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Design and FEA Analysis of a Double Wishbone Suspension System

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Abstract - *In this research study an independent type suspension system is considered to be exact a double wishbone suspension system used in racing vehicle is considered. First research on existing double wishbone suspension system is made to design a new double wishbone suspension system. A double wishbone suspension parts are designed in a CAD tool Onshape and assembled in the CAD tool itself. This geometry is then imported to an analysis tool Simscale for FEA analysis or to be exact static and dynamic analysis. Materials of various parts are considered according to the standards and both the analysis are carried out to validate if the made suspension assembly is a good design in terms of strength. According to the results from both the analysis static and modal/frequency analysis the made geometry has a good strength and can be used for practical application in a race vehicle.*

Key words: FEA, Suspension system, Double Wishbone, Coil spring, Contour Plot.

1. Introduction

A double wishbone suspension system is mostly used in luxury or race cars as it provides better traction and stability compared to other suspension like Macpherson strut as the suspension geometry like camber is slight negative which provides a good traction due to increase in the area of contact between the tyre and the road. Due to presence of double or two wishbones in this suspension the camber angle can also be changed from the setting nuts provided by the manufacturer. Also, due to this manufacturing cost is expensive for double wishbone suspension as it contains many numbers of parts which thereby also increase its maintenance. A double wishbone and Macpherson strut suspension system are the two commonly used and well-known independent suspension used in automobile sector and they are selected according to the application like passenger vehicle have Macpherson and racing and luxury vehicle have double wishbone suspension system.

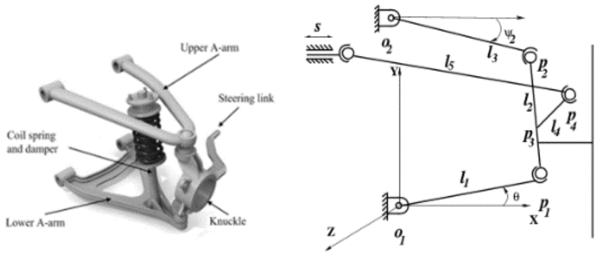
1. 1 Background

A double wishbone suspension system was introduced in the year of 1930s which was later implemented by Citroen a French automaker in its model Rosalie and Traction Avant in year 1934. Later Packard Motor Car Company based in Detroit; Michigan also implemented this suspension from year 1935 in its Packard One-Twenty model. Observing Double wishbone suspension system and Macpherson strut suspension system it feels like they are related to each other but that's not the case a Macpherson strut suspension design inspiration was taken from the landing gears of an aeroplane which has similar setup like Macpherson and Double wishbone was implemented much more earlier than Macpherson strut suspension system and thus they don't have any genetic relationship between each other. A double wishbone suspension system is only used by premium or luxury automakers and in the racing car as it provides very superior load handling characteristics also double wish bone suspension system are expensive to manufacture than other suspension system making them expensive in terms of buying as well as in its maintenance. [1]

2. Literature review

Amir Afkar et. al. In this paper a double wishbone suspension system is used to improve comfort, handling and stability in ADAMS software by using a genetic algorithm. A comparison of the normal double wishbone suspension system with optimized suspension system is presented by showing variation of geometry parameters on a rough road surface and various steering angles are taken from the ADMAS software. Also, sensitivity analysis and variation of the suspension geometry is also compared according to different road conditions bumps on road and rolling of the vehicle while turning in sharp curves. In this research the results are compared considering three different conditions like the simple double wishbone suspension system, modified double wishbone suspension system and optimization of double wishbone suspension system using genetic algorithm. In results it can be seen that the optimized suspension system by genetic algorithm gives the best output out of all by providing better stability and also a better comfort. [2]

Mohammad Iman Mokhlespour Esfahani et al. In this research study a double wishbone type suspension system is optimized by providing a passive hydraulic mechanism to control caber angle which will help the vehicle's tyre to have maximum surface contact with the road and increase vehicles stability as well as braking and acceleration even while turning thereby keeping the vehicle safe by keeping it under control. The developed mechanism for adjusting caber angle of the wheel is inexpensive. By using this mechanism camber angle can changed from -5.5 degree to 5.5 degree also, the movement of piston with rod can vary from 60mm and the crankshaft can rotate to 650 degree. study the made mechanism's performance a kinematic analysis is done using Nastran software to get the results. According to the kinematic analysis results the caber angle changes in very short time and provides better stability than a standard double wishbone suspension system. [3]



(a) Solid model (adapted from: (b) Kinematic model

Fig- 1: Double Wishbone Suspension system with Kinematic model

Aditya Arikere et. al. In this research study a double wishbone suspension system is optimized by changing considering suspension geometry of the vehicle like toe and camber which are the main parameter when it comes to stability of a vehicle. In this study multi objective genetic algorithm (MOGA) with NSGA- || is used for optimization purpose to minimize jounce and rebound of the wheel travel. A result is formed in a graph with the help of pareto optimal front method for comparison. After comparing the results of optimized and classical suspension system it can be seen that an optimized version of suspension works better than the classical one. This is how two main parameters can be focused using MOGA and this method can be used for any other type of suspension as well to focus toe and camber. [4]

2.2 Aim

Study various types of suspension system and do a detail research on double wishbone suspension system. Calculating the components of double wishbone mathematically and designing a double wishbone suspension system from the mathematical data and assign material to each and every component to carry out a static analysis on the suspension system.

2.3 Objectives

- Do a research study on a double wishbone suspension system
- Make a CAD model of the double wishbone suspension system considering various parameters like design, material, weight, etc.
- Carry out a static and modal analysis on the made double wishbone suspension geometry.
- And lastly validating the results of the through the yield strength of the assigned material.

2.3 Double wishbone suspension system

A double wishbone was invented by Citroën a French car manufacturer in the year 1934 and implemented on the model Rosalie. A double wishbone suspension system is also called as double arm. This suspension has two mounts on the chassis at upper and lower and knuckle joint at its other end. A wishbone has two main categories on which it is classified independent suspension system and dependent suspension system. A double wishbone suspension system falls under independent suspension classification as both the side i.e. right and left side are not connected to each other and are independent from each other also in independent suspension system a torsion bar/ anti roll bar/ sway bar are provided to reduce rolling movement in case if one side of the suspension is down and the other suspension is at a level.

2.3.1 Parts of Double wishbone suspension system

Control arms: A double wishbone consist of two wishbone which is the lower wishbone and upper wishbone also called control arms. These control arms are connected to one end with car body and other side to the wheel due to which it provides up and down movement to the wheel.

Coil spring: a helical spring which is compressed in strut for providing supports to the suspension's damper this spring varies according to the vehicle type as it can be kept stiff or soft

Steering knuckle joint: It is a main part in the steering system as it controls the turning movement of the vehicle. It is apart in which lower control arm or lower wishbone is connected to at its lower side and strut at its upper assembly at its upper side.

Strut assembly: It is main part of the suspension as it consists of damper and a coil spring with proper bushing to it making a complete strut assembly.

Shock absorber: also called as damper is used to damp the motion of the vehicle and it is a part of strut assembly. This shock absorber comes in different types and various length.

Bushes: To reduce direct contact of the metal and make less wear and tear and also reduce noise even at high damping.

Upper strut mount: It is a point where the strut's upper end is joined to the vehicle's frame to provide a fix point to the strut.

Sway bar: This bar controls rolling or swaying motion in case of any uneven road surface at only one side of road that is either faced by left suspension or right suspension.

Steering linkage: This part serves to steer the vehicle as Macpherson strut suspension is commonly used for front wheels. It also increases turning radius compared to other suspension setup hence, this setup is used in drifting vehicles.

2.3.2 Construction of Double Wishbone suspension system: The A-arms end are connected to the vehicle body and the other end is connected to the wheel these A-arms are parallel to each other from a particular distance and are also called as lower wishbone and upper wishbone. End of the A arms are called control arms. An arm is uneven in length to provide camber to the wheels. A strut goes between the control arms and mounted on the control arms itself. It uses chromium-molybdenum steel as its part material.

2.3.3 Pros and Cons of double wishbone suspension system

Pros of Double Wishbone suspension system [5]–[7]

Two control arms provide good handling and stability while cornering by keeping the tyres contact with the road. It contains two wishbones but then to the setup is compact and flexible leaving extra empty space other than the whole suspension assembly. Control arms are not connected directly to the car body which makes it easy during off-road conditions due to long suspension travel. Due to difference in control arms a slight negative camber is present instead of positive camber resulting in a better grip. Even after setup of two control arms there remains an enough empty space for both normal shock absorber or a coilover setup.

Cons of double wishbone suspension system. A double wishbone is expensive suspension setup. Due to main parts present in the assembly the system becomes complex. It has high maintenance as there are many numbers of parts present in its setup.

Being a complex setup if one part fails then the its functioning will fail as well.

It occupies more space than other suspension setup.

2.3.4 Design of coil spring

Modulus of rigidity, G = $205 \times 10^3\ MPa$

Shear stress, $\tau = 550\ MPa$

Spring index, C = 4

Deflection, $\delta = 25\ mm$

Load, W = 7402 N

Using Wahl's factor

$$K = \frac{4C-1}{4C-4} + \frac{0.65}{C}$$

$$K = \frac{4\times 4-1}{4\times 4-4} + \frac{0.65}{4}$$

$$K = 1.4125$$

$$\text{Max shear stress} = k \times \frac{8WC^3 \times n}{\pi d^2}$$

$$\therefore 550 = \frac{1.40 \times 8 \times 7402 \times 4}{\pi d^2}$$

$$d^2 = \frac{331.609 \times 10^3}{\pi \times 550}$$

$$d = 13.853\ \approx 14$$

d = 1.4 Cm

Mean diameter, D = $C \times d$

$$D = 4 \times 13.85$$

$$D = 55.41\ \approx 56$$

D =5.6 Cm

Outer diameter, $D_o = D + d$

$$D_o = 5.6 + 1.4$$

$$D_o = 7\ Cm$$

For number of coils

$$Deflection, \delta = \frac{8 \times W \times C^3 \times n}{G \times d}$$

$$25 = \frac{8 \times 7402 \times 4^3 \times n}{[(205 \times 10^3) \times 14]}$$

$$25 = 1.32 \times n$$

$$n = \frac{25}{1.32}$$

n = 18.93 ≈ 19

For ground ends, $n' = n + 2$

$$n' = 19 + 2$$

$$n' = 21$$

$$\text{free length} = n' \times d + \delta + 0.15\delta$$

$$Free\ length = 21 \times 14 + 25 + 0.15 \times 25$$

$$free\ length = 322.75\ mm$$

$$Pitch\ of\ the\ coil = \frac{free\ length}{n' - 1} = \frac{322.75}{21 - 1}$$

$$Pitch\ of\ coil = 16.14\ mm$$

3. Methodology

3.1Research on various design of double wish bone suspension system

A wishbone has two main categories on which it is classified independent suspension system and dependent suspension system. A double wishbone suspension system falls under independent suspension classification as both the side i.e. right and left side are not connected to each other and are independent from each other also in independent suspension system a torsion bar/ anti roll bar/ sway bar are provided to reduce rolling movement in case if one side of the suspension is down and the other suspension is at a level. Figure shows three different design of double wishbone, first is double A-arm design, second is one A-arm and single arm and the last one is one A-arm and L-arm. [8] [9] [10]

3.2 Selecting a design of a suspension

Choosing a double A-arm wishbone suspension system as a design as it has more strength and ability to absorb shocks and vibration then other design and therefore a double A-arm wishbone is mostly commonly used design in a double wishbone suspension system.

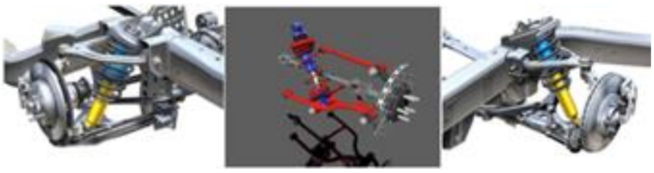


Fig- 2: Double A- arm wishbone system, A-arm and Single arm double wishbone suspension system And One A-arm and L-arm double wishbone suspension system

3.3 3D modelling/CAD modelling a double wishbone suspension system

Modelled a double A-arm suspension system in a CAD tool Onshape keeping various parameters in mind like strength, weight, fit and finish, etc. to make sure the made suspension system is feasible and do its work as efficiently as possible. This made suspension is made in various parts to be exact in 17 parts in total and assembled it in the CAD tool itself providing various contacts points like cylindrical mate, revolute mate, pin slot and fastened mate.

3.4 Importing model in analysis tool for FEA (Finite element analysis)

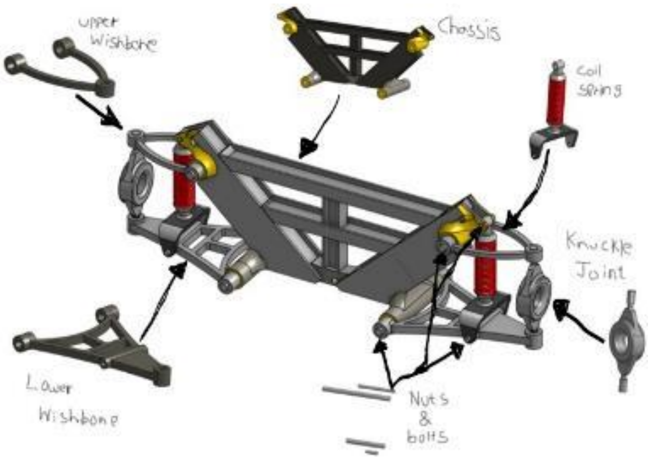


Fig - 3: Parts and assembly of CAD modelled double wishbone suspension system

Imported the made double wishbone suspension system in an analysis software Simscale in an IGS format to carry out FEA analysis on it like static and modal analysis. Gave name to each and every parts of the suspension system just like named selection through topological entity for better understanding and easy access to various parts.

3.5 Providing contacts and assigning material

Gave contacts to each and every mating parts in the geometry to let the analysis software know which parts are mated with each other and what type of contact do they have between them like bonding or sliding. Total 21 different contacts were providing in this assemble.

Assigning material

Assigned material to the double wishbone suspension system according to the standards. Aluminium, Steel and Iron are the three following parts which are assigned to the part according to its application. Following is the material assigned to double wishbone suspension system parts; Chassis as an Aluminium alloy, knuckle joint as a cast iron, lower and upper wishbone made from carbon steel according to AISI, coil spring and its various tightening parts from steel alloys, bolts, washer and nuts assigned as steel.

Material assigned and its properties considered for static and modal/frequency analysis

Fig - 4: Assigned Material and its properties

3.6 Boundary conditions for static analysis

Applied two boundary conditions in a static analysis that are fixed support and a force. A fixed support is applied to the lower and upper part of the chassis and a force of 2000 Kg is applied in upwards direction to the knuckle joint just like in case when a vehicle goes through a pot hole the tyre moves in upward direction. Force 2000 Kg is calculated in the following manner;

Weight of the vehicle: 1600 kg

Weight distribution on suspension system: 67% at rear and 33% at front

Gravitational force: 9.81

To find: F, Force on the vehicle =?

$$Load = (force\ on\ the\ vehicle) \times \frac{weight\ distribution\ at\ the\ rear}{100}$$

$$1600 = (F)\left[\frac{67}{100}\right]$$

$$F = \frac{1600}{\left[\frac{67}{100}\right]}$$

$$F = 2388\ \times 9.81$$

$$F = 23426.28\ N$$

As the weight is distributed in two side of suspension system dividing it by 2

$$F = 243426.28\ \times 2$$

$$F = 11713{,}14\ N\ \ OR\ \ F = 1194.14\ kg\ \approx 1200\ kg$$

Considering factor of safety

$$\therefore F = 2000\ kg\ \ OR\ \ F = 20000\ N$$

3.7 Boundary conditions for Modal/Frequency analysis

Only one boundary conditions applied in a modal/frequency analysis which is a fixed support. This fixed support is applied on the upper and lower portion of a chassis same case like provided in static analysis.

3.8 Grid/Mesh generation with Mesh setting for both static as well as modal/frequency analysis

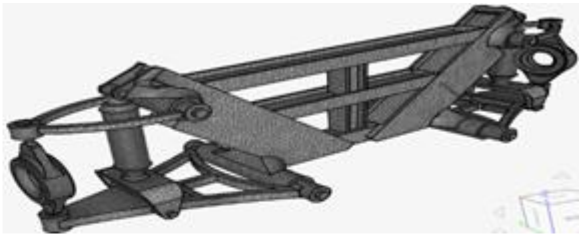


Fig –5: Mesh/grid generated on made CAD model for static and modal/frequency analysis

A fine mesh is given to the suspension geometry with a 10-size fineness in automatic mesh sizing using a standard algorithm of a Simscale.

Mesh quality for both static and modal/frequency analysis

Average Non-orthogonality is 20.222

Average Skewness is 0.1879

Average aspect ratio is 1.608

Average tetAspect ratio is 1.608

4. Results

4.1 Static analysis results of double wishbone suspension system

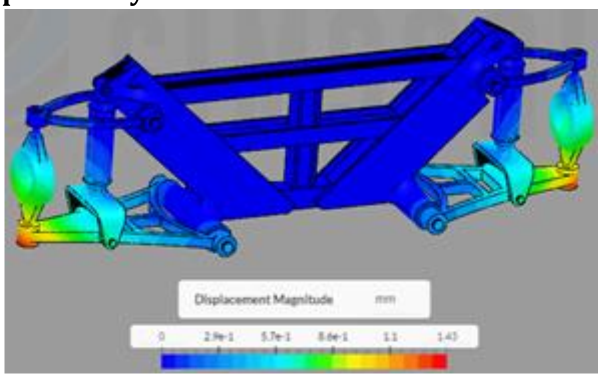


Fig -6: Contour plot for displacement

Applying 2000 kg of force results near to1.43 mm or 0.143 cm of max displacement which indicates there is not much of a displacement taken place in any component only lower wish bone has the max displacement according to displacement contour plot which is under permissible stress or under the yield strength.

Below is a contour plot for von mises stress on a double wishbone suspension system with max legend limit as $1.3 \times 10^8\ pa$ OR 240 Mpa which indicates the suspension is safe.

4.2 Modal/frequency analysis for a double wishbone suspension system

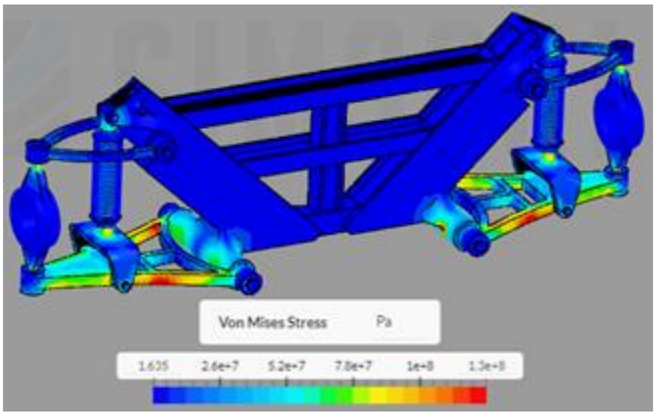


Fig -7: Contour plot for Von Mises Stress

Below picture is at EIGENMODE 11 with at 94.135 EIGENFREQUENCY and statistical table data in right with 15 EIGENMODES and their EIGENFREQUENCY.

4.3 EIGENFREQUENCY plot

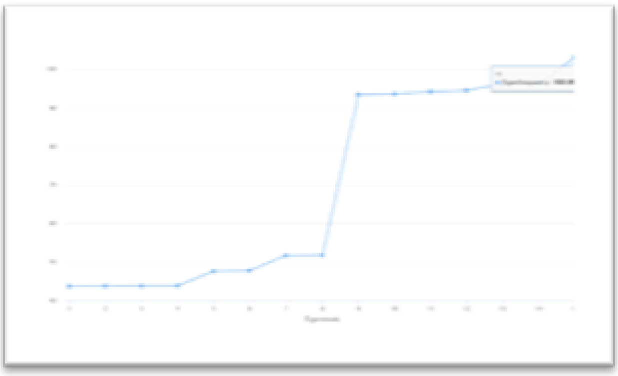


Fig -9: Eigenfrequency plot for modal/frequency analysis

Table -1: Generated static analysis results for Double Wishbone Suspension System

Static analysis on a suspension system		
Sr no.	Parameters	Range of legend
1	Displacement magnitude	0 – 1.43 (mm)
2	Von-mises stress	$1.63 - 11.3 \times 10^8$(Pa)

Table -2: Generated Modal/Frequency analysis results for Double Wishbone Suspension System

Modal/frequency analysis on a suspension system		
Sr no.	Parameters	Range of legend
1	Displacement magnitude	0 – 11.8 (mm)
Number of EIGENMODES		15

5. Conclusion

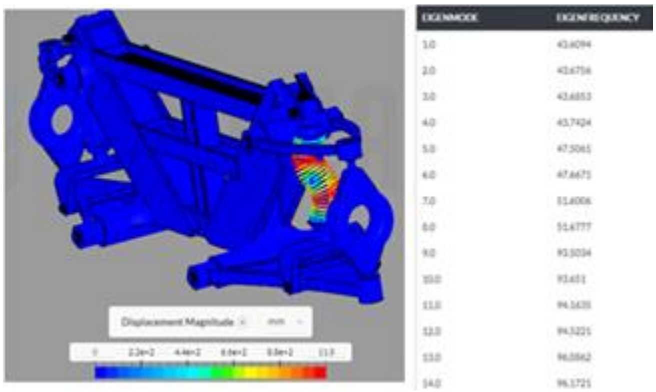


Fig -8: Eigenfrequency contour plot and its modes

Max displacement in modal/frequency analysis for suspensions system is 11.8 mm and max displacement in static analysis is 1.43 mm. After carrying two different type of analysis on a designed double wishbone suspension system and materials assigned according to standards in both the analysis i.e. static and modal analysis it can be seen that after applying force evenly to the double wishbone suspension system it is not crossing the yield strength/ultimate point of any material like aluminium, carbon steel and iron that has been used in the whole suspension system indicating the made double wishbone suspension system is safe and can be designed and used for a practical application.

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