INTI JOURNAL | eISSN:2600-7320
Vol.2020:23

Finite Element Analysis of a Buggy Car's Suspension Arms for Off-Road Usage

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Abstract

A buggy car is a versatile small-sized car without a roof that could be utilized in various terrains and purposes. This study designs a robust suspension arm for an off-road buggy-car. The study only focuses on the shape of the arm and its respective structural strength. Therefore, both the upper and lower arm were designed and simulated. The double wishbone suspension system was referred as the benchmark for this study. Furthermore, the BAJA SAE standard was followed in designing the new suspension arm. The CAD model was developed via the Inventor software and finite element analysis (FEA) was conducted via ANSYS software. With reference to the literature, the simulation was made by applying the load of 882.9 N onto the upper and lower suspension arm. The simulation results showed that the upper arm experienced 302.2 MPa and 5.5801 mm of deformation, whilst, the lower arm recorded the reading of an almost similar 302.2 MPa and 5.5731 mm deformation via FEA. These readings are however undesired, since it showed a relatively high bending stress and especially critical deformation for both the upper and lower arm. Conclusively, the design developed does not coincide with the goal of developing a robust suspension arm for an off-road buggy-car. Therefore, this design could serve as a platform for improvement for future studies.

Keywords

Suspension arm, buggy car, finite element analysis, BAJA SAE

Introduction

The FSAE, known as the Formula SAE, is a type of competition where university undergraduate students would fabricate a FSAE car prototype. The function of a suspension arm is to absorb the vibrations when the vehicle passes rough roads (Nor et al. 2019). The system is an integral

International Conference on Innovation and Technopreneurship 2020
Submission: 4 September 2020; Acceptance: 17 September 2020

component in a vehicle which aids in controlling the vehicle and stabilizes when accelerating, cornering, braking, loading and unloading etc. (Jubri 2015). The suspension arm is important since it controls the up and down motion of the wheels when the vehicle hits bumps on the road. It increases the friction between the road and the tires providing a stable movement of the vehicle while it ensures the safety of the passengers (J., 2015). The aim of this study was to design a new suspension arm for the INTI International FSAE car for a non-competition off-road usage. The study only focuses on the shape of the arm and its respective structural strength. In designing the new suspension arm, the BAJA SAE requirement was referred.

Literature Review

There are many different types of independent suspensions, which include swing axle suspensions, transverse leaf spring suspensions, trailing and semi-trailing suspensions, Macpherson strut suspensions, and double wishbone suspensions (Vivekanandan et al. 2014)**.** For this study, the double wishbone setup was selected as the suspension system setup of interest. The wishbones are designed in a way where the roll center is located nearby to the center of gravity of the vehicle and the distance of roll center closer to the ground. The double wishbone setup is the focus of this study due to its versatility and overall great attributes in term of performance. Double wishbone system is generally used at the rear end of the vehicle. There are few benefits of double wishbone system has the increase of negative camber due to a vertical suspension movement of the upper and lower arms which increases the stability of the vehicle by maintaining further contact with the road surface. This also makes the vehicle to improve its handling performance such as constant steering and wheel alignments when the system experiences high level of stress. Double wishbone system is more stable and rigid and stable compared to other suspension systems. Alternatively, one of the major complications of this system is the design of the double wishbone itself. Failure of any small part leads to failure of the whole system (Khan et al. 2017). Hence, a number of items need to be taken into serious consideration in designing the wishbone setup.

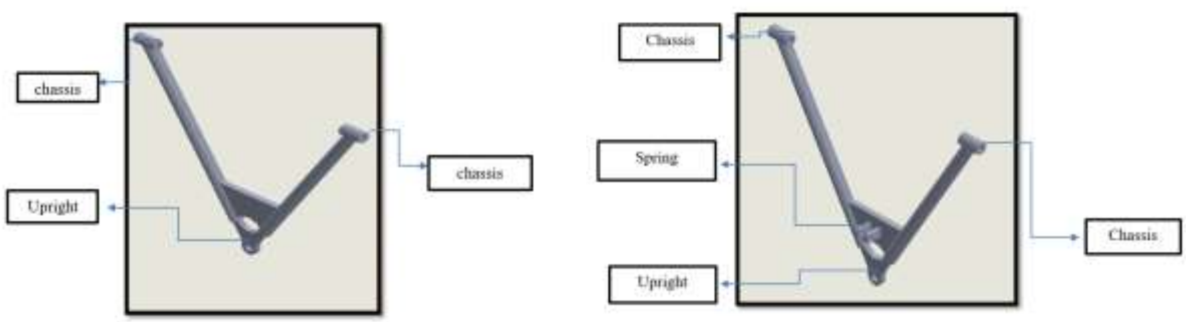
When designing the wishbone setup, the knuckle, caster, camber and kingpin inclination must be taken into consideration. Moreover, the length of the wishbone is determined by the wheel track width and chassis mounting points which are A-shaped links made of steel. Therefore, these must withstand great bending force, partial impact loading due to bumps and potholes. The dimensions of control arms are defined by considering the required functions and outcomes. Moreover, improvements can be made on the stability, control by roll center and the mounting points (Vignesh et al. 2019). Therefore, when designing the suspension arms for the buggy car for off-roading purposes, the design must be carefully analyzed and the dimension of the wishbone components must be precisely measured in order to prevent excessive bending force on the wishbone that acts when the buggy car passes through rough pathways. For instances, off paved or gravel surfaces which makes the load of the chassis unbalanced and causes failures on the suspension systems (Vignesh et al. 2019). Since the suspension arm is strictly for off-road usage, bending force experienced by the suspension arm has to be critically determined.

In short, these literatures provide evidence on the various parameters that need to be taken into consideration during the design stage of a suspension system arm (upper and lower). The wishbone design in the suspension system is a result of following initial steps. Firstly, the material is selected by using Pugh's Concept of Optimization which is based on the strength of the material. It should be able to withstand loads acting in dynamic conditions, and must also consider factors such as carbon content, material properties. Most importantly it should be cost efficient and must be available in the market. Then the allowable stress is calculated by using the shear stress theory of failure. Next, the roll-center is determined to find the tie-rod length. Finally, the wishbones that were designed are modeled by using software and is analyzed using ANSYS software which determines the maximum stress and maximum deflection in the wishbone, in using Vivekanandan et al. (2014) as reference.

The basic parameters that were required for designing, analyzing and simulation of double wishbone suspension system for formula student vehicle were: (i) wheelbase, (ii) camber angle, (iii) toe angle, (iv) kingpin inclination angle, (v) sprung weight, and (vi) sprung weight. Design of the wishbone and knuckle was the most important part of the suspension system such that they were designed in a way that the roll-center is close to the center of gravity of the vehicle and the roll-center is close to the ground. The analysis of the wishbones was that these components were the members connecting the chassis to the wheel assembly. Brackets were used to mount the springs on the wishbone.by attaining accurate suspension geometry, the wishbones must be properly manufactured. This provides the movement of knuckle when the vehicle experiences a bump on the road (Sinha et al. 2018).

Methodology

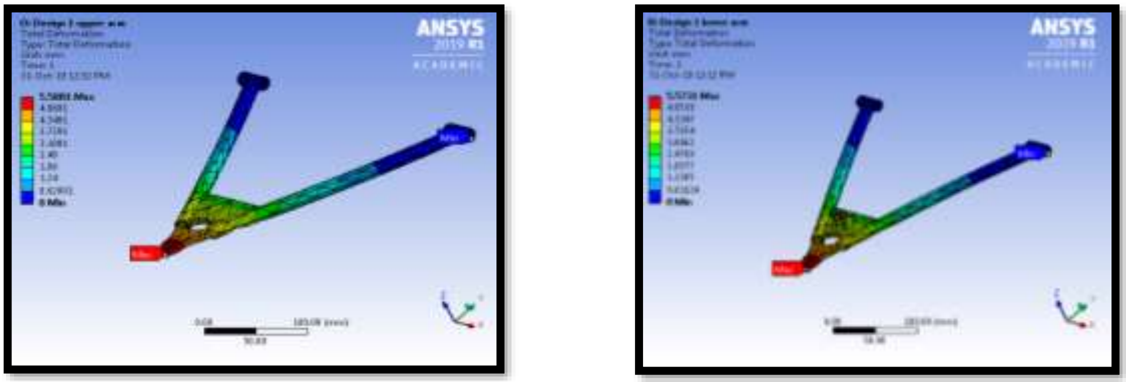
Finite element analysis (FEA) simulation was performed via ANSYS software. The aim for the FEA simulation was to determine the Von-Mises bending stress and the deformation experienced by the upper and lower suspension arms. The shape and dimension of the suspension arms as conducted in the FEA is shown in Figure 1.



(a) (b)

Figure 1. Design of the suspension arms (a) upper arm, and (b) lower arm

Results and Discussion



(a) upper arm (b) lower arm

Figure 2. Total deformation: (a) upper arm, and (b) lower arm

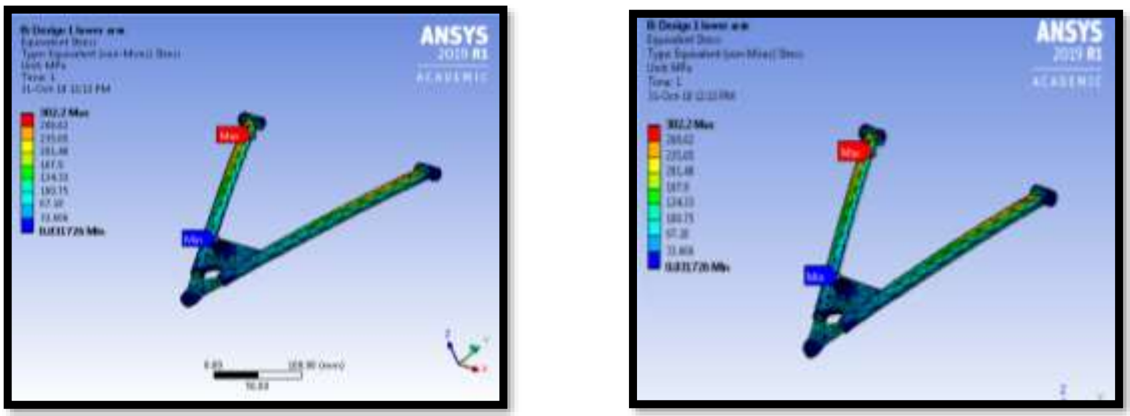


Figure 3. Maximum bending stress: (a) upper arm, and (b) lower arm

Table 1 The bending stress and total deformation experienced by the suspension arm

Design	Bending stress (MPa)	Deformation (mm)
Upper	302.2	5.5801
Lower	302.2	5.5731

The aim of this study was to design a new suspension arm for the INTI International FSAE car for off-road usage. The study only focuses on the shape of the arm and its respective structural strength. In designing the new suspension arm, the BAJA SAE requirement was referred. Figures 2 and 3 show total deformation and maximum bending stress for upper and lower arms, respectively. These readings were however undesired since it showed a relatively high bending stress and especially critical deformation for both the upper and lower arm. From the results obtained as shown in Table 1, the bending stress was higher since the load applied to the structure was high creating high stress in all directions. This, in turn, increases the positive principal stresses compared to the negative stress which causes the values of Von-Mises to be high. Higher value of Von-Mises stress means that there is a higher probability of failure to occur.

The deformation occurred in both the upper and lower arm were due to the smaller surface area of the upright arm. The upright acted as a pivot point in the suspension system therefore, when a massive load is applied at the pivot it tends to deform since a high force is applied. This will cause the upright to fracture followed by the shock absorber and the spring which results in overall failure the suspension arms. This will result in steering problems of the buggy car and eventually fails the brake and will be difficult to turn the wheels and brake.

To overcome these issues, it is suggested to use a short upper arm in order to create a negative camber allowing the wheel to have more contact to the road surface. In addition, testing on multiple connections for shock absorber and spring at different positions between the upper and lower arm could also be performed in to determine the performance of the buggy car. For future assessments, consideration in the use of different materials for the design is recommended due to the variations of mechanical properties. Secondly, assessment is made by applying more variations of loads (angle) to the structure which would support the suspension arm.

Conclusion

This paper presents the Finite Element Analysis of a Buggy Car's suspension arm for off-road usage. The results indicated that the proposed designs from the upper and lower suspension arms exhibits high bending stress in all direction. Hence, this had contributed to the increment of the positive principal stresses and the eventual escalation of Von-Mises stress. Therefore, both the upper and lower suspension arms have high probability to fail. Consequently, these designs do not coincide with the goal of developing a robust suspension arm for an off-road buggy-car, yet, could serve as a platform for improvement for future studies. In addition, for future assessments, assessment and improvements could be made in utilizing the use of different materials due to the variations of mechanical properties of said materials. Secondly, assessment is made by applying more variations of loads (angle) to the structure which would support the suspension arm. These suggestions shall facilitate for a better assessment for the upper and lower suspension arms of a vehicle.

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