Design and analysis of double wishbone suspension system

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Abstract. Suspension system serves purpose of providing stability to vehicle which results improving comfortability of riding. It provides traction control and steering stability. This paper proposes a method for designing double wishbone suspension system for electric solar vehicle with damper to lower wishbone. Recent trends in suspension system have focused on improving innovations in ride quality and handling of vehicles. It maintains a viable spectrum of economic growth by reducing costs and increasing efficiency simultaneously. Theoretical analysis is conducted using Lotus and Solid works to design double wishbone suspension system. The analysis is done for tadpole geometry car with double wishbone in front and swing arm in the rear wheels. Results in the paper are going to improve vehicle handling characteristics by controlling camber, toe angles and A-arm’s length. This is accomplished by changing the length of A-arm and the ground clearance and attach angle with the chassis by hit and trial method and improving possible traction and maneuverability. Results of the paper are presented in form of graph as a result of simulation conducted.

1. Introduction
The suspension system of a vehicle is generally designed to maintain traction with the road. Suspension are designed to meet the following requirements: (1) Ride comfort (2) traction and (3) Handling. Suspensions generally fall into either of two groups: Dependent and Independent Suspensions. Double wishbone suspension helps in controlling the motion of the wheel throughout suspension travel, controlling such parameters as camber angle, caster angle & toe angle. In this suspension research we are focusing on the A arm design and have proposed a design with geometry optimization. The geometry of the suspension is Damper to lower wishbone. For designing A-arms we have used Solid-Works (2018) in which we are able to do different material analysis and testing to make the A-arm light weight and economically feasible while satisfying the driving condition. Calculation of stiffness of shocker was done to get angle between A-arm and shocker best feasible for our ESVC 2019.

2. Literature Review
X. L. Bian et al. [1] has researched on Roberson and Wittenburg (RW) methodology of multi-body dynamic analysis. To simulate the actual working conditions they consider wheel bouncing to the steering performance & employed two weight functions for their model. A passenger vehicle and group of desirable design variables was an example for their procedure examination.
Vinod Cherian et al. [2] have worked on non-linear model of a double wishbone suspension and found a procedure in which we can find the effect on transmission, tire distribution forces acting on wheel
spindle & chassis by variation in suspension parameters. The equations of motion are derived with the help of Lagrange multiplier method, and solved numerically using MATLAB.

J. S. Hwang et al. [3] has worked on how to find hard points position with the help of kinematic design of double wishbone which would increase stability of a vehicle.

Ramon Sancibrian et al. [4] have done an attempt of using multi objective dimensional synthesis technique on the kinematic design of double-wishbone suspension systems in vehicles. The Jacobian matrix was obtained by using exact differentiation constructed on gradient determination by synthesis method.

N. Vivekanandan et al. [5] have a main objective to design double wishbone. Material section was done on the basis of carbon content, tensile strength, yield strength, hardness & cost. According to their analysis AISI 1040 was best for their wishbones. Geometric roll center was located by suspension geometry and principles of the instant centre of rotation.

R. C. Silva et al. [6] aims to propose analytical equations implemented computationally in MATLAB which were set to evaluate the double wishbone suspension. Simple concepts of trigonometry were used to develop their formula. Predefined points Cartesian coordinates (x, y, z) which are attained from the CAD design are given as input to formula which will give us the caster, camber angles.

Damodaran, P et al. [7] have presented an optimal dimensional synthesis of 5 link suspension mechanism in terms of length of the 5 links and positions of the ten spherical joints, which are installed on the vehicle chassis and wheel carrier. The influence of the complaint joints on the dynamic behaviour of the suspension system is approached. Matlab optimization tool box is used for this optimization. The aim was to take the motion of the body to the wheel carrier with respect to the vehicle chassis as close as possible to a vertical translation.

Shijil P et al. [8] have done a dynamic study of the vehicle when driven on an offroad racetrack conditions were analyzed on the parameter dynamic and static suspension system of an ATV. The performance of the ATV is affected by many parameters. This paper work is focused on design and analysis, determination, optimization of suspension systems and their assembly best performance. The aim was to identify and optimize the parameters which affects the dynamic performance of suspension systems.

Arun Y Patil et al. [9] have researched on an upper A arm which was designed so as to help in accommodating a coil spring shock absorber in ATVs without altering the motion ratio and providing more flexibility in choosing an angle correction factor. Solidworks is used for CAD model. The virtual simulation and structural analysis were performed on ANSYS Workbench. Several iterations were carried out to optimize the proposed design using the software in terms of strength factor, stress concentration and weight.

2.1. Literature Review Conclusion

From literature survey above it is evident that various softwares are available to conduct analysis on suspension geometry and to conduct structural analysis of A-arms. Out of these softwares we found out that a combination of Solid Works and Lotus will suit our purpose. The analysis conducted by all the researchers has been done for various configuration of their vehicles. We are conducting analysis for tadpole geometry solar vehicle being manufactured for ESVC-2019. Analysis results for various configurations of A-arms are presented in paper and final optimized results for Lotus geometry are showcased in this paper. Our objective is to reduce weight and optimize geometry in order to maintain stability of vehicle and maintain traction with road.

3. Stiffness of shocker

The weight transfer calculation was done according to driving conditions to calculate stiffness of shocker mounted on lower A-arm for absorbing loads and maintaining traction with road. Shocker stiffness is
defined as amount of deflection or travel, shocker will show when force is applied at different driving conditions.

4. Selection of material for A-Arm
For manufacturing of A-arms simulation of the A-arms is done on Solid works with different materials to make the A-arm economical and light weight. The list of different materials is enlisted. The simulation of the A-arms is performed by using Solid works (2018) to find the stress distributed on the A-arms.

Properties of different Materials:

| Properties               | AISI1020     | AISI4130     | AA6063 T6 | AA6061 T6 |
|--------------------------|--------------|--------------|-----------|-----------|
| Yield Strength           | 351.57 MPa   | 460MPa       | 214MPa    | 276 MPa   |
| Ultimate Strength        | 420 MPa      | 670MPa       | 241 MPa   | 310 MPa   |
| Density                  | 7900kg/m3    | 7850kg/m3    | 2700kg/m3 | 2700kg/m3 |
| Young’s Modulus          | 205GPa       | 205GPa       | 68.9GPa   | 70GPa     |
| Moment of Inertia        | 2.027*10^8m^4 | 2.027*10^8m^4 | 1.263*10^{-7}m^4 | 1.263*10^{-7}m^4 |

The total weight of the vehicle is 250Kg (assumed) including the driver's weight, which is taken by including the Factor of Safety i.e. that the design is safe.

From calculations (refer pg. 13) we calculated that the maximum force on the front wheel will be at the time of braking condition.

Total mass transfer on each front wheel = 110 kg (refer pg. 10)
Total Weight on wheel = 110 + 20% of total weight
= 110 + 50 = 160 kg

All the simulation is being performed at 1600N of force on different material with different dimensions. Result is show in the following table 2.

5. Result and Discussion
Figure 1-3 represents the analysis of A-arm with requisite boundary conditions for AISI 4130 and 1.25mm, 2.00 mm, 2.50 mm thickness of pipe. The results of FOS for Von mises criteria and maximum stress are presented in table 2. Figure 4-6 shows the analysis of A-arm with requisite boundary conditions for AISI 1020 and 1.25mm, 2.00 mm, 2.50 mm thickness of pipe. The results of FOS for Von mises criteria and maximum stress. Similarly, figure 7-9 represents the analysis of A-arm for material AA 6061-T6 and 1.25mm, 2.00 mm, 2.50 mm thickness of pipe. Also, the tests are done on AA 6063-T6 in figure 10-12 for the analysis of A-arm with requisite boundary conditions and 1.25mm, 2.00 mm, 2.50 mm thickness of pipe. The results of FOS for Von mises criteria and maximum stress are presented in table 2. All the above-mentioned pipes are taken as experimental setup and are analyzed to obtain optimized results for concluding the final material to be selected for fabrication of the control arm (commonly called as A-Arm). The simulations are done on Solidworks-2018 software and the simulation results have been shown below in fig. 1-12. The control arm has been fixed at the points where it is attached directly to the chassis and the load of 1600 N is applied at the points which are fixed directly to the suspension of the vehicle and the wheel assembly point.
Fig 1. AISI 4130 1inch 1.25mm.

Fig 2. AISI 4130 1inch 2mm.

Fig 3. AISI 4130 1-inch 2.5mm.

Fig 4. AISI 1020 1-inch 1.25mm.
Fig 5. AISI 1020 1-inch 2.00mm.

Fig 6. AISI 1020 1-inch 2.00mm.

Fig 7. A-6061T6 1-inch 1.25mm.

Fig 8. A-6061T6 1-inch 2mm.
Fig 9. A-6061T6 1-inch 2.5mm.

Fig 10. A-6063T6 1-inch 1.25mm.

Fig 11. A-6063T6 1-inch 1.25mm.

Fig 12. A-6063T6 1-inch 1.25mm.
6. Conclusion

After analyzing the data it has been found that AISI 4130 is best suited for A-Arm material as for same FOS weight of component is optimized when we use AISI 4130. But for this application further analysis led to conclusion that pipe of outer 1 inch and 2 mm thickness is best suited as FOS for this will be 1.8 as per analysis. From the data its predicted to use AISI 4130 inch outer diameter and 2 mm thickness for this application.

7. References

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