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Structural Analysis of Double-Wishbone Suspension System

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Abstract: A suspension system is a crucial part of the vehicle system which assists in handling the vehicle and safety of the occupants. From leaf spring type suspension to multi-link suspension and modern adaptive suspension systems, different modifications and researches are practiced to enhance dynamic characteristics of suspension optimizing drivability and ride comfort. The presented study focuses on the analysis of double wishbone suspension system. The components used and working of this suspension are also explained as well as the numerical calculation for creation of the spring is presented. The Finite Element Analysis (FEA) is carried out using Simscale software. The suspension is analyzed through static analysis and results show acceptable values.
Keywords: Structural Analysis, Vehicle Suspension System, Double Wishbone Suspension System, Analysis of Suspension System, Finite Element Analysis (FEA), SIMSCALE, Suspension Spring, Suspension Spring Calculation.

I. INTRODUCTION

In a vehicle, the suspension system plays an important role in handling of vehicle. It is used to keep the tyres in contact with road surfaces all the time. Suspension system connects vehicle to the wheels. The system absorbs shocks and vibrations due to uneven road surfaces enabling improved rode quality and decreasing body roll. The suspension system consists of tyres, springs, shock absorbers and linkages which connects the chassis or/and body of the vehicle to the wheels. Three classifications of suspension system include dependent, semi-independent and independent suspension systems. In modern cars independent type of suspension is usually seen. This type of suspension system includes MacPherson suspension system, swinging arm suspension system, double wishbone suspension system, multi-link suspension system etc.

This study is based on Double Wishbone Suspension System which is an independent type of suspension system. It means each wheel of the same axel has vertical movement independent of each other. The double wishbone suspension system also known as double A-arm suspension was first introduced in 1930 and in 1934 the carmaker Citroen started using it in their vehicle models. The greater dynamic characteristics and load-handling capacities is the reason why this suspension system is used in sports cars as well. This type of suspension is commonly fitted in rear of the vehicle though front applications are common too. Short long arm (SLA) is a type of double wishbone suspension where the upper A-arm is shorter than the lower arm. SLA is usually fitted in front of the vehicle as the shorter arm induces negative camber while cornering resulting in better handling the vehicle. SLA can be seen in high performance cars. In passenger vehicles an L-shaped lower arm is used for better compromise of handling and comfort tuning. Double wishbone suspension system is also popular on open wheel race cars such as formula 1 for its dynamic characteristics.

II. COMPONENTS AND WORKING

The suspension system consists of two wishbone shaped arms (also called as control arms) with ball joints at both ends. This allows its movement in multiple directions. The arms are connected between the knuckle of wheel assembly and car body chassis. A shock absorber with coil spring is mounted on the lower wishbone and connected to the chassis to control vertical movement. Double wishbone suspension system design allows engineer to have feasibility in controlling parameters such as camber & caster angle, roll center height, toe angle, scuff, scrub radius etc.

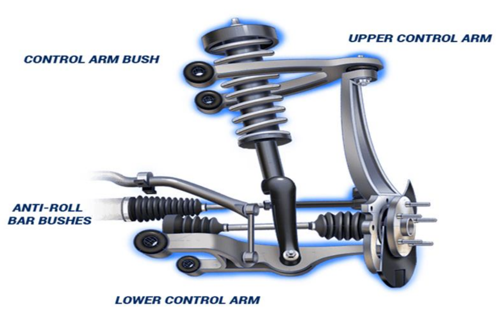

Figure 1: Double-Wishbone Suspension Components

When the tyres come in contact with uneven road surfaces, the impact from the tyre is transferred to the lower arm which connects the vehicle frame through shock absorber. The shock absorber then absorbs the impact by compressing the spring and damper while the upper arm maintains the camber angle of the wheel. The length of the upper wishbone can be modified to optimize the ride quality and handling.

While selecting a material for manufacturing any component, some facts such as material availability, its cost, density of the material, yield and bending strength of the material, its weight etc. must be considered. Many researches have been carried out on designing components with more strength but less weigh where replacing material becomes prime suggestion. Wishbones are usually made up of mild carbon steel. Some researches have proven using T6 Titanium, chromoly etc. In f1 cars they are made up of carbon fiber which is lighter yet stronger than steel. The spring on the other hand is made from variety of material depending upon its use in particular types of vehicles. Steel alloys are the popular raw materials for making springs. These alloys include high carbon steel, oil-tempered low-carbon steel, chrome silicon steel, chrome vanadium steel and stainless steel. Other parts might need different materials to get manufactured for this particular type of suspension system. The study is conducted referencing different literature provided below.

III. LITERATURE

A double wishbone front suspension is designed and analyzed. The suspension geometry is created using Solidworks tool. The real time behavior of the system is predicted considering parameters such as road profiles, stiffness, damping coefficient etc. A multi body dynamic simulation is carried out using Matlab-Simulink tool. From its results a structural analysis was done. They used ANSYS software for static structural analysis. The results showed maximum deformation in lower arm. Hence, modal analysis is done on lower arm and connecting arm only. The results helped predict total deformation a particular vibrating frequency. [1] The paper aims in designing a suspension system for formula student vehicle. a methodology is presented for designing and analysis of knuckle, spring and wishbones. The 3D designs of these components were created in CATIA software and analyzed in ANSYS workbench. The whole assembly was set for kinematic simulation in ADAMS software. [2] The main objective of the study is to design, analyze and simulate double wishbone suspension system for an all-terrain vehicle. For material selection of wishbones Pugh's concept of optimization is used. The designs were prepared in Pro-E software and analysis were done in ANSYS software. The suspension geometry of the system was determined using LOTUS simulation software.[3] The intended research is to design and analyze suspension system for all terrain vehicle. the double wishbone suspension system was chosen for the study and components are modeled in Solidworks software and analyzed in Ansys workbench. Dynamic characteristics are calculated. The camber angle and toe angle were studied and modified accordingly using LOTUS software.[4] A study is done on designing and analyzing wishbones for a double wishbone suspension. The CAD model is created using CREO software. Material selection is based on Pugh's concept. The camber and toe angles were dynamically observed and changed using LOTUS software. [5] A model of double wishbone suspension system for off road vehicle is created in ADAMS software. The focus of the paper is on improving ride comfort, handling and stability of vehicle. Generic algorithm (GA) is used to optimize geometric parameters of the model. Simulation results under varying road conditions are presented in ADAMS software.[6]

IV. ADVANTAGES AND DRAWBACKS OF THE SYSTEM

The system provides more design choices to the engineer. It offers a superior ride quality and handling of the vehicle. The negative camber gain is one of the important advantages. The system takes less vertical space hence ride height stays low improving aerodynamics and providing better handling. It is easy to work out the loads that different parts are subjected to which allows more optimized lightweight parts. Suspension characteristics such as the camber, caster, and toe angles can be effectively modified. Though it is feasible to modify the system it has many parts that makes it very complex which results in expensive design and manufacturing. Even if one part fails it causes the service and repair of whole system and it takes more servicing time than other suspension systems. It is heavier and takes more horizontal space than other suspension systems.

V. METHODOLOGY

In this work, the finite element analysis of the double wishbone suspension system has been carried out. An analytical method for designing a spring for suspension system is also presented considering the studying suspension. The materials and their properties for each component of the system that are used in industry are also studied. Further a static structural analysis is carried out using FEA software Simscale.

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Designing the spring:
The material chosen for spring is steel. Hence, we have,
G = 205*10^3 MPa
τ = 550 MPa

Load applied to the spring = w = 5258N
δ = 25mm
c = 4

Solution,
K= (4c-1/ 4c-4) + (0.615/ c) = (1.25)+(0.15) = 1.4
We know that,
τ = K (8wc/ πd^2)
550 = 1.4 [8(5258)(4)/ 3.14d^2]
550 = 1.4(168256/ 3.14*d^2)
550 = (75018.5)/ d^2
d^2 = 136.39
d = 11.67mm i.e. 12mm

Mean diameter,
D = cd
D = (4)(11.67) = 46.68mm i.e. 47mm

Outer diameter,
= D + d
= 47 + 12
= 59mm

Number of coils (n),
δ = 8w(c^3)n/ Gd
25 = 8(5258)(4^3)n/ (205*10^3)(12)
25 = 2692096n/ 2460000
25 = 1.09n
n = 23

For ground ends,
n` = n + 2
n` = 25

Free length,
= n`d + δ + 0.15 δ
= (25)(12) + 25 + 0.15(25)
= 328.75mm

Pitch of the coil,
= Free length / (n` - 1)
= 328.75/ (25-1)
= 13.6mm

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The 3D geometry of double wishbone suspension system is shown below,

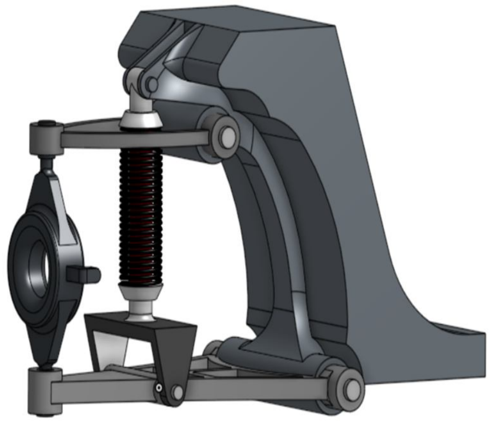

Figure 2: 3D model of suspension system

The materials used for the components are shown below:

Component	Material
Spring	Steel
Shock absorber unit	Steel
Chassis Frame	Aluminum
Knuckle	Mild carbon steel
Wishbones	Mild carbon steel

Table 1 : Material Selection

The properties of the selected materials are shown below:

Material	Poisson's Ration	Young's Modulus (Pa)	Density Kg/m^3
Steel	0.28	2.05e+11	7870
Aluminum	0.34	7e+10	2700
Mild Carbon Steel	0.3	2.06e+11	7850

Table 2: Material Properties

A fine mesh model of the proposed wishbone system has been generated and put to test.

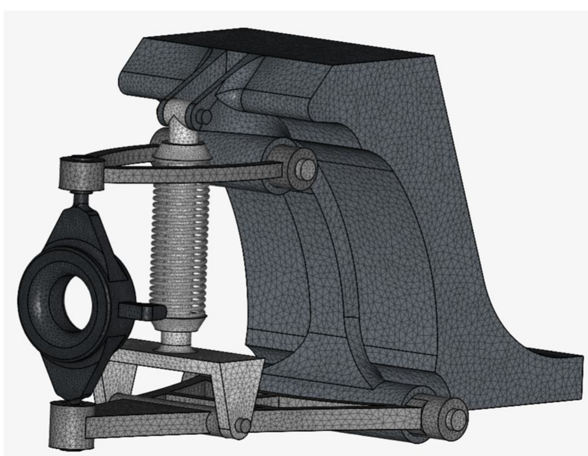

Figure 3: Meshed Model

The static structural analysis is carried out to measure the capacity of certain subjected body when put under constant load. Static analysis determines the displacements, strains and forces in structures due to the applied loads. The types of static analysis loading conditions include a) externally applied forces, b) Steady state inertial forces, c) nonzero displacement and d) temperature for thermal strain. The proposed design is put under static structural analysis with materials selected as per above tables. The shock absorber mount and chassis frame is given fixed support as boundary condition. The quarter model is used for quick and more precise analysis. The load is applied to the knuckle in upward direction. The assumed weight of the vehicle is 800kg and the system is subjected to the load of 5258.16 Newtons. The results of von mises stress and displacement magnitude are shown below.

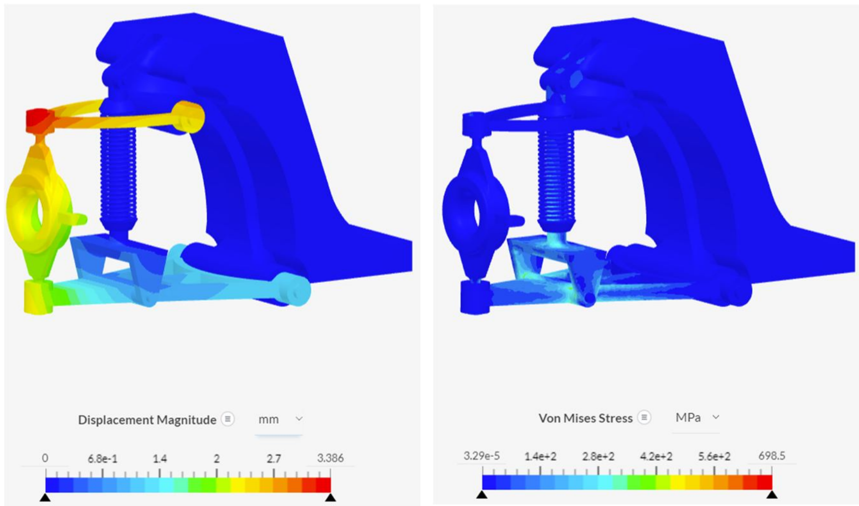

Figure 4: Results obtained from static analysis

VI. RESULTS & CONCLUSION

The static analysis of presented suspension system carried and the results show von mises stress induced is 698.5 MPa max and total displacement magnitude is 3.386mm. The paper lay down a methodology for static analysis of the double wishbone suspension design. The results obtained are found to be satisfactory and this method can be useful in double wishbone suspension's applications.

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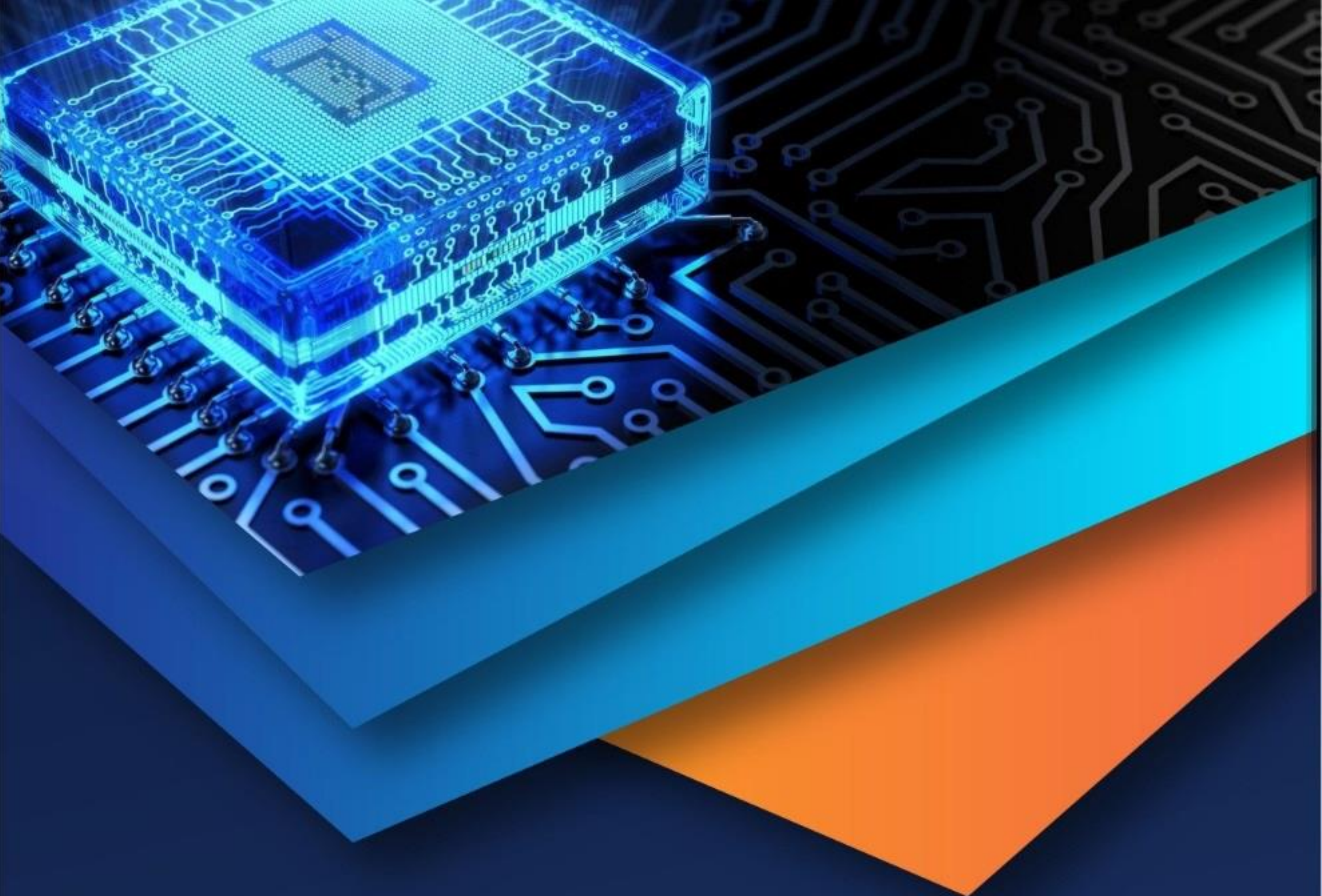

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