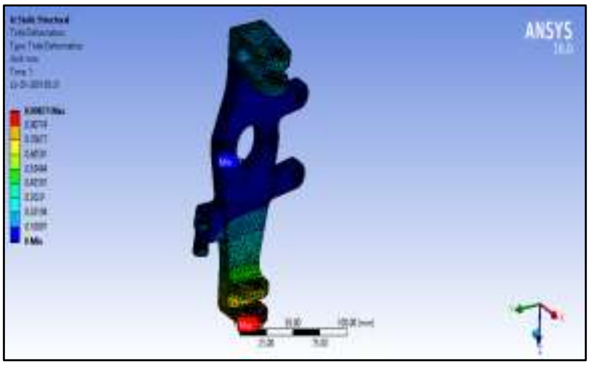

Fig -8: Total Deformation Analysis of Upright.

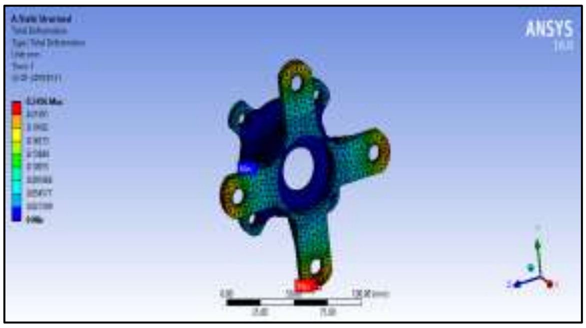

Fig -9: Equivalent Stress Analysis of Hub.

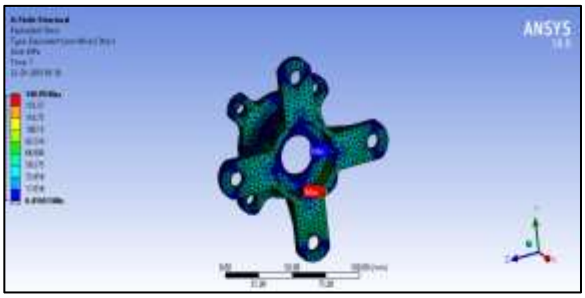

Fig -10: Total Deformation Analysis of Hub.

6. SIMULATION

The kinematic simulation is carried out on ADAMS software. It offers simulation tools which enable the user to generate models very quickly, using a mixture of embedded design criteria and well-structured interface functionality.
All the suspension and steering hardpoints are filled in the respective table within the software to construct a model of the system then we fill various other specifications of the vehicle like its CG, mass, trackwidth, wheelbase etc.
Once done we can find out the variations in various dynamic parameters like camber, caster, toe, slip angle etc. which are extremely important for the vehicle. These parameters are plotted in a graph with wheel travel rate on the x-axis and the parameter whose variation is to be measured.

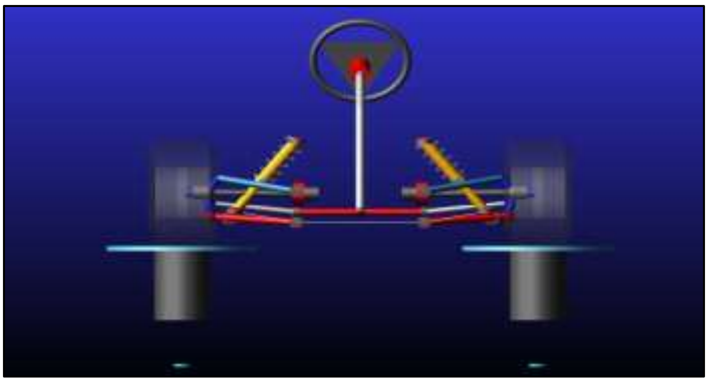

Fig 11: Suspension model in ADAMS

Results of the above simulation are shown below.

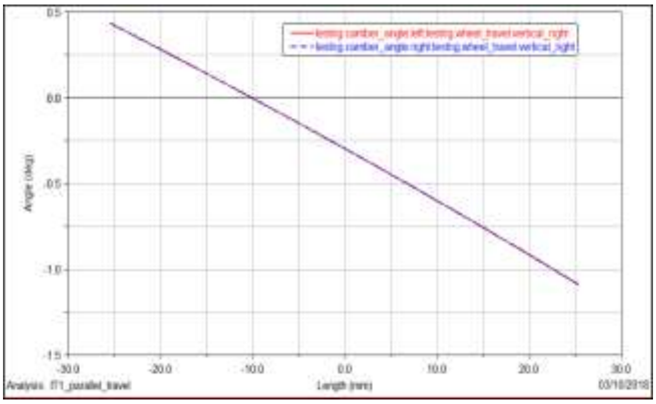

Fig -12: Camber Angle VS Wheel Travel.

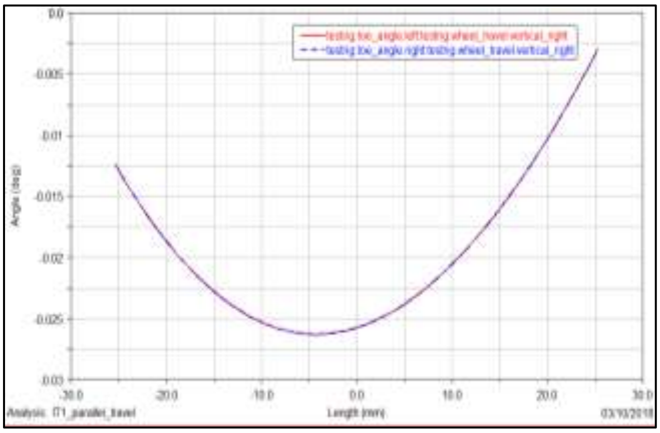

Fig -13: Toe Angle VS Wheel Travel.

7. MANUFACTURING

Manufacturing process are the steps through which raw materials are transformed into a final product. The manufacturing process begins with the product design, and materials specification from which the product is made.

7.1 Manufacturing of Wishbones:

As discussed earlier the wishbone material selected is AISI 1020.The following process was followed to manufacture the wishbone:

i) Cutting:

We get the length of the pipe to be cut from the CATIA roll center geometry.

ii) Grinding:

The pipes that were cut are brought to exact length by grinding the pipe ends.

iii) Fixtures:

To get the exact angle between the A-Arms we have to make fixtures in order to prevent the wishbones from changing angle.

iv) Fitting:

Fit all the cut pipes into the fixtures made.

v) Welding:

Weld the pipes to the bracket which will be bolted to the upright via a spherical bearing which will be press fitted into the bracket.

vi) Drilling:

Drill the ends of the pipes with M8 drill bit. This is done as a prerequisite for threading for fitting the rod end.

vii) Threading:

An M8 threading is done on wishbone.

7.2 Manufacturing of Upright and Hub:

As discussed above the upright and hub material selected is Aluminium 6061.

The following process was followed to manufacture the upright and hub:

i) Sizing the aluminium block and round bar to the dimensions required:

For Upright : L × B × H = 127 mm × 65 mm × 195 mm.

For Hub : Diameter × Length = 135 mm × 50 mm.

ii) Milling:

The edges of the block and bar are milled at different angles according to the design. Here complicated angles and finishing is not done as the accuracy of milling machines is moderate.

iii) VMC Operation:

After initial milling operation the block and bar is then machined on a VMC machine, to machine complicated shapes and holes which can't be done on a milling machine or a DRO machine. These designs include the upper portion of the upright, steering arm, calliper mounting etc.

The programmer first designs the fixtures to hold the block and the bar in the machine. Next he decides the flow of operation or basically from where to start the machining of the block and bar. Once the code is ready he uploads it into the machine which takes care of the rest.

Fig -13: Manufactured Upright and Hub.

8. CONCLUSIONS

For a formula styled vehicle handling and control of the vehicle at high speeds is a necessity and by using Double wishbone system we were able reduce to weight of the vehicle while improving its performance. The paper lays down the steps which one has to take for designing and manufacturing suspension system and the wheel assembly for a vehicle.

One of the primary benefits of double wishbone suspension system is the increase of negative chamber as a result of the vertical suspension movement of the upper and lower arms. Due to which handling performance also increases. Material selection is another important factor for designing a vehicle as this is the department where we can increase the performance of the vehicle by reducing its weight while keeping in mind the safety of the designed components.

References

[1] Trushar Bhope, Prof.Anurag Nema, Prof. Anantharma,"Design, Analysis and Experimental Investigation of Double Wishbone Independent Suspension System for Agriculture Trolley", International Research Journal of Engineering and Technology (IRJET)' e-ISSN: 2395-0056, Volume 3, Issue 9, Sep-2016, pp.1067-1071.

[2] Asst. Prof. N.Vivekanandan, Abhilash Gunaki, Chinmaya Acharya, Savio Gilbert and Rushikesh Bodake, "Design, Analysis And Simulation of Double Wishbone Suspension System", "International Journal of Mechanical Engineering (IIJME)", Volume 2, Issue 6, June 2014,pp.1-7.

[3] Reena Mishra, Anand Baghel, "Design, Analysis and Optimization of front suspension wishbone of BAJA 2016 of All-terrain vehicle- A Review", International Journal of Research in Mechanical, Mechatronics and Automobile Engineering (IJRMMAE), ISSN : 2454-1435, Volume 2, Issue 3, 28th Feb, 2017, pp.40-52.

[4] Sarvadnya Ajinkya Thakare, Prasad C Antapurkar, Divyaj S Shah, P R Dhamangaonkar and S N Sapali , "Design and Analysis of Modified Front Double Wishbone Suspension for a Three Wheel Hybrid Vehicle", Proceedings of the World Congress on Engineering 2015, ISSN: 2078-0958, Volume II, July 1 - 3, 2015, pp.1-4.

[5] V. B. Bhandari, "Design of Machine Elements", 3rd ed., McGraw Hill Education Private Limited, India, 1994, pp.393-447.