e-ISSN: 2582-5208
International Research Journal of Modernization in Engineering Technology and Science
(Peer-Reviewed, Open Access, Fully Refereed International Journal)
Volume:07/Issue:04/April-2025 Impact Factor- 8.187 www.irjmets.com

DESIGN AND ANALYSIS OF WISHBONE SUSPENSION

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ABSTRACT

In automobiles, a double wishbone suspension is an independent suspension design that uses two wishbone-shaped arms to attach the wheel. Each wishbone or arm has two mounting points to the chassis and one joint at the knuckle. The coil over shock absorber mount to the wishbones to controls the vertical movement of the wheel. Double wishbone designs allow the engineer to carefully control the motion of the wheel throughout suspension travel, controlling such parameters as camber angle, caster angle, toe pattern, roll center height, scrub radius, scuff and more. In this project, the modeling of SUSPENSION SYSTEM OF A FORMULA CAR is done using modeling software SOLIDWORKS and analysis is carried out using analysis tool ANSYS. The suspension system is analyzed using ANSYS Workbench.

Keywords: Double Wishbone Suspension, Formula Car, SOLIDWORK Modeling, ANSYS Analysis.

I. INTRODUCTION

In automobiles, a **double wishbone suspension** is an independent suspension system that uses two wishbone-shaped arms to attach the wheel to the vehicle's chassis. Each wishbone (or control arm) has two mounting points on the chassis and one at the steering knuckle. A coilover shock absorber is mounted to the wishbones, controlling the wheel's vertical movement. This design allows engineers to precisely control various parameters throughout the suspension travel, including camber angle, caster angle, toe pattern, roll center height, and scuff. Due to its geometry, the double wishbone suspension is also referred to as "**double A-arms**" since the arms can be A-shaped, L-shaped, or even single rod linkages.

II. OBJECTIVE

The objective of this study is to understand the working principle, advantages, and design requirements of a double wishbone suspension system. It involves reviewing various materials commonly used in suspension arms such as AISI 4130, 6061-T6 aluminum, and carbon fiber composites, and selecting a suitable material based on factors like strength-to-weight ratio, manufacturability, and cost. The kinematic parameters including upper and lower arm lengths, pivot locations, caster, camber, and kingpin angle are defined to ensure optimal suspension geometry. A 3D CAD model of the double wishbone suspension is developed using software like SolidWorks, AutoCAD, Fusion 360, or CATIA, with accurate constraints and joint connections. Realistic vehicle conditions are simulated by applying static vertical loads that replicate actual weight transfer on the suspension arms. Finite Element Analysis (FEA) is carried out to identify stresses, deformations, and safety factors under load, ensuring the meshing quality and applying appropriate boundary conditions for accurate results. The stress distribution across critical sections of the upper and lower control arms is analyzed and verified by comparing the maximum induced stress with the yield strength of the selected material. A convergence study is performed by refining the mesh and observing the consistency of stress values. Fillets and radii are incorporated into the CAD model to minimize stress concentrations, and the geometry is optimized for weight reduction without compromising structural integrity. The simulation results are compared with theoretical calculations based on static equilibrium and mechanics of materials. The factor of safety (FoS) for each component is estimated, and deformation under load is investigated. Design improvements are proposed based on the analysis findings. The entire design and analysis workflow is documented to ensure reproducibility and to serve as a foundation for future dynamic or fatigue analyses. Finally, the scalability of the double wishbone design is evaluated for potential applications in various vehicle types such as sedans, SUVs, and Formula vehicles.

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Figure 1: Suspension System

III. METHODOLOGY

AISI 1020 steel is a low carbon steel known for its excellent weldability, high ductility, and good machinability. With a nominal composition of approximately 0.22% carbon and 0.55% manganese, it is typically used in turned and polished or cold drawn conditions. The Brinell hardness of AISI 1020 ranges from 119 to 235, and its tensile strength lies between 410 MPa and 790 MPa. Due to its low carbon content, it resists flame and induction hardening and lacks sufficient alloying elements to support nitriding. However, it can be carburized to achieve surface hardness exceeding Rc65 for smaller sections, though the core strength remains consistent across section sizes. Carbonitriding can be an alternative treatment, offering benefits over traditional carburizing. Widely used in industrial applications, AISI 1020 is favored where enhanced weldability and machinability are desired.

Cast iron, another candidate material, belongs to the iron-carbon alloy family with carbon content above 2% and silicon ranging from 1% to 3%. Its low melting point and excellent fluidity make it suitable for casting complex shapes. The mechanical behavior of cast iron is largely influenced by how carbon is present within the microstructure. White cast iron contains cementite, making it hard but brittle. In contrast, grey cast iron contains graphite flakes that resist crack propagation, and ductile cast iron features spherical graphite nodules that enhance toughness. Cast iron is widely used in the manufacturing of components such as cylinder blocks, gearbox housings, and pipes. While it offers good wear resistance and machinability, it is generally brittle and difficult to weld, limiting its application where high tensile strength and flexibility are required.

Titanium alloys represent another advanced material choice, known for their exceptional strength-to-weight ratio, corrosion resistance, and high-temperature performance. These alloys typically contain small amounts of aluminum and vanadium (commonly 6% and 4%, respectively) which significantly improve mechanical performance through precipitation strengthening. Titanium alloys are used in high-performance sectors like aerospace, medical devices, sports equipment, and automotive components. Commercially pure titanium is biocompatible and has adequate mechanical properties, but for demanding applications, the alloyed versions are preferred due to their higher tensile strength and enhanced durability. Though expensive, titanium's durability and lightweight nature make it a valuable option in performance-critical suspension systems.

Structural steel is also considered for suspension system applications due to its high toughness, ductility, and strength. Depending on the processing route—such as as-rolled, normalized, or thermo-mechanically rolled—its mechanical properties can be significantly improved. Normalized steel is reheated to around 900°C and cooled naturally, refining the grain size and enhancing impact toughness. Thermo-mechanically rolled steel, with a lower finishing temperature around 700°C, is more difficult to process but retains superior strength characteristics unless reheated above 650°C. These steels are designated with an "N" or "M" marking, respectively. Structural steels are particularly useful when designing components that must endure fluctuating loads and harsh environments without compromising on weight or strength.

The research methodology begins with an exploration of various double wishbone suspension system designs, which fall under the category of independent suspension systems. In these configurations, the left and right suspension units operate independently, enhancing ride quality and handling. Torsion bars, anti-roll bars, or

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sway bars are commonly integrated to minimize body roll, especially when one wheel encounters a bump while the other remains level. Among the different design approaches reviewed—including the double A-arm, an A-arm paired with a single arm, and an A-arm combined with an L-arm—the double A-arm wishbone design is selected for further study. This configuration is widely preferred due to its superior load-handling capabilities, efficient shock absorption, and higher structural integrity under dynamic loading conditions. The double A-arm setup offers more precise control of camber and caster angles, improving both stability and cornering performance. Its geometry allows for optimized packaging within the chassis and provides consistent tire contact with the road surface, making it the most suitable choice for the suspension model to be developed in the project.

Table 1: Cast Iron

	UNIT	CAST IRON
COMPRESSIVE STRENGTH	MPa	600-1000
TENSILE STRENGTH	MPa	410-560
FLEXURAL STRENGTH	MPa	150-400
DENSITY	kg/m^3	7150-7250
YOUNG'S MODULUS	GPa	80-140
THERMAL CAPACITY	$J/(kg \cdot K)$	0,5
THERMAL CONDUCTIVITY	$W/(m \cdot K)$	45-50
THERMAL EXPANSION	$10^{-6}/K$	9-12

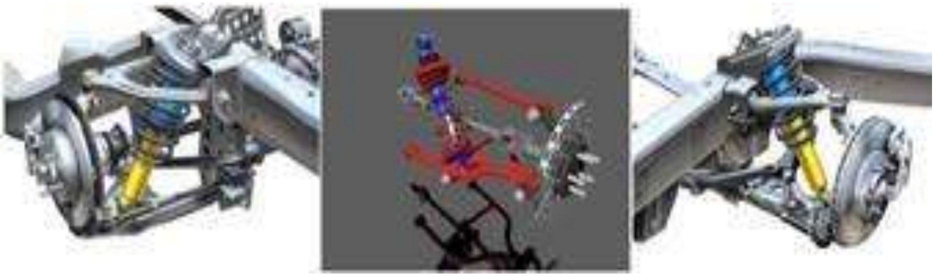

Figure 2: Double arm wishbone

IV. PRODUCT DESIGN

The final assembly of the wishbone suspension system integrates all key components including the upper arm, lower arm, spring damper, and knuckle joint into a complete mechanical structure. Designed using SolidWorks, the system ensures accurate alignment and smooth interaction between parts through precise mating conditions and parametric features.

The upper and lower arms form the basic framework of the wishbone configuration, providing structural stability and facilitating vertical motion of the wheel hub. The spring damper is mounted between the arms to absorb shocks and maintain ride comfort. The knuckle joint connects the arms to the wheel assembly, enabling steering movement and proper load transfer.

During assembly, concentric, coincident, and distance mates are used to accurately position each component, ensuring realistic mechanical behavior in simulations. The assembly is tested within SolidWorks for motion, interference, and load analysis using built-in simulation tools.

This model reflects the true design intent, helping engineers evaluate performance under various conditions. The complete digital twin of the suspension aids in visualizing movements and provides a solid foundation for manufacturing and further optimization. Final 2D drawings and BOMs (Bill of Materials) are generated from the 3D model for documentation and production.

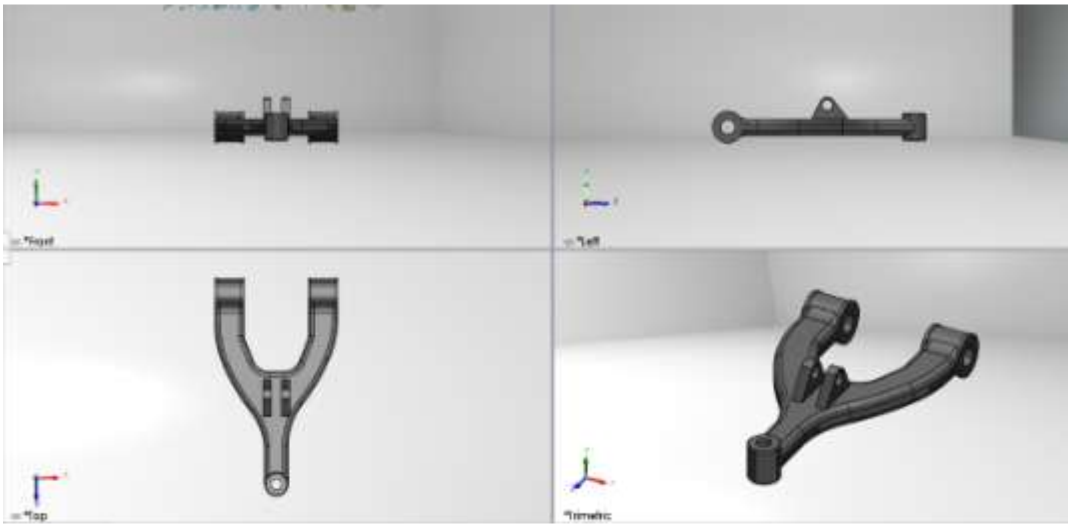

Figure 3: Upper and Lower arm.

V. ANSYS MESHING

ANSYS Meshing is a crucial pre-processing step in finite element analysis (FEA) that involves breaking down complex geometries into smaller, simpler elements—known as a mesh—for computational analysis. The mesh acts as a discrete representation of a continuous domain, enabling engineers to perform accurate simulations of structural, thermal, fluid, or electromagnetic behaviors. Each cell within the mesh carries its own set of equations, and the collective solution across all cells provides an approximation of the real-world behavior of the model.

The primary purpose of meshing is to transform infinite degrees of freedom in a physical body into a finite set of equations that can be solved numerically. ANSYS offers automatic, semi-automatic, and manual meshing options with control over element size, shape, and refinement. Mesh quality greatly affects the accuracy, convergence, and computational efficiency of a simulation.

Meshes are classified into structured and unstructured types. Structured meshes have a regular grid layout and use quadrilateral (2D) or hexahedral (3D) elements, offering better accuracy and faster computation. Unstructured meshes, composed of triangular (2D) or tetrahedral (3D) elements, are more flexible for complex geometries but may require more computational power. ANSYS supports both types, allowing optimal meshing strategies for different engineering applications.

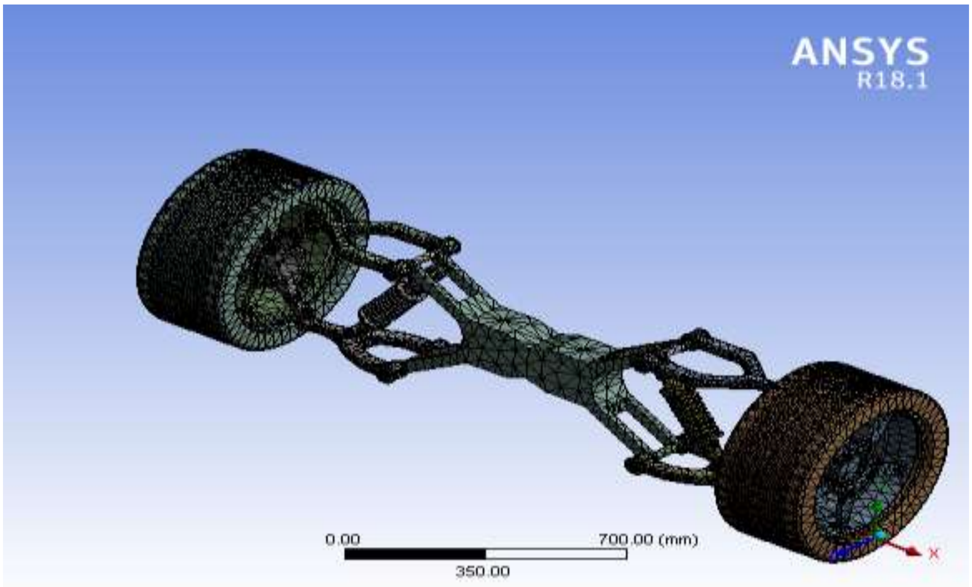

Figure 4: ANSYS Meshing.

VI. STRUCTURAL ANALYSIS AND RESULT

The structural analysis of the Wishbone Suspension system was carried out using Finite Element Analysis (FEA) to evaluate the stress, strain, and deformation characteristics of different materials under a maximum force of 7845 N. The analysis was performed using ANSYS, with Titanium Alloy and Structural Steel as the primary materials.

For **Titanium Alloy**, the equivalent Von-Mises stress was recorded at **13.459 MPa**, with an average equivalent elastic strain of $\mathbf{1.4316 \times 10^{-4}}$. The total displacement observed was $\mathbf{1.9363 \times 10^{-3}}$ **m**, and the factor of safety was **0.29**.

For **Structural Steel**, the equivalent Von-Mises stress was **13.545 MPa**, with an average equivalent elastic strain of $\mathbf{6.8911 \times 10^{-5}}$. The total displacement was $\mathbf{9.312 \times 10^{-4}}$ **m**, and the factor of safety was **0.3.**

The results indicate that Structural Steel exhibits **lower deformation and strain** compared to Titanium Alloy under the applied load, making it a more rigid material. However, Titanium Alloy, being lighter, offers advantages in weight reduction while maintaining acceptable stress levels. These insights assist in optimizing material selection for high-performance suspension systems in automotive applications.

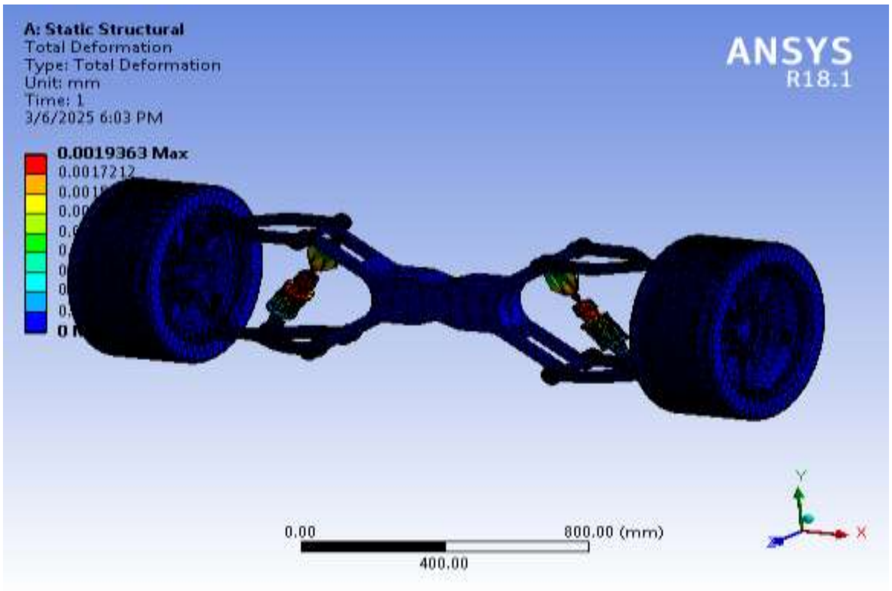

Figure 5: Total Deformation.

VII. CONCLUSION

In automobiles, a double wishbone suspension is an independent suspension design using two (occasionally parallel) wishbone- shaped arms to locate the wheel. Each wishbone or arm has two mounting points to the chassis and one joint at the knuckle. Due to this the maximum dampening may not occur in some cases. In this paper, the problem is solved by shifting the upper mounting point of coil over spring absorber from knuckle to the upper wishbone. So that the maximum dampening will occur. After the successful design of suspension components, the structural analysis of the components is carried in ANSYS. And the optimum material is chosen for the suspension components. The static analysis of presented suspension system carried and the results show von misses stress induced is 13.459 MPa max and total displacement magnitude is 1.9363e^{-4} mm. 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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