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# Assessment of FSAE Car's Rear Suspension Arms for Bump Force

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**Abstract:** The aim of this study was to design a new upper and lower suspension arm for INTI International University's Formula Society of Automotive Engineers (FSAE) car with the purpose of off-road usage. The new suspension arm was designed in accordance to regulations of an intercollegiate design competition, BAJA Society of Automotive Engineers (Baja SAE). The material selected for the suspension arms were the 4130-alloy steel. The specifications of the new suspension arms were determined by the size of the bush, inner diameter of 20mm and the position of the mounting on the existing INTI International University's FSAE car. The study had focused solely on the overall structural strength of the upper and lower suspension arms for off-road usage. The 3D models of the arms were developed using Computer-Aided Design (CAD) via SpaceClaim software. Finite element analysis (FEA) via ANSYS Workbench software was used to determine the structural performance of both suspension arms. The FEA carried out on the designs was bump-force assessment where the vehicle would have jumped and landed on one wheel. For the upper suspension arm, the Maximum Equivalent (von-Mises) Stress (MPa), Maximum Total Deformation (mm) and Minimum Safety Factor were 340.39MPa, 0.42155mm and 1.3514 respectively. Whereas, the lower suspension arm recorded the value of 55.124MPa, 0.12918mm and 8.3448 respectively. These results indicated that the with respect to the design and in using the 4130-alloy steel, both suspension arms will not yield as the Equivalent (von-Mises) Stress value is under the yield limit of 460MPa. The safety factor of the respective designs was also above 1, thus, the safety aspect is indeed ensured for bump force. Nonetheless, the lower suspension arm could be rated as over-designed in accordance to the Safety Factor. Thus, further optimization could be made with respect to the lower arm in future studies.

**Keywords:** BAJA SAE; suspension arms; off-road; finite element analysis

## 1. Introduction

FSAE are participated by teams of university undergraduate and graduate students to develop and compete in a small, formula style vehicle (Shazwan et al., 2020). FSAE cars are lightweight and have lower center of gravity making it nimble when taking corners (Nor et al., 2019). But with this setup, it is only suitable for racing it in tracks. INTI International University has a tube chassis designed and built by students. This tube chassis is designed according to FSAE technical regulations. Nevertheless, the vehicle constructed by the students is only limited to the usage at the track. The background of this study is to improve the coverage of utilization of the INTI International University's FSAE race car where the vehicle could now cater for both track and off-road, hence, it is now multipurpose and unique to the university only. With the multipurpose credential, the FSAE race car – now an off-road buggy car, can be used for other automotive projects**.**

**Figure 1.** Boundary Conditions Applied Replicating Bump Force

In off-road racing, suspension system is a significant component for the car to perform well in off-road races. Good off-road suspension system has longer travel than road track car's suspension system. This is to allow the car to absorb bumps in higher speed. The aim of this study was to design a new set of rear suspension arms for INTI International University's FSAE car for off-road use the study only focuses on the design and analysis of the suspension arm for the vehicle's suspension system.

The newly designed rear off-road suspension arms is semi-permanent so that it can be swapped out to install FSAE tech regulation's suspension arm. This is to ensure if INTI International University wants to participate in FSAE, the car still complies to FSAE rules and regulation. In designing the new suspension arms, the BAJA SAE requirement will be referred. Figure 1 showed the bump force applied on one end of suspension arm. The force applied was 3 times the mass of a car. The other end of suspension arm was set as frictionless support and shock absorber bracket was set as fixed support.

The aim of this study was to design a new upper and lower suspension arm for INTI International University's FSAE car with the purpose of off-road usage. The new suspension arm was designed in accordance to the BAJA SAE regulations. The material selected for the suspension arms were the 4130-alloy steel. The specifications of the new suspension arms were determined by the size of the bush and the position of the mounting on the existing INTI International University's FSAE car. The study had focused solely on the overall structural strength of the upper and lower suspension arms for off-road usage.

## 2. Methodology

**Table 1.** Variables of the ANSYS Simulation

| Constant Variable | Manipulated Variable | Responding Variable |
|---|---|---|
| Material | Design | Equivalent (von-Mises) Stress |
| Length | | Total Deformation |
| Width | | Safety Factor |
| | | Mass |

The 3D models of the arms were developed using Computer-Aided Design (CAD) via SpaceClaim software. Finite element analysis (FEA) via ANSYS Workbench software was used to determine the structural performance of both suspension arms. There FEA carried out on the designs was bump force assessment where the vehicle would have jumped and landed on one wheel.

The benchmark was designed using 1.25inch 4130 tube based on literature review. Due to design limitation of the shock absorber bracket, a cross member was needed to connect the left and right side of the suspension arm to house the shock absorber bracket.

There were two scenarios that required stress analysis. The first was vertical loading. This scenario happens when the car jumps off a surface having airtime and lands on one wheel. Table 1 shows the variables set for this study. Material, length and width of the suspension arms were set as constant variables. The designs of suspension arms were set as manipulated variables. Equivalent (von-Mises) Stress, Total Deformation, Safety Factor and Mass of suspension arms were set as responding variables.

## 3. Result and Discussion

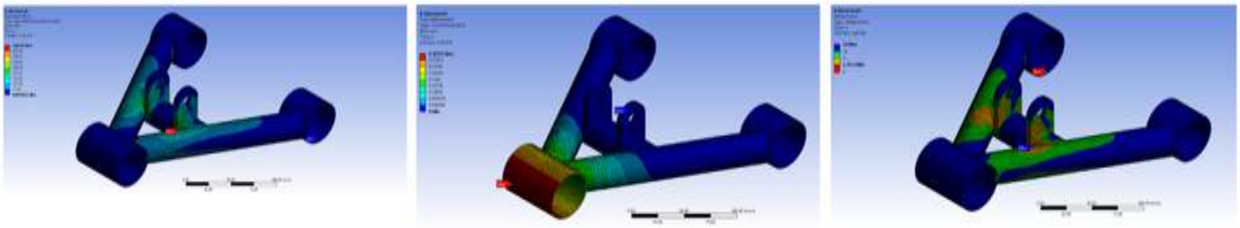

**Figure 2.** Finite element analysis for the upper suspension arm (bump force)

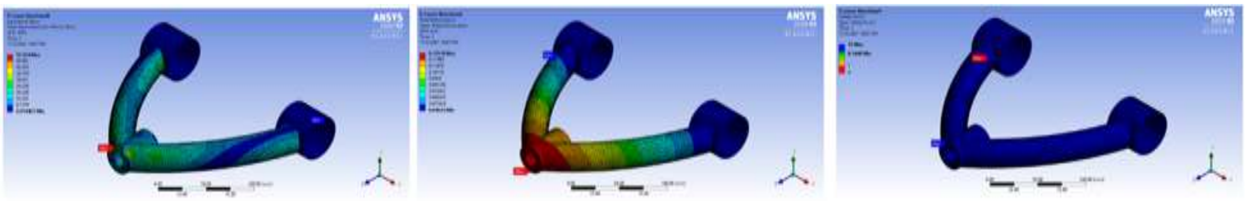

**Figure 3.** Finite element analysis for the lower suspension arm (bump force)

**Table 2.** Example of the caption for the table

| Table 1 | Maximum Equivalent (von-Mises) Stress (MPa) | Maximum Total Deformation (mm) | Minimum Safety Factor |
|---|---|---|---|
| Upper suspension arm | 340.39 | 0.42155 | 1.3514 |
| Lower suspension arm | 55.124 | 0.12918 | 8.3448 |

Figures 2 and 3 show finite element analysis for the upper and lower suspension arms, respectively. For the upper arm, the Maximum Equivalent (von-Mises) Stress (MPa), Maximum Total Deformation (mm) and Minimum Safety Factor were 340.39MPa, 0.42155mm and 1.3514 respectively (See Table 2). Whereas, the lower arm recorded the value of 55.124MPa, 0.12918mm and 8.3448 respectively. These results indicated that the with respect to the design and in using the 4130-alloy steel, both suspension arms will not yield as the Equivalent (von-Mises) Stress value is under the yield limit of 460MPa. The safety factor of the respective designs was also above 1, thus, the safety aspect is indeed ensured for bump force.

The design of benchmark was based on “Design of Double Wishbone Suspension System of BAJA Vehicle” of International Journal of Advance Engineering and Research Development. According to the results in the journal, the highest equivalent (von-Mises) stress was 369MPa. The benchmark has an Equivalent (von-Mises) Stress of 340.39MPa. It has a similarity of 92.50%. Due to the design of benchmark was designed for INTI’s FSAE car, there are design limitations to ensure it is suitable according to the specific application. Hence, the benchmark was validated.

The critical region of suspension arm under load was compared with “Design of Double Wishbone Suspension System of BAJA Vehicle” of International Journal of Advance Engineering and Research Development. The critical regions where it has highest equivalent (von-Mises) stress was the shock mount brackets. The region that has highest total deformation was also the similar when the new designs were compared to the total deformation of “Design of Double Wishbone Suspension System of BAJA Vehicle” of International Journal of Advance Engineering and Research Development. The region that has highest total deformation which was at the end of suspension arm that houses bush which attaches to the upright and wheel hub. Hence, with the results of simulation of bump force was indeed confirmed.

From the result of the of the simulation the safety factor did not fall below 1. Although the deformation did happen which is 0.42155mm and 0.12918mm on the upper suspension arm and lower suspension arm, respectively. The upper suspension arm and lower suspension arm is indeed safe and will not break down easily as the deformation is small, as the minimum safety factor is 1.3514 and 8.3448, respectively.

## 4. Conclusions

To conclude the analysis of upper suspension arm, when the FSAE car jumps and lands on only one wheel, the new designs will not yield as the equivalent (von-Mises) stress value is under the yield limit of 460MPa. The safety factor of all the designs were all above 1, making the new designs safe when bump force was applied. Nonetheless, the lower arm could be rated as over-designed in accordance to the Safety Factor. Thus, further optimization could be made with respect to the lower arm in future studies.

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Mises yield criterion states that if the von Mises stress of a material under load is equal or greater than yield limit of same material, then the material will yield, where the results indicated the von Mises stress is lower than yield limit of the material.

**References**

Anuphappharadorn, Suratsawadee & Sukchai, Sukruedee & Sirisamphanwong, Chatchai & Ketjoy, Nipon. (2014). Comparison the Economic Analysis of the Battery between Lithium-ion and Lead-acid in PV Stand-alone Application. Energy Procedia. 56. 352–358. 10.1016/j.egypro.2014.07.167.

Das, A., Unnikrishnan, N., Shankar, B., & Freeman, J.U. (2014). Design, Fabrication and Testing of the Suspension Subsystem of a Single Seater Off-Road Buggy. International Journal of Applied Engineering Research, 9(5), pp. 525-536.

Klahn, C., & Leutenecker, B., & Meboldt, M., (2014). Design for Additive Manufacturing – Supporting the Substitution of Components in Series Products. Procedia CIRP. 21. 10.1016/j.procir.2014.03.145.

Kumar, S Arun & Balaji, Vignesh & Krishnamurthy, Balachandar & Kumar, D.. (2016). Analysis and optimization of lower control arm in front suspension system. 14. 1092-1098.

Mohd Amir Shazwan, H., Balaji P, M., Shaheerthana, S., Nor, M.I. and Girma, T.C., 2020. Finite Element Analysis of a Buggy Car's Suspension Arms for Off-Road Usage. INTI JOURNAL, 2020(23).

Mujavar, M.H., Ahmed, A., Akbar, M., & Dakhani, M.S. (2018). Design and Analysis of Double Wishbone Suspension System using Fea and Matlab. International Journal of Engineering Research & Technology (IJERT), 7(5), pp. 445-450.

Nor, M.I., Nur Qistina, J., Nurzaki, I., Suresh, A. and Girma, T.C., 2020. Selection of A Roll Cage Assembly for The FSAE Racing Car Via Priority and Design Matrix. INTI JOURNAL, 2020(52).

Oren, & Nicholas W., "Design and Fabrication of Rear Suspension and Drivetrain for Union College's SAE Baja Car" (2011). Honors Theses. 1040. https://digitalworks.union.edu/theses/1040

Pal, A., Sharma, S., & Jain, A., & Naiju, C.D., (2013). Optimized Suspension Design of an Off-Road Vehicle. The International Journal Of Engineering And Science (IJES) , 2(6), pp. 57-62.

Samant, Saurabh & Kumar, Santosh & Kamal Jain, Kaushal & Behera, Sudhanshu & Gandhi, Dhiraj & Sivapuram, Raghavendra & Kalita, Karuna. (2016). Design of Suspension System for Formula Student Race Car. Procedia Engineering. 144. 1138-1149. 10.1016/j.proeng.2016.05.081.

Shinde, Saurabh & Maheshwari, Shruti.(2018). Literature review on analysis of various Components of McPherson suspension. Materials Today: Proceedings. 5. 19102-19108. 10.1016/j.matpr.2018.06.263.

Sierra, A., Estrada. O. A. C., & Chacón, P.C., (2018). Stress analysis of a suspension control arm. 10.13140/RG.2.2.12817.28007.

Sundaravel, S. & Pakash, S. & Navas R, Kaja & Rajasekaran, T.. (2019). Design and Analysis of Camber Angle Adjustment Using Actuators by Transverse Motion in All Terrain Vehicle. Materials Today: Proceedings. 16. 1226-1232. 10.1016/j.matpr.2019.05.218.