Analysis of a front suspension system for UniART FSAE car using FEA

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Abstract. In recent years, many research works from institutions that participated in Formula SAE had highlighted on suspension systems. The aim is to improve the system in term of performance and robustness. However, every suspension system for a racing car is tailored to the car itself. Thus, this paper proposes a new design for front suspension system for UniART FSAE car. The new design was than being compared to the previous suspension system for enhancement. The analysis covered in this paper based on several conditions such as braking, cornering and bumping condition and was carried out using finite element analysis. Each main component for the suspension system such as lower arm, upper arm and knuckle has been analysed in term of strength and performance. From the results, the proposed new design of the suspension system has improved in term of strength and performance compared to the previous suspension system.

1. Introduction
Suspension system typically plays a crucial and importance role in vehicle comfort and stability [1]. Generally, a suspension system arrangement of a vehicle connection the unsprung mass includes wheels, brakes, knuckle and large portion of the heaviness of control arm and dampers, with the sprung mass including the total body [2]. The suspension has primarily two function which is give the transfer limitation of road irregularities to the sprung mass and also maintain the tire always contact with the road at all times [2]. In other words, it give protection for passenger from shock and vibration producing by tires and road interaction as well as give smooth handling and stability [3].

Looking into the automotive industries, generally suspension system needs to comply with safety demand as important priority to experience under or over steer, bounce and gripping when the vehicle faces under certain condition [4]. Furthermore, it must resist roll of chassis and also to keep the wheels take after any uneven road condition by separating the chassis from the unpleasantness of the road [5].

In racing competition, it is crucial for the suspension system to be able to withstand severe conditions. For Universiti Malaysia Perlis Automotive Racing Team (UniART) racing car, the suspension system has undergone failure during the racing competition. Thus, a new front suspension system will be designed based on several conditions and all possible engineering parameters that have been indicated in FSAE regulations for UniART racing car. The aim for a new design is to enhance
the strength and performance through the entire system by referring to the previous design as reference. The analysis is conducted based on the related conditions such as cornering, braking and bumping conditions. Besides that, the worst condition will be taken into account for the analysis. Each individual component of a suspension system will be analysed for strength and performance analysis for the fully system.

2. Methodology

2.1. Suspension geometry and rules

The suspension geometry section concentrates on some of the basic guideline which have been highlighted by the SAE organization. Therefore, FSAE suspension system should be focus on the constraints of the competition. For example, the wheelbase parameters must have dimension at least 1525mm or 60 inches whereas for wheel track must be no less than 75% of the larger track [6]. These two parameters basically influence the performance impact of the racing car itself. Figure 1 shows the previous design and the new design for the suspension system. The new suspension system has redesigned to also reduce the weight of the suspension system.

![Figure 1: Suspension system for UniART FSAE car. (a) Previous design and (b) new design](image)

2.2. Analysis in ANSYS Workbench

All the suspension components were designed using CATIA. ANSYS Workbench was utilized for further analysis of strength and performance of the suspension system. Material assigned for this for the suspension components is mild steel. Three main conditions are set for the analysis which are braking, cornering and bumping condition. Table 1 tabulates the parameters that are important for the analysis purposes. First condition consideration is due to braking condition which the g-force applied is 1.5g at the horizontal position (x-direction). Secondly, the cornering condition which g-force applied at 2g and lastly for the bumping condition that the g-force applied at 2.5g.

Table 1: List of parameter for analysis

| Parameters    | Values   |
|---------------|----------|
| Weight (kg) * | 340kg    |
| Length car (mm)| 1600mm  |
| g-cornering   | 2.0      |
| g-braking     | 1.5      |
| g-bumping     | 2.5      |

3. Result and Discussion

Static stress analysis has been carried out by using ANSYS for the previous and new design of the suspension system. The analysis focuses on major components of suspension system, which are A-arm
and knuckle, and also the full suspension system for a better evaluation between the previous and new design.

3.1 Lower arm analysis

The results of equivalent stress for lower arm are shown in figure 2. For each of the condition, the maximum equivalent stresses are compared as shown in figure 3. From the results, the maximum equivalent stress for the new design is lower than the previous design and the value is not exceeding the yield stress of the material, which is better compared to the previous design. The percentage of reduction for braking, cornering and bumping condition are 28.1%, 38.1% and 66.3% respectively.

Figure 2: Result for lower arm under various conditions (a) original, (b) braking, (c) cornering and (d) bumping.

Figure 3: Comparison of equivalent stress for each condition for lower arm

3.2 Upper arm analysis

The results of equivalent stress for lower arm are shown in figure 4. For each of the condition, the maximum equivalent stresses are compared as shown in figure 5. From the results, the maximum equivalent stress for the new design is lower than the previous design and the value is not exceeding
the yield stress of the material, which is better compared to the previous design. The percentage of reduction for braking, cornering and bumping condition are 43.4%, 68.2% and 71.9% respectively.

![Image](a)

![Image](b)

![Image](c)

![Image](d)

**Figure 4:** Result for upper arm under various conditions (a) original, (b) braking, (c) cornering and (d) bumping.

![Graph](a)

**Figure 5:** Comparison of equivalent stress for each condition for upper arm

3.3 Knuckle analysis

A good design for the knuckle is when it can withstand under critical condition, which is a combined loading. Figure 6 shows the design comparison between the previous and new design of the knuckle. From the results in figure 7, the maximum equivalent stress for the previous knuckle exceeding the yield stress of material. While the value for the new design is below the yield stress, which is good. The percentage of reduction between the previous and new design is about 30%.
Figure 6: Result for knuckle under critical condition (a) previous design and (b) new design

Figure 7: Comparison of equivalent stress for the previous and new design under critical condition

3.4 Full suspension system
In order to obtain an overall performance and strength of the suspension system, each component was assembled and the analysis on the full suspension system was carried out. A force of 1667.7 N was applied to the system, which equivalent to the bumping condition. Figure 8 shows the previous and new full suspension system. The pushrod in the previous design was removed and the absorber is now directly attached between lower arm and chassis.

Figure 8: Front suspension system. (a) Previous design and (b) new design
Figure 9: Result for suspension system (a) previous design and (b) new design

Figure 9 shows the result of the maximum equivalent stress (von-mises stress) for both designs. When a force applied on the suspension design, the previous design has undergone the maximum equivalent stress of 169.8MPa. While the maximum equivalent stress for new design is about 160MPa. This gives about 6.2% reduction in term of maximum equivalent stress compared to the previous design. This shows that the new design has a significant improvement compared to the previous.

4. Conclusion
The analysis of front suspension system has been conducted to analyse the performance of the new design compared to the previous design in term of maximum equivalent stress. From the results, the overall performance of the new design has improvement significantly compared to the previous design. From the analysis of the a-arm and knuckle component, the results show that the components are not exceeding the yield stress of the material in all conditions. This indicates the components can withstand any condition and the chances for failure are minimal.

5. References
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