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Testing of Design and Functionality of Front Suspension Arm in UNY Automotive Electric Vehicle for Individuals with Disabilities

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ABSTRACT

This study aims to evaluate the design and functionality of the front suspension arm in an electric vehicle specifically designed for users with disabilities. The research focuses on the lower arm component, analyzing its structural integrity through finite element analysis using ANSYS Student Version. The simulation was conducted under two loading conditions: 1300 N and 4800 N, representing different stress scenarios based on the vehicle's weight distribution. The safety factor analysis indicates that under a 1300 N load, the lower arm achieves a safety factor of 9.37, demonstrating high structural strength. Under an increased 4800 N load, the safety factor decreases to 2.54, which remains within the acceptable range (2.5–4.0) for static components subjected to dynamic loads. In terms of stress distribution, the simulation results indicate that the maximum stress is 39.51 MPa at a load of 1300 N. In contrast, it reaches 145.9 MPa at 4800 N. The displacement analysis reveals that the maximum deformation under 1300 N is 0.03023 mm, increasing to 0.1116 mm under 4800 N, indicating minimal structural deformation. Based on these findings, the lower arm suspension is deemed structurally safe and capable of withstanding the expected operational loads. These results offer valuable insights for the development of adaptive electric vehicles, ensuring their reliability and safety for users with disabilities.

1. Introduction

Land transportation serves as the primary mode of daily mobility for the Indonesian population. However, the continuous increase in fuel-powered vehicle usage poses a significant challenge due to the depletion of fossil fuel resources, which are non-renewable. Consequently, alternative solutions are required to ensure sustainable mobility without exacerbating existing issues [1].

In the context of globalization and industrialization, Indonesia must strategically leverage both challenges and opportunities to remain competitive on a global scale [2]. One of the emerging transportation alternatives is the electric vehicle, which was first introduced by Robert Anderson in Scotland between 1832 and 1839. However, during that period, fossil fuels were abundant and inexpensive, leading to a preference for fuel-powered vehicles over electric alternatives [3]. Electric vehicles operate using an electric motor powered by energy stored in rechargeable batteries. Given the rising fuel prices and increasing environmental concerns, electric vehicles have gained prominence as an energy-efficient and environmentally friendly transportation option, as they do not produce harmful emissions [4].

Simultaneously, accessibility to transportation remains a critical issue for individuals with disabilities. The term "disability" originates from "different ability," referring to individuals with distinct capabilities or specific needs. This terminology replaces "handicapped," which carries a negative connotation [5]. Disabilities are generally classified into three categories: physical disabilities, which involve impairments affecting bodily functions; mental disabilities, which pertain to limitations in cognitive and logical reasoning; and social disabilities, which manifest as difficulties in adapting to societal norms, regulations, and environmental conditions [6].

The development of electric vehicles designed specifically for individuals with disabilities aims to enhance mobility, particularly for those with physical impairments. These vehicles are designed as single-passenger units, offering wheelchair accessibility to accommodate users with mobility impairments. Currently, the development of electric vehicles for individuals with disabilities remains in the prototyping stage, serving as part of ongoing technological advancements. The selection of suspension systems and materials represents a critical aspect of vehicle design, necessitating a thorough review of existing literature to inform the engineering and innovation processes in the field of automotive technology [7, 8]. This study focuses on the design and development of the upper and lower control arms for the front suspension system of an electric vehicle prototype designed for individuals with disabilities, developed at Universitas Negeri Yogyakarta (UNY). The research process follows a structured and systematic approach, requiring interdisciplinary collaboration to ensure the successful completion of this project [9].

2. Methodology

This research employs the ADDIE development method, which consists of five main stages: Analysis, Design, Development, Implementation, and Evaluation. This method was chosen because it follows a systematic and procedural approach, ensuring that the designed product meets the specified requirements while minimizing the risk of failure in the development process [10, 11].

2.1 Analysis

At this stage, an analysis is conducted on the design requirements of the electric vehicle for people with disabilities, including factors that influence the design of the front suspension. Additionally, observations and literature studies related to vehicle design for people with disabilities are conducted to gather relevant references [12]. This section also includes simple calculations using basic static mechanics equations [13] based on Newton's Third Law to determine the load used in the design process, where

$$F\ action = f\ Reaction \tag{1}$$

2.2 Design

After the design requirements and specifications are determined, the design phase is carried out using Autodesk Inventor 2021 student version. This process involves creating a three-dimensional model of the front suspension's upper and lower arm components, as well as conducting an initial simulation to determine the resulting stress, which serves as a reference for material selection.

2.3 Development

The designed model is then tested using ANSYS 2022 student version to analyze the material strength and stress distribution on the suspension components. The simulation is conducted with loading conditions based on the vehicle's weight calculations to ensure the design's strength and safety. If the simulation results indicate potential structural failure, the design will be revised before proceeding to the next stage.

2.4 Implementation

After the design is approved based on the simulation results, the fabrication process is carried out to realize the design. The material used for manufacturing the components is steel, chosen for its ease of modification and high toughness. The fabrication process is conducted using MIG welding, which is selected for its precision and minimal impact on material properties, ensuring dimensional accuracy according to the design specifications.

2.5 Evaluation

The final stage of this research involves evaluating the fabricated components, which includes testing the vehicle to assess the suspension's performance under operational conditions. This evaluation is qualitative and subjective, meaning no quantitative measurements are taken; instead, a descriptive analysis is conducted to determine whether the suspension functions properly or not [14].

3. Result and Discussion

Fig. 1 shows the dimensions of the designed vehicle and the modified front suspension components. Based on these dimensions and assuming a total vehicle weight of 412 kg, the load distribution on each wheel is calculated using Equation 1. The results indicate that the front suspension supports a load of 248.95 kg, while the rear supports 81.525 kg. This means that each front wheel bears a load of 128.475 kg. Thus, in the design process, a 1300 N load is used, which is a rounded conversion of the load supported by the front wheels.

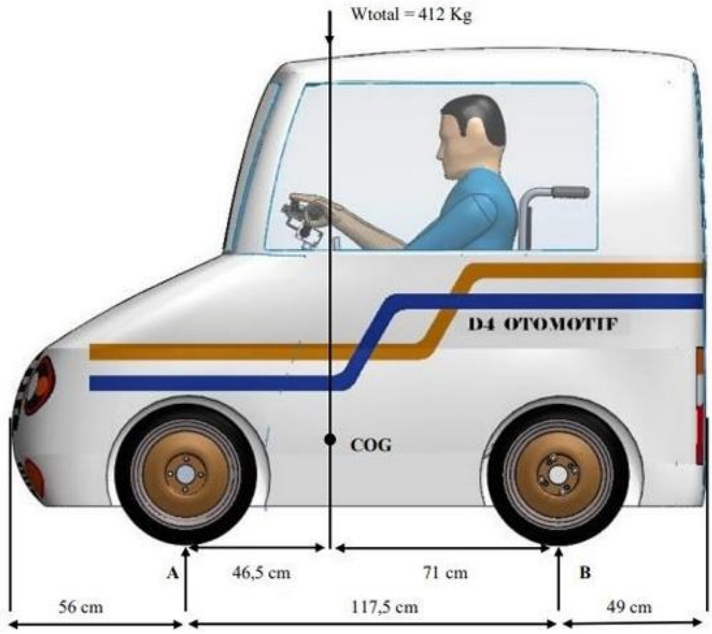

Figure 1. Dimensions of the design vehicle.

Next, the upper arm and lower arm designs used in the vehicle suspension system are shown in Fig. 2. The dimensions have been adjusted to meet the vehicle's requirements, taking into account both functionality and ease of fabrication. The design follows a simple concept that allows for manufacturing using basic tools, thereby reducing production costs. Additionally, ease of installation is a key factor considered in shaping the design.

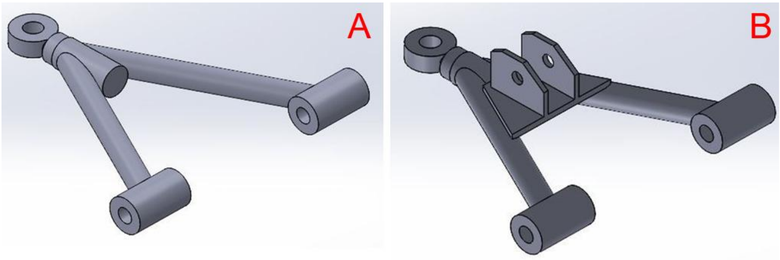

Figure 2. Design of a) upper arm and b) lower arm

To ensure that the lower arm can withstand the vehicle's load, an analysis was conducted using Ansys Student Version. The simulation model used in this analysis is illustrated in Fig. 3. The analysis includes a safety factor calculation, which serves as a benchmark for determining whether the design is safe under load testing conditions. The testing was performed under two loading scenarios: 1300 N and 4800 N. This is based on the fact that each front suspension side supports 128.475 kg or 1284.75 N.

According to the analysis results, under a 1300 N load, the lower arm exhibits a safety factor of 9.37, indicating excellent resistance to the applied forces. Meanwhile, under a higher load of 4800 N, the safety factor decreases to 2.54, which still falls within the safe range of 2.5 to 4.0, commonly used as a guideline for static components under dynamic loads [15]. Thus, it can be concluded that the lower arm can safely support the vehicle's weight, even up to a maximum load of 4800 N. The safety factor visualization from this analysis is presented in Fig. 4.

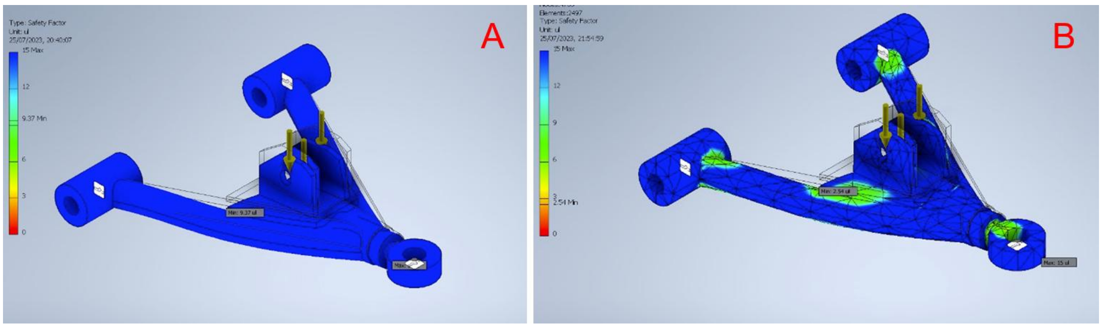

Figure 3. Lower arm safety factor simulation of a) 1300 N and b) 4800 N

Besides safety factor analysis, stress analysis was also performed on the lower arm to evaluate the stress distribution caused by loading. The simulation results indicate that under 1300 N, the minimum stress is 0.04 MPa, while the maximum stress reaches 39.51 MPa. When the load increases to 4800 N, the minimum detected stress is 0.2 MPa, while the maximum stress rises to 145.9 MPa. The stress distribution on the lower arm under both loading conditions is shown in Fig. 5.

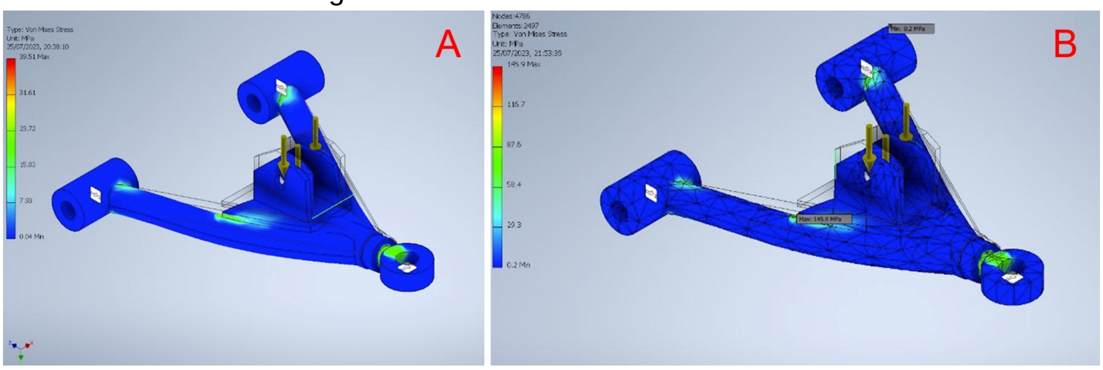

Figure 4. Lower arm stress simulation of a) 1300 N and b) 4800 N

Additionally, a displacement analysis was conducted to determine the magnitude of deformation in the lower arm under load. The results show that at a load of under 1300 N, the maximum displacement is 0.03023 mm, while the minimum remains 0 mm. When the load increases to 4800 N, the maximum displacement rises to 0.1116 mm. Despite this increase, the displacement values remain within a safe range that does not cause structural failure in the lower arm. The displacement visualization is displayed in Fig. 6, and the complete simulation results are summarized in Table 1.

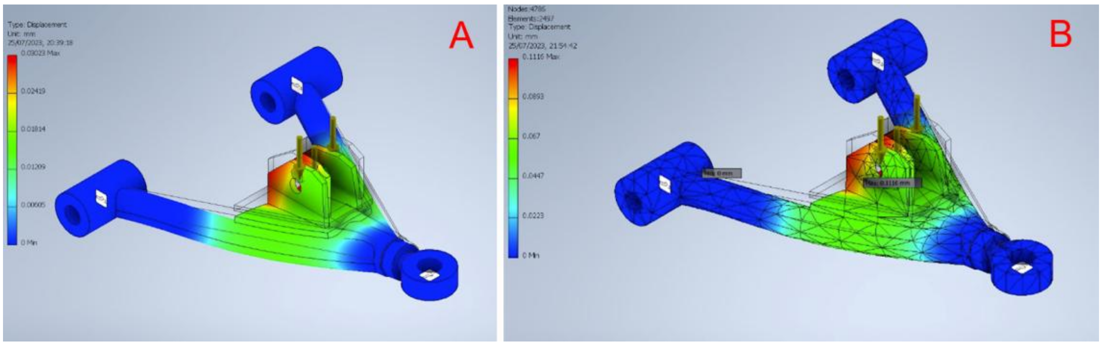

Figure 5. Lower arm displacement simulation of a) 1300 N and b) 4800 load

Table 1. Simulation result

Aspect	1300 N	4800 N
Safety factor	9.37	2.54
Max stres (MPa)	39.51	145.9
Max displacement (mm)	0.030	0.11

Based on the analysis, it can be concluded that the designed lower arm has a high level of safety and can effectively support the vehicle's weight. The obtained safety factor confirms that the component is safe for use. At the same time, stress and displacement analyses indicate that the design functions as intended, with no excessive deformation. However, to verify that the component is not only structurally strong in theory but also functions effectively in real conditions, functional testing was conducted on both the upper arm and lower arm [16].

The functional tests aimed to evaluate the ability of the component to control wheel movement, support the knuckle, support the shock absorber, and adjust the camber angle [17]. The first test examined whether the upper arm and lower arm could properly control wheel movement. The vehicle was subjected to internal shocks, causing the wheels to move up and down. The results confirmed that both components effectively controlled wheel movement smoothly without obstruction or mechanical issues.

Next, a knuckle support test was conducted. The knuckle was installed and directly connected to the wheel, then secured using the upper arm and lower arm with bolts [18]. The results showed that these components provided a strong grip on the knuckle, enabling stable wheel movement. This indicates that the design is suitable for firmly supporting the knuckle, as illustrated in Fig. 6.

The next test ensured that the lower arm could adequately support the shock absorber. In the vehicle's suspension system, the lower part of the shock absorber is connected to the lower arm, while the upper part is attached to the vehicle chassis [19]. The test involved applying internal load shocks to verify whether the shock absorber could absorb impacts properly. The results showed that the shock absorber functioned optimally, and the lower arm supported it without deformation or performance issues. The test illustration is presented in Fig. 6.

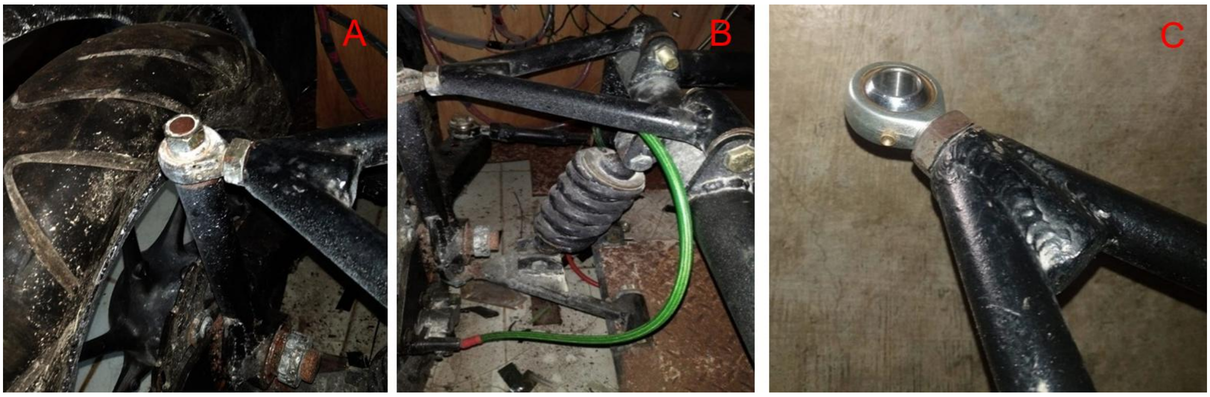

Figure 6. Design testing of a) Knuckle support test, b) Suspension test and c) camber angle test

The final test evaluated the upper arm and lower arm in adjusting the camber angle, which is crucial for vehicle stability during motion. The test involved rotating the bearing rod ends to adjust the length of the upper and lower arms, thereby modifying the camber angle as needed [20]. The results confirmed that the bearing rod ends functioned effectively, allowing optimal suspension geometry adjustments. The test results are shown in Fig. 6.

From all the tests conducted, it can be concluded that the upper arm and lower arm designs applied to UNY's automotive electric vehicle for disabled individuals meet the required functional standards. These components are not only structurally strong but also function effectively in controlling wheel movement, supporting the knuckle and shock absorber, and allowing precise camber angle adjustments. Therefore, this suspension design can be effectively used to enhance vehicle comfort and stability in various operating conditions.

4. Conclusion

The results of the research show that the electric vehicle prototype's upper and lower suspension arms are strong enough and safe enough to withstand dynamic loading conditions. The lower arm component shows a substantial safety margin in the finite element analysis conducted using ANSYS. The safety factor is 9.37 under a 1300 N load and 2.54 with a 4800 N load. All of these numbers are within the safe range for components that are dynamically stressed, thus it looks like the structure can handle both typical and exceptional loads. There would be no structural collapse under those conditions because the associated stress values, 39.51 MPa for 1300 N and 145.9 MPa for 4800 N, are significantly lower than the yield strength of the chosen material.

The suspension unit is structurally sturdy, and it also serves its functional purpose well. The capacity of the upper and lower arms to sustain important suspension components, like the knuckle and shock absorber, was evaluated. These parts keep the knuckle in position and make sure the shock absorber works properly, so it can absorb energy from bumps in the road, according to the tests. Also, you may change the camber angle with the bearing rod ends and the suspension system is flexible enough to adapt the alignment. Electric vehicles made for people with impairments benefit greatly from this function because it improves the vehicle's handling and stability. The design's simplicity is another noteworthy achievement. It was with this ease of fabrication and installation in mind that the suspension arms were devised. In addition to facilitating possible manufacturing scalability, this method simplifies and lowers the cost of production. Little distortion seen in the simulations proves that performance is unaffected by the design's seeming simplicity. The greatest displacement measured was a respectable 0.03023 mm under a 1300 N loading and a somewhat higher 0.1116 mm under a 4800 N loading, both of which are well within the allowable tolerance limit.

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