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Design and Static Stress Analysis of Double Wishbone Suspension

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***Abstract:** Double Wishbone suspension systems are by far the best choice of suspension systems recommended for sports vehicles. It is more stable and stiffer when compared to the other suspension geometries. In this report a brief study of how a double-wishbone suspension system acts under loading conditions when traveling at high speeds is presented, also the forces acting on its components are analysed, and post-processed results are discussed. The geometry of the whole suspension is designed on SolidWorks and analysis is performed on Ansys software. Further the results from the analysis are studied based on material selection and various analysis methods. Finally, the proposed suspension system is concluded safe to use when the values of Equivalent stress, Total Deformation, and Factor of Safety were measured and under threshold limits.*

***Keywords:** double wishbone suspension, static structural, suspension system, analysis, deformation, Ansys, stress analysis, FOS, FEA, structural analysis.*

I. INTRODUCTION

A suspension system is a basic as well as an important component of a vehicle, it upholds ride comfort even in most undesirable road conditions by maintaining a constant hold over the vehicle. With the correct tire pressure, spring quality, and right shock-absorber a suspension can provide optimum comfort. A double-wishbone suspension system consists of a combination of helical compression springs, shock absorber strut, linkages, upper and lower control arm, steering knuckle, and wheels hub. This combination is based on the various requirement of the vehicle [1]. The spring and shock absorber setup's lower end is fixed to the lower arm (lower control arm) and the upper portion of the setup is bolted to the chassis of the vehicle; this suspension system fits with the majority of chassis structures.

The material selection for each component is also different. In this report, a double-wishbone suspension is presented because it is ideal for a single-seater race car as it maintains optimal camber angle at the event of turn. Due to its compact design and a greater number of parts, it is firmer and exhibits fewer vibrations. The construction of this suspension is shorter which improves the center of gravity which is crucial for a sports car. This type of suspension is also capable of handling torque steer. Therefore, a new suspension geometry is designed with selective suspension materials.

II. LITERATURE REVIEW

[2] This study represents a mechanism that can change the camber setting of a double-wishbone suspension, having a variable camber angle saves time and effort by not removing the wheel. The author says that the camber angle plays a vital role while the vehicle is taking a turn. Having a proper camber angle in a turn increases the grip of tires, reduces uneven wear, improves braking as well as acceleration. A piston and crankshaft mechanism is employed which has a short response time is designed on Visual Nastran software. The camber setting mechanism is fitted to the upper wishbone and when the crank rod rotates the camber angle changes accordingly. Further kinematic analysis is performed and through results, it has been concluded that it is a major advantage for overall improvement in automobile stability.

[3] The following paper presents a comparative study of linear and progressive spring rates used in double wishbone suspension, thus concluding the ideal spring structure to be used in lower-class rally cars. According to rally cars, the servicing period at the service park is limited and suspensions like air suspension or hydro-pneumatic in a double-wishbone suspension setup are risky, as they are not cheap and can consume a lot of time. A technical form of multi-body analysis and statistical assessment of both the spring rates, for their capacity to provide road traction and cruise luxury performance is defined. For comparing both the suspensions, the CAD model is created by scanning all actual components of the dual wishbone suspension as well as the computerized road is generated on 3D software like MSC ADAMS/View.

The required data is obtained from the simulation and applied in MSC software. Further IBM SPSS software was used for statistical analysis for comparison of both the data. As a result, it was justified that the linear spring suspension with the wishbone setup is the most affordable and better choice for lower-class rally cars, as there are no additional components like linkages, it would be good for servicing with minimum cost expenditure.

[4] This paper presents a lower control arm of wishbone suspension wherein two materials are considered aluminium and mild steel, on which critical loading is measured by adding forces as well as their optimization is achieved, and the obtained results are calculated. With the help of CAD software Pro-E, the design is achieved. Various analysis like modal and static analysis is performed on Hyper Works software. Results concluded that both materials had passed the test with maximum displacement being under the limit. The aluminium had better strength as well as the mild steel had better strain properties. In modal analysis, it was considered that both materials have different properties which lead to dissimilar resonance conditions. The optimization was carried out and the factor of safety was improved along with reduced weight.

III. OBJECTIVE

To design a Double Wishbone suspension system and carry out FEA analysis by subjecting the suspension model to the forces expected when working in high-speed situations and validating your selected material.

IV. METHODOLOGY

From the above study of literature review and introduction, it was assessed that the structural stability of suspension systems is crucial for an automobile. From various types of suspension systems, the Double Wishbone Suspension system was a suitable system that can be used in a single-seater sports vehicle. Before planning the geometry, the materials were considered for every part of the suspension. Detailed research was carried out on the material for parts of the suspension. Design calculations were considered for the suspension system.

Based on that data SolidWorks software was chosen to create geometry, the suspension system along with all its parts was designed on SolidWorks software, the individual parts of the system were designed and generated in Part Module. Assembly of all the components is done in the SolidWorks Assembly module. The analysis part is performed in ANSYS software.

TABLE I

MATERIAL SELECTION AND PROPERTIES

Components	Materials	Tensile strength	Poisson's ratio	Young's modulus
Springs	Titanium alloy	280 MPa	0.32	36.9 Gpa
Upper and lower control arm	Aluminium alloy	230 MPa	0.34	70 Gpa
Bump stopper	Polyurethane foam (rigid)	103 MPa	0.53	12.8 MPa
Shock absorber strut	Stainless steel austenitic	215 MPa	0.27	190 Gpa
Chassis	Aluminum 7075 – T6	512 MPa	0.33	71.7 Gpa
Steering knuckle	Nodular cast iron	580 MPa	0.22	165 Gpa
Wheel hub	Cast aluminum alloy	152 MPa	0.33	26.5 Gpa

A. Mathematical Calculation Suspension System

Weight considered for the vehicle = 900 Kg
The force acting on the vehicle-
F = Load × Earth's Gravity
F = 900 × 9.81
F = 8829 N
The weight distribution considered for the single-seater performance car,
45.5 % - Front axle and 53.3 % - Rear axle

Therefore, the load acting on the rear is calculated as-
Load @ rear = F × 53.3 % ÷ 100
Load @ rear = 8829 × 53.3 % ÷ 100
Load @ rear = 4705.9

B. Design Calculation of Spring

Obtained data:
Load taken is 2352.9 N. (Load acting at the rear axle is 4705.9N and it is further divided by 2 which given the value 2352.9N)
W =2352.9N
Spring index (C) = 5 …(Assumed)
Modulus of rigidity (G) = 44 GPa ≈ 44×10^3 N/mm^2(of the titanium alloy)
Shear stress (τ)= 760 MPa = 760 N/mm^2… (of the titanium alloy)
Spring deflection (δ) = 60mm …(Assumed)

1) Find the wall factor (K)-

K= (4 C-1)/(4 C-4)+0.615/C
∴ K= (4 (5)-1)/(4 (5)-4)+0.615/5
∴ K= 1.4

2) To find wire diameter (d)-

τ= K ×(8 ×W ×C)/(π ×d^2)
∴ 760= 1.4 ×(8 ×2352.9 ×5)/(π ×d^2)
〖∴ d〗 ^2=1.4 ×(8 ×2352.9 ×5)/(π ×760)
〖∴ d〗 ^2=55.2mm
∴ d=7mm

3) To find spring outer diameter (OD)-

C= D/d… D = Mean Diameter
∴ 7= D/7
∴ D = 35mm
Now, Finding (OD) outer diameter
Do = D + d
∴ Do = 42mm

4) To find the active number of the coil (η)-

δ= (8 × W ×C^3× η)/(G ×d)
∴ 60= (8 × 2352.9 × 〖(5)〗 ^3× η)/(44×10^3 × 7)
∴ η= (60 × 44×10^3 × 7)/(〖(5)〗 ^3 × 2352.9 × 8)
∴ η=7.9 ≈8
∴ η= 8
Now, find spring support ends (η^')

$\eta' = \eta+2$
$\therefore \eta' = 8+2$
$\therefore \eta' = 10$

5) To find the length of the spring (L_f)-
$L_f = \eta' \times d + \delta + 0.15\,\delta$
$\therefore L_f = 10 \times 7 + 60 + 0.15\,(60)$
$\therefore L_f = 139mm$

6) To find the Pitch of coil (p)-
$p = L_f/(\eta'-1)$
$\therefore p = 139/(10-1)$
$\therefore p = 15mm$

Based on the above calculation, the spring was created in SolidWorks.

C. *Component Design*

Solid modeling was done on SolidWorks and the necessary components are given below-

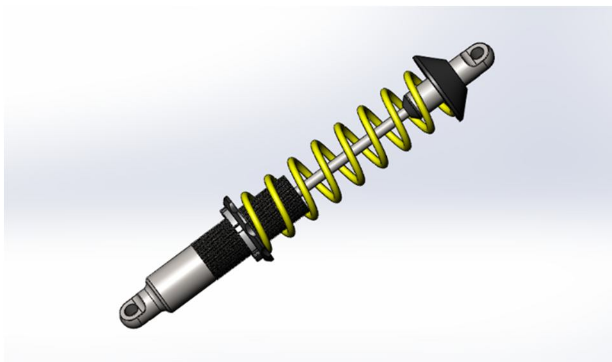

Fig. 1 Spring and Strut Assembly

The above assembly of suspension strut is designed on SolidWorks software, coil spring with proper dimensions is modeled along with upper and lower absorber strut, the rubber bump stop is then modeled, and all the parts of the setup component are mated together to form a coil spring and strut setup.

Fig. 2 Chassis

The chassis is designed by considering the lightweight build of the vehicle, the boss extrudes for this chassis is taken by considering realistic chassis and strut mounting locations are redesigned, half part of the chassis is a mirror to save time. The chassis is kept hollow to accumulate the brake components below it.

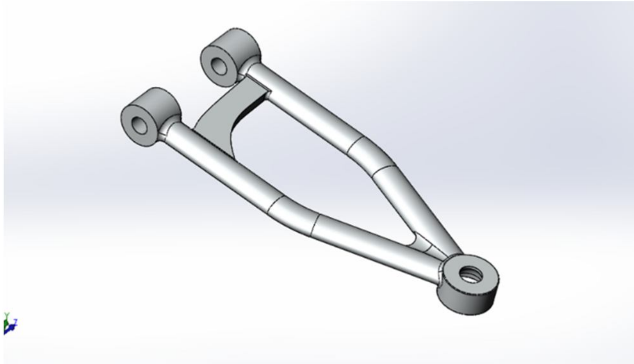

Fig. 3 Upper Control Arm

The upper arm is designed to be lightweight with less as well as lightweight material and all the edges are chamfered for smooth operation with Strut mounts and bushing.

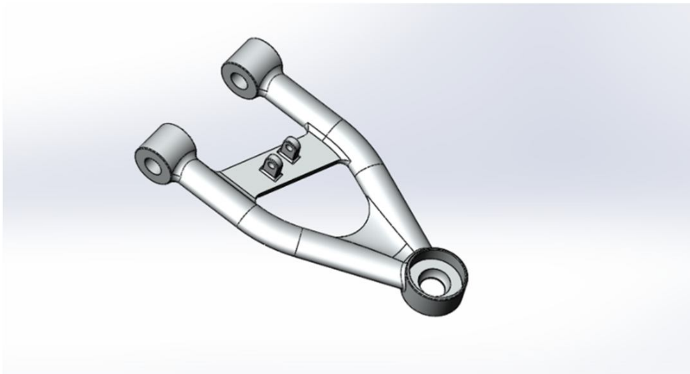

Fig. 4 Lower Control Arm

The lower arm has the lower strut mounts and the revolve cut at its knuckle mount side is improvised for the knuckleball bearings to move freely.

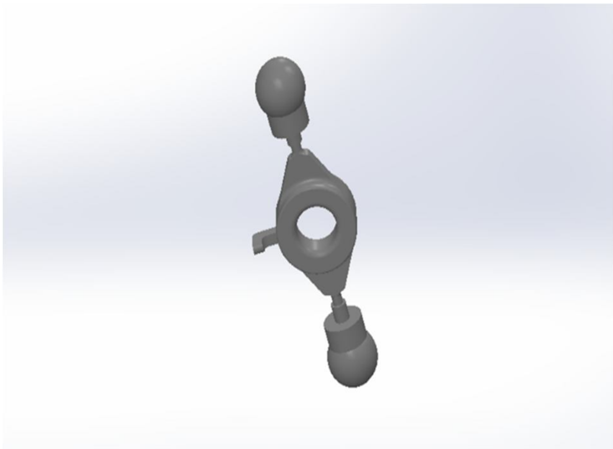

Fig. 5 Knuckle Joint

The knuckle joint is designed to be flexible in suspension operation as the dome structure is made with a bigger radius. Various features like extrude-cut, revolve were used in making this geometry.

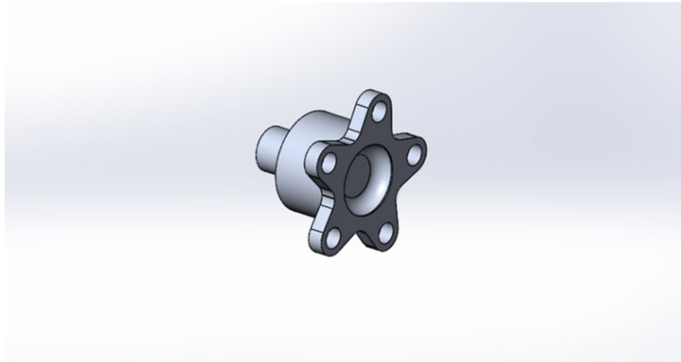

Fig. 6 Wheel Hub

The wheel hub is a key part where the wheel is attached, with the combination of extruding and extrude cut this geometry is designed. The bolts are uniform by keeping in mind the practicality of the suspension. The strut bolts are smaller compared to the control arm bolts, they have a lesser diameter and are made with the same methods as the above bolts.

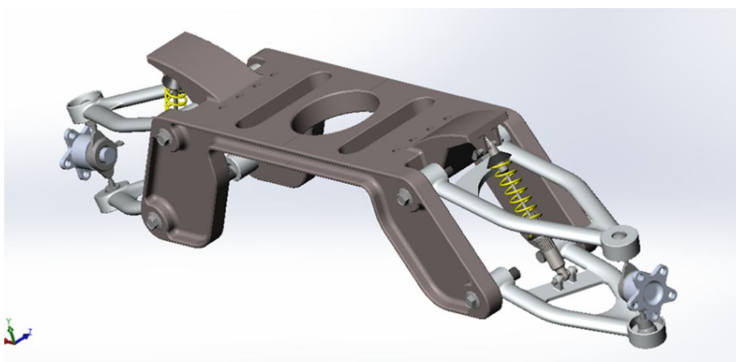

Fig. 7 Fig. 7 Double Wishbone Suspension System Assembly

This figure shows the final assembly of the proposed suspension system in which various mates are given to components to form a system. The above-given components are inserted via the insert components tool in the Assembly module. The mates' option is used to give mates to all the components and the chassis is fixed at two points, Concentric and parallel are the most used mate in this assembly. To show realistic connections bolts are used, fixed at suitable locations.

D. Analysis of the Suspension

1) Meshing

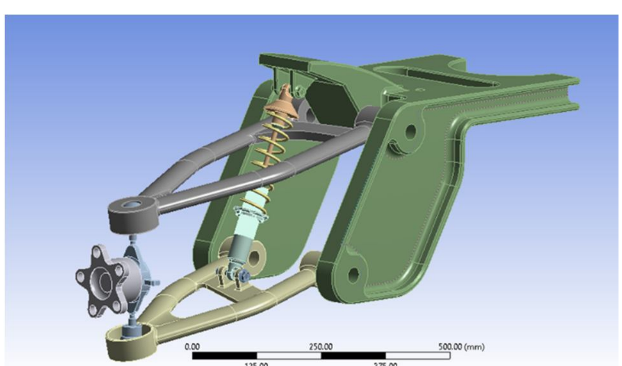

Fig. 8 Before meshing

This photo shows a half section of the suspension system which is generated on ANSYS by adding a body delete option. It is turned to half to save time and to achieve good results in meshing. The bolts at the control arm are deleted for optimum meshing results.

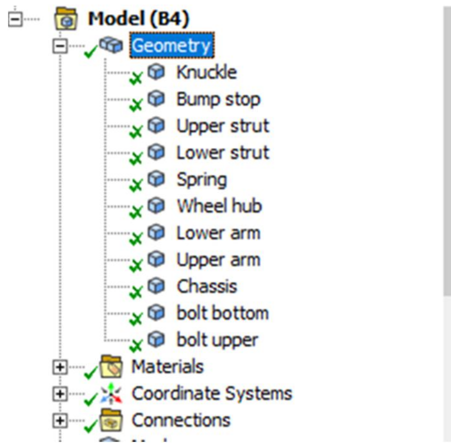

Fig. 9 Geometry selection

As you can see in the above image the model tab is opened where each part is assigned with different material and connections are added to every part in the assembly. The materials assigned to parts are listed above with their mechanical properties.

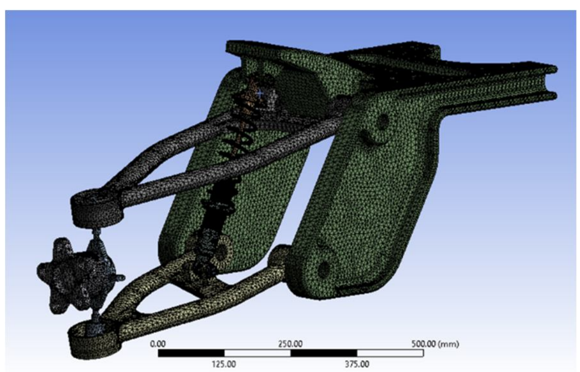

Fig. 10 Meshing for Suspension

The meshing is performed where the total number of Nodes is 446642 and the elements are 236588. The element size kept for this meshing is 5 mm with meshing quality set to tetrahedron mesh structure. Various mesh aspects are taken into consideration such as Aspect Ratio, Orthogonal Quality, Skewness, etc, and satisfactory values were achieved in all of these.

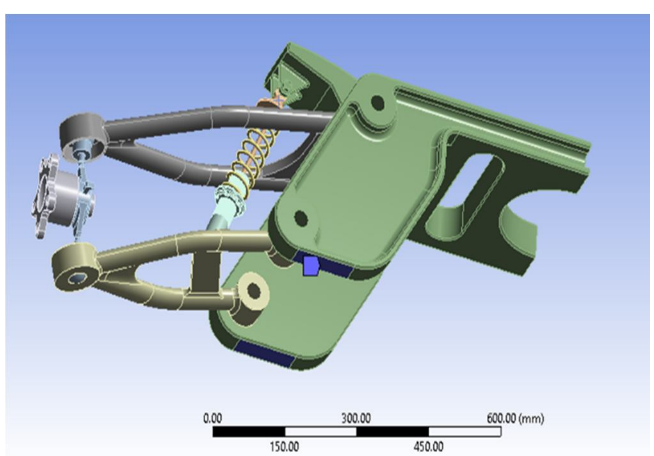

Fig. 11 Fixed support suspension

After meshing the Chassis was set to be fixed at selected points, the purple marked area shown in the image represents fixed support that is added to keep the chassis stationary.

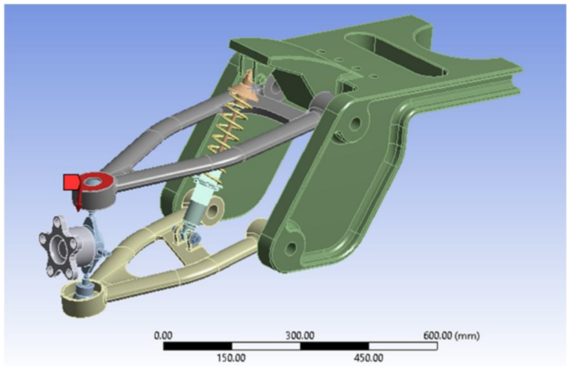

Fig. 12 Force applied on control arm

In this figure, a Force of 1567 N was applied on the upper control arm to represent actual loading conditions on the vehicle. The face selection option is used to select the faces of the control arm.

V. RESULTS AND DISCUSSION

A. Static Structural Post Process

After achieving finite meshing, assigning materials, and adding fixed support and load the Solution tab was selected where the equivalent stress and total deformation were nominated because the forces need to be identified when the vehicle is traveling at high speed. For this purpose, the deformation of the suspension needs to be recorded along with stresses acting on the suspension.

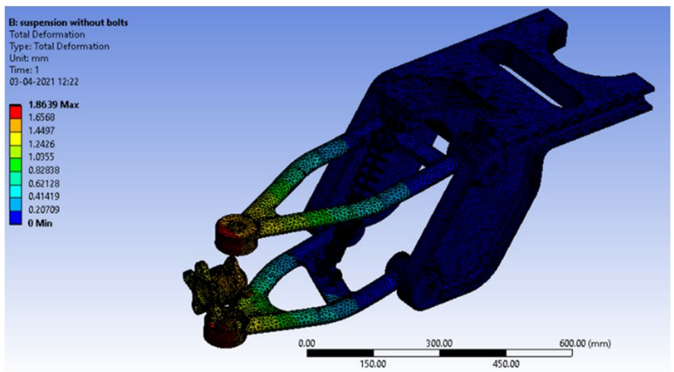

Fig. 13 Total Deformation of the Suspension System

As shown in the above image the Total Deformation of the Suspension is calculated based on its geometry. The average deformation value is 0.2476 mm. The maximum deformation calculated is 1.86 mm, the deformation value should not exceed above 2 mm, so this design is considered to be safe.

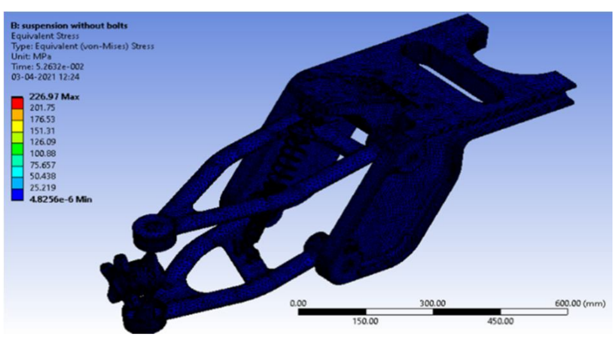

Fig. 14 Equivalent (Von-Mises) Stress of Suspension system

In this image, the stresses acting on the suspension system are presented where the Min stress recorded is 4.8256e-006 MPa, maximum stress is at 226.97 MPa and average stress is at 1.8447 MPa. allowable tensile strength is 280 MPa and it is far greater than the working stress of 226.97 MPa. So, this design is considered to be a safe design.

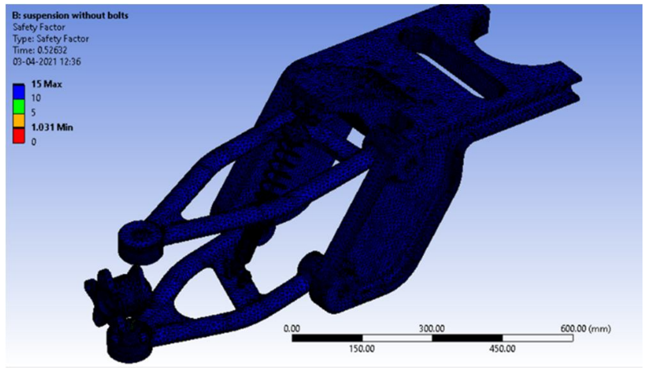

Fig. 15 Factor of Safety of Double wishbone suspension system

As this image shows the factor of safety of this system is 15 at max value with an average value of 14.944, the properties of effects the factor of safety, so in this case, the model is passed as its factor of safety is below 15.

VI. CONCLUSION

When considering a Double wishbone suspension system for a single-seater sports car it needs to be lightweight and stiffer. The above calculations, meshing, and analysis results are studied, and the values are compared with the material properties. This research is majorly focused on the suspension system and the components used in it. As previously stated, when forces apply on a double-wishbone suspension in high-speed scenarios, equivalent stress and total deformation analysis of the suspension system are performed. The proposed suspension designed for a single-seater car is analysed the Maximum Equivalent Stress is recorded to be 226.87 MPa, the Maximum Total Deformation values are recorded to be 1.86 mm as well as the Factor of Safety is calculated at 15. The deformation is under 2mm, the equivalent stress below the allowable limit and the value obtained for a factor of safety is below 20. Hence, the presented design is considered safe as it does not exceed the limitation of the properties of the material.

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