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The Double Wishbone Suspension Design of The Gajah Oling Electric Vehicle

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ABSTRACT
The ongoing development of electric vehicles is aimed at swapping conventional fossil fuel-powered automobiles, namely those reliant on petrol and diesel. In order to achieve optimal use in practical scenarios, electric vehicles must possess the capability to navigate diverse terrain elements. The utilization of suspension systems serves the objective of reducing the magnitude of the load exerted on the tires, hence facilitating enhanced driver control over the electric vehicle. The spring performance of the suspension system in an electric car design is evaluated for different weight configurations. Specifically, when the car weight 120.4 Kg, the suspension exhibits a spring constant of 59.0N/m. Similarly, when the weight is 115.4 Kg, the suspension system demonstrates a spring constant of 62.8N/m. Finally, in the front suspension configuration with a weight of 129.4 Kg, the spring constant is measured to be 57.7 N/m. The constant data have been aggregated to determine that the maximum load capacity of the suspension system under shock conditions is 365.8 kg. Based on the findings of the design results, it was seen that the highest damping constant was recorded in the case of a load weighing 120.4 Kg, specifically in the low mode with a value of 285.41 Ns/m, and in the mid mode with a value of 196.6 Ns/m.
Keyword: Electric car, Suspension, Double wishbone, Motion simulation, Displacement

ABSTRAK
Mobil listrik saat ini banyak dikembangkan untuk dapat menggantikan mobil berbahan bakar fossil seperti bensin dan solar. Faktor medan yang beragam harus mampu ditempuh oleh mobil listrik agar dapat sepenuhnya digunakan pada kondisi yang sesungguhnya. Tujuan dari penggunaan suspensi adalah untuk membuat beban yang bekerja pada ban lebih kecil dan dapat memudahkan pengendara dalam mengontrol mobil listrik. Kinerja pegas sistem suspensi pada rancangan mobil listrik berat 120.4 Kg pada suspensi mendapatkan konstanta pegas sebesar 59.0N/m, berat 115.4 Kg pada suspensi mendapatkan konstanta pegas sebesar 62.8N/m dan, untuk berat 129.4 Kg pada suspensi depan mendapatkan konstanta pegas sebesar 57,7 N/m. Hasil dari perhitungan nilai konstata yang telah ditotal sehingga dapat diketahui kemampuan maksimal shock dalam menerima beban adalah suspensi 365.8 Kg. Dari hasil perancangan didapat bahwa konstanta redaman terbesar adalah pada variasi dengan beban 120.4 Kg pada mode low 285.41Ns/m dan mode mid 196.6 Ns/m.
Keyword: *Mobil listrik, suspensi, Double wishbone, Simulasi gerak, Perpindahan*

1. Introduction

The Earth has a diverse range of natural energy resources that encompass numerous types of fuel, which can be harnessed by people to fulfill the requirements of multiple sectors. Energy consumption is a fundamental aspect of human existence [1] , encompassing various activities such as the utilization of fuel for transportation, the creation of electricity, and household activities. The escalating need for energy sources among human populations may lead to a depletion of natural resources, potentially resulting in their exhaustion [2], [3]. Given this circumstance, it is imperative for the government to devise strategies aimed at ensuring the availability of energy reserves that can effectively meet the demands of the future. One of the initiatives involves the development of alternative cars with enhanced environmental sustainability. One category of transportation is represented by vehicles that rely on electrical energy, including solar cells and other related technologies.

The imperative to replace fossil-fuel vehicles with electric vehicles as a primary mode of transportation necessitates the development of electric vehicles that minimize energy consumption while maintaining a high level of battery durability[4], energy efficiency[5], [6], and real-time speed across diverse road conditions. This would enable a comprehensive understanding of energy consumption levels, as well as the advantages and disadvantages associated with their usage on highways. The performance parameters of electric vehicles, including battery voltage [7], thermal condition [8] , power [9] , electric current [10], speed and acceleration, are continuously monitored and recorded. These values are then presented in the form of a speed profile, allowing for analysis of energy consumption, road slope, track temperature, and driver behavior. Further improvement is still necessary for electric vehicles to achieve maximum operational performance. Electric vehicles must possess the capability to navigate diverse terrain conditions. The essential characteristics expected from an electric vehicle encompass the attainment of high velocities, the generation of prompt and efficient acceleration, the capacity to generate substantial levels of torque, and the ability to endure significant burdens. The durability of an electric vehicle must have a high level of performance [11].

The suspension system is a critical component that significantly contributes to enhancing the driving experience by providing support for the vehicle's weight (static load) and effectively dampening unexpected dynamic loads [12]. An equally significant requirement, in addition to the suspension system, is to ensure vehicle stability[13] across all road conditions, encompassing turning, stopping, and high-speed driving. The primary objective of employing suspension systems in electric vehicles is to reduce the magnitude of the load exerted on the tires, hence facilitating enhanced driver control. The purpose of suspension systems is to maintain consistent contact between the tire and the road surface, so enabling the tire to fully utilize its performance possibilities. The double wishbone suspension is one of a type of suspension system. The double wishbone suspension is a form of vehicular shock absorber that enables independent movement of two wheels situated on a common axle, without any mutual interference. One illustrative instance is the utilization of a double wishbone configuration for the front suspension of an automobile. In the event that the right front wheel experiences vertical upward movement as a result of encountering an impediment, the left front wheel will remain stationary in terms of vertical displacement, provided that no comparable obstacle is present on the left wheel [14].

Suspension is an integral constituent tasked with mitigating vibrations and shocks arising from the road conditions encountered by the vehicle, hence enhancing its overall comfort. The suspension system is positioned in the intermediate space connecting the vehicle body and the wheels, with the primary purpose of mitigating the impact of road irregularities [15]. This serves to enhance the overall driving experience by promoting both stability [15] and comfort, while concurrently enhancing the traction of the wheels on the road surface. The suspension system comprises several components such as springs, shock absorbers, stabilizers, and other related elements. Prior to commencing testing, it is imperative that the suspension system is robust and dependable. Sensitivity assessments confirm that the suspension system achieves the intended and competitive performance by effectively supporting and transmitting the loads from the road wheels [16]. This study examines the system design of a double wishbone suspension for Gajah Oling electric automobiles, which is a crucial component of the suspension system employed in the production of electric cars at Banyuwangi State Polytechnic. The utilization of suspension serves the objective of generating an operational burden. The reduced size of the tires enhances the driver's ability to effectively manipulate the vehicle's electric power system. The purpose of the suspension system is to maintain consistent contact between the tires and the road surface, so enabling the tires to be utilized to their maximum potential.

2. Method

The initial step in the preparation for the development of this electric vehicle entails doing field observations or engaging in research investigations, alongside seeking relevant references pertaining to the suspension system and design calculation. The manufacturing planning of this electric vehicle is executed with precision to ensure optimal functionality of the subsequent output. Testing is conducted in order to determine the functionality and effectiveness of a product or system. In the course of designing the suspension system for an electric vehicle, one essential evaluation entails subjecting the frame to a load in order to assess the suspension's capacity to withstand external forces. This particular study carried out under the category of research and development (R&D) research. The sequential phases involved in the manufacturing process encompass the following research steps.

The frame design is the main thing that needs to be done before the chassis work process. This process aims to facilitate and minimize problems that occur during the work process so that results are in accordance with the framework design; prepare and identify the tools and materials needed to support the work easily and in accordance with the classification required for making the chassis. The materials used are black steel pipe or carbon steel pipe, RD-260 electrode, stainless steel plate. The machine tools used are hand grinding machines, welding machines, hand drilling machines; The process of making an electric car frame requires several stages in sequence in order to get results according to the design and reduce errors in the work process.
Following the assembly of the various components, the subsequent phase entails the execution of motion simulation. Next, the suspension component is equipped with a spring. Prior to this, it is necessary to select the surface on which the spring will be attached as the initial point. The spring can be modified to suit individual requirements by making appropriate adjustments. Work testing is the final stage in the work process which aims to check the performance results or road tests on a particular machine or tool. Data collection techniques through simulation using Solidwork software [17] and observation of the test road. The flow chart of this research can be observed in Fig. 1.

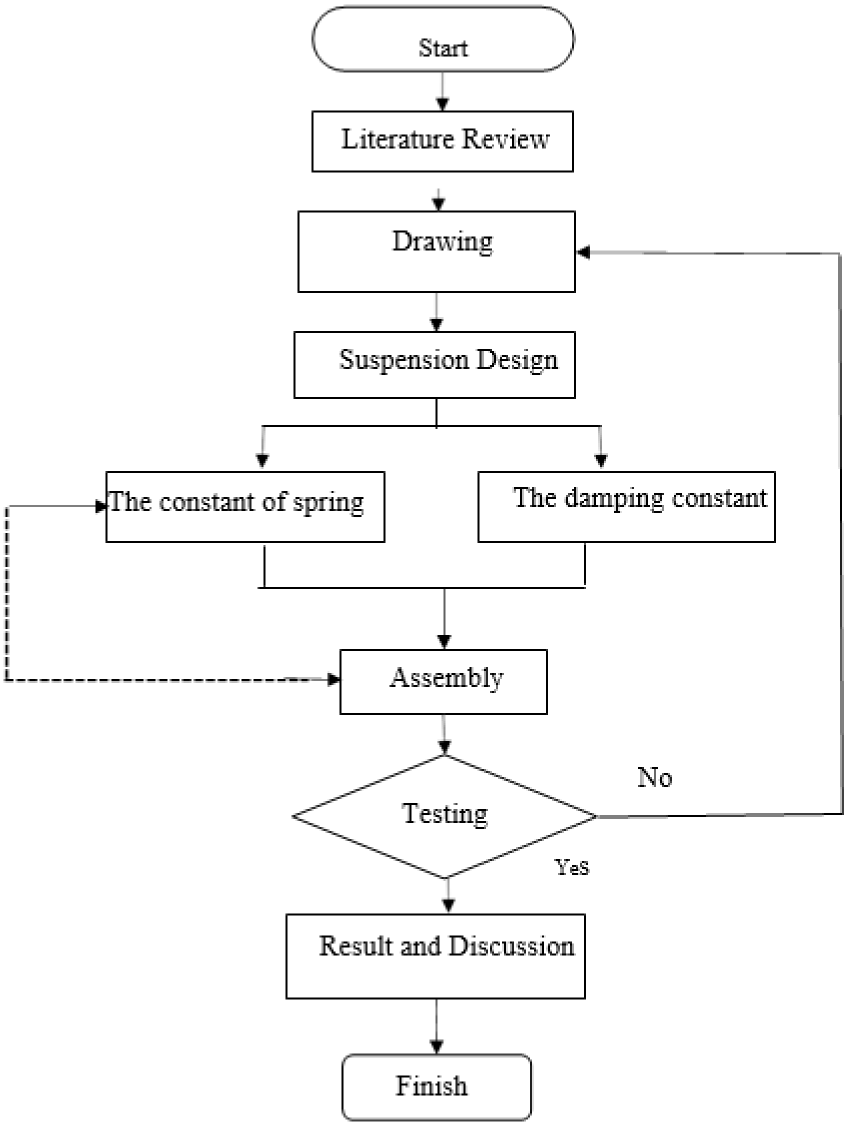

Figure 1. Flowchart diagram of research

3. Result and Discussion

3.1 Placement of Suspension Components in Car Systems

The placement of the shock absorber on an electric automobile is typically on the chassis. The spring's position plays a crucial role in its ability to withstand the rotational forces exerted on the chassis, particularly during vehicle manoeuvres [18] and encounters with road irregularities. The utilization of the vertical position of springs and shock absorbers is precluded in electric automobiles due to constraints imposed by limited space and the design of the chassis. The springs and shock absorbers employed in electric vehicles are positioned at an inclined angle. The upper segment of the spring and shock absorber assembly is affixed to the primary framework of the chassis, whereas the bottom segment is attached to the lower arm. The positioning of the suspension system for electric vehicles is depicted in Fig. 2.

Figure 2. The placement of Suspension

The suspension specifications can be seen in Table.1, which pertains to the front suspension, and Table. 2, which pertains to the rear suspension.

Table 1. Specification of Suspension (front)

Model Number	RD220-280P-14-84P-XD
Unit	1 Set
Dimension (cm)	32.4 x13.9 x 6.6
Colour	Yellow
Product Code	51300 - ALL05 – TP8BY
Weight	2.4 Kg

Table 2. Specification of Suspension (rear)

Model Number	RD220-280P-14-15P-XD
Unit	1 Set
Dimension (cm	32.4 x13.9 x 6.6
Colour	Red
Product Code	51300 - ALL05 – TP8CR
Weight	2.4

3.2 The Influence of Loading on the Suspension System

The procedure of measuring the suspension system through the testing of a pre-established load. During the procedure of assessing the load on the rider, three individuals are involved, each possessing a distinct weight, hence leading to uneven distribution of pressure. The process of collecting data occurs during periods of electric vehicle immobilization. In the process of weight measurement for the drivers, it was observed that there were three individuals, with respective weights of 50 kg, 55 kg, and 68 kg. Next, proceed to determine the mass of both the battery and panel box, yielding a combined mass of 64.4 kg. The subsequent step involves the procedure of quantifying the beginning and final lengths of the shock absorber under load, utilizing a ruler. Based on the acquired results, it can be determined that the initial length of the shock absorber is 165 mm. The next step involves quantifying the pressure outcomes resulting from the application of a load by means of a ruler. The procedure for evaluating the outcomes of this pressure entails assessing the extent of displacement exhibited by the shock absorber upon being subjected to the applied load. The outcomes derived from each driver are as follows: 18, 20, and 22 cm (see Table 3).

Table 3. The result of measurement

F total	Initial length	Final Length	Suspended Pressing Outcomes
115.4 Kg	165 mm	147 mm	18 cm
120.4 Kg	165 mm	145 mm	20 cm
129.4 Kg	165mm	143 mm	22 cm

3.3 The determination of the spring constant in a suspension system

The determination of the spring constant is calculated utilizing the subsequent equation,

$$k_{shock}=\frac{k_1+k_2+k_3}{3} \quad (1)$$

$$k = m \cdot g / x \quad (2)$$

Which,

m: mass (kg)

g: 9.8 m/s^2

x: length of suspension (mm)

Based on the data presented in Table 3, the values of k_1, k_2, and k_3 can be determined using Eq 2., as 62.8 N/m, 59.0 N/m, and 59.8 N/m respectively. The shock's maximum load-bearing capacity can be determined by observing its maximum shortening stroke, which measures 60 mm obtained 365.8 Kg.

$$F = x \cdot K \quad (3)$$

$$F = 0.06 \text{ m} \cdot 59.8 \text{ N/m}$$

$$F = 3588 \text{ N}$$

3.4 The process of motion simulation

Once the various components have been built, the subsequent step involves conducting motion simulation by including a spring into the suspension component (see Fig. 3). Prior to this, it is necessary to carefully select the surface that will serve as the initial point for installing the spring. The adjustment of the spring can be made in accordance with the specified mathematical requirements. Next, input the K value into the designated menu within the spring section, specifying a value of 59.8 N/mm. Subsequently, the force and location of the loading point for the load are determined based on the maximum capability value of the shock breaker, denoted as F = 3588 N. The F value is determined by dividing it by 4, which corresponds to the number of shock breakers utilized in the electric automobile. As a result, the calculated F value is 897 N.

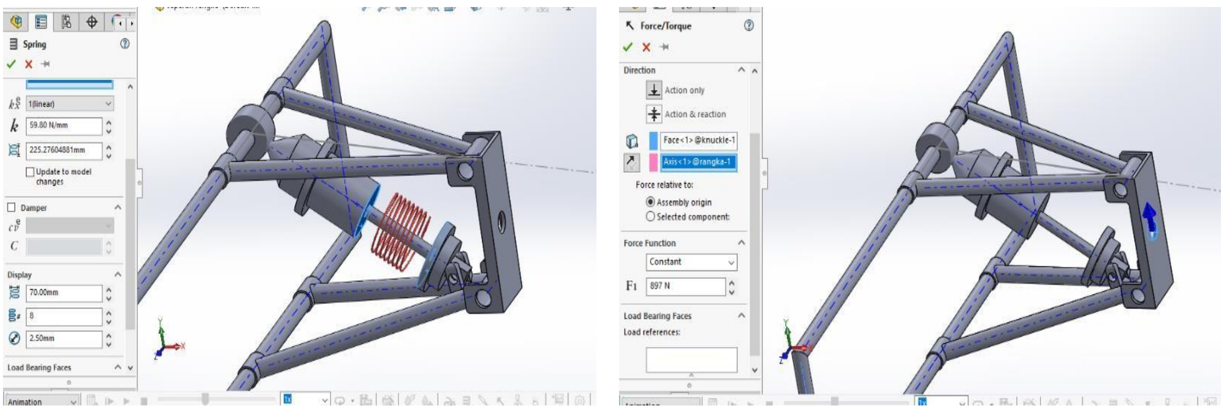

Figure 3. The placement of spring and force

After inserting the spring and force, the results of the motion simulation can be simulated using motion study 1. When a force of 897 N is applied, the simulation produces waves that rise and subside on the breakwater. There are rising and declining waves in the resulting graph, indicating that the size of the shock absorber influences the interpretation of the simulated data. Consequently, the burden also influences the damping. The closer the wave path, the greater the applied force. The simulation outcomes yielded the analysis graph depicted in Fig. 4.

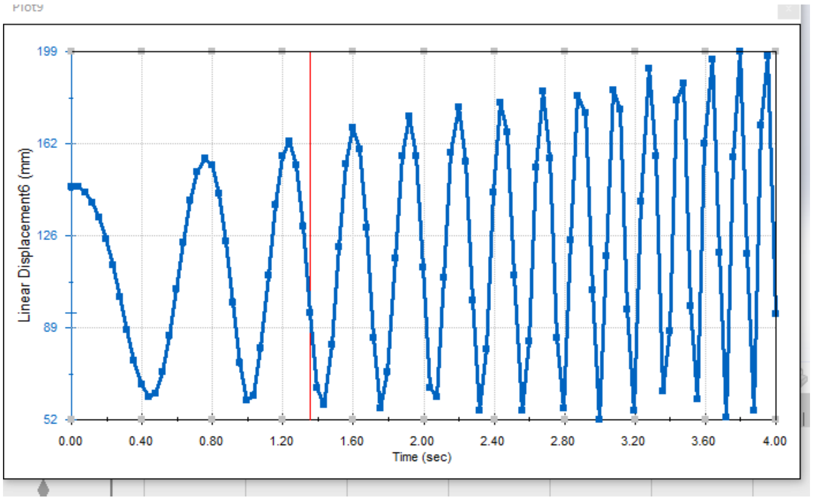

Figure 4. The result of motion simulation

3.5 The calculation of the damping constant.

In order to determine the damping constant, it is necessary to obtain measurements of time and distance during the testing process. Two modes, specifically low and mid mode, are employed in the evaluation of electric automobiles' speed.

a. The concept of "low mode" refers to a state or condition characterized by a lower level of functioning or performance.

The low mode refers to a mode of operation characterized by a low rotational speed. The stability of the testing procedure utilizing the low mode is enhanced when conducted on both flat and potholed road surfaces. During the low mode testing procedure, the suspension performance exhibited consistent results when traversing roads characterized by potholes, bumps, and bends. Notably, one of the contributing elements to the performance variability on these roads was occasional loose connections in the battery connector. The calculation of the damping constant in the suspension can be performed when the damping results exhibit higher values. The findings obtained from the conducted tests reveal the mean values for time (t), displacement (m), and velocity (m/s). The technique of data gathering testing involved the determination of a pre-established distance of 400 meters. The testing procedure consisted of a total of 20 cycles, which were categorized into two mid modes and one low mode.

b. The concept of "mid mode" refers to a statistical measure that identifies the value that occurs most frequently in a dataset, specifically when there are two values that occur with equal

The mid mode refers to the operational mode that is situated at the middle range of the revolutions per minute (rpm) scale. The stability of the testing procedure utilizing the mid mode is enhanced when conducted on flat surfaces or surfaces with potholes. Similarly, the mid mode bears resemblance to the low mode as the variance in speed is merely 10%. However, when considering a 400-meter lap on the track, no significant issues arise. One occasional concern is to the potential loosening of the battery connector. The damping outcomes exhibit modest variations in comparison to the low mode, owing to the presence of a higher speed factor. The data is presented in a tabular format, as depicted in Table 4. The data presented in this study pertains to test results that have been categorized according to both time and distance.

Table 4. The test results are based on time and distance

LOW	No	Displacement	M (Kg)	s (m)	t (s)	V (m/s)
	1	0.02 m	120.4 Kg	96.66	1. 611	4.1382
	3	0.02 m	120.4 Kg	82.99	1.3832	5.1053
	5	0.02 m	120.4 Kg	78.35	1.3058	5.1053
	7	0.02 m	120.4 Kg	77.88	1.298	5.1361
	9	0.02 m	120.4 Kg	84.55	1.4092	4.7309
MID	1	0,02 m	120.4 Kg	66.5	1.1083	6.015
	3	0,02 m	120.4 Kg	60.36	1.006	6.6269
	5	0,02 m	120.4 Kg	58.76	0.9793	6.8074
	7	0,02 m	120.4 Kg	59.1	0.983	6.7682
	9	0,02 m	120.4 Kg	57.87	0.9545	6.912

The damping constant derived from the calculation results for the electric car's time and distance measurements in low mode and mid mode may be observed in Table 5.

Table 5. The results of the calculation data

	Suspension				
Speed Mode	x (m)	m (Kg)	t (s)	k (N/m)	c (Ns/m)
LOW	0.02	120.4 kg	1.611	59.8	285.41
	0.02	120.4 kg	1.382		231.35
	0.02	120.4 kg	1.3058		231.35
	0.02	120.4 kg	1.298		229.96
	0.02	120.4 kg	1.4092		249.66
MID	0.02	120.4 kg	1.1083	59.8	196.6
	0.02	120.4 kg	1.006		178.23
	0.02	120.4 kg	0.9793		173.50
	0.02	120.4 kg	0.985		174.51
	0.02	120.4 kg	0.9645		170.8

Based on the experimental findings obtained through the application of loads on both the front and rear suspension, it is observed that the front suspension's shock absorber exhibits a maximum load capacity of 365.8 kg. The analysis of the oil suspension shock absorber revealed that there is a direct relationship between displacement and load, and the resulting damping constant [19]. Specifically, it was observed that larger displacements and loads lead to higher damping constants, while smaller displacements and loads result in lower damping constant [20]. Based on the results obtained from the 0.02m displacement test, it can be inferred that the highest damping constant is observed in the case of a load of 120.4 Kg, with values of 285.41 Ns/m in the low mode and 196.6 Ns/m in the mid mode. Hence, alterations in displacement have an impact on the vibrational response of the shock absorber. As depicted in Fig. 5, the YSS Suspension is observed.

Figure 5. The result of motion simulation

4. Conclusion

Based on the conducted design and testing procedures, the following conclusions can be drawn:
Analysis of spring performance and damping characteristics of the suspension system in electric car design was carried out for three different weight configurations. The first configuration weighs 120.4 kg and exhibits a spring constant of 59.0 N/m. The second configuration weighs 115.4 kg with a spring constant of 62.8 N/m. Finally, the third configuration weighs 129.4 kg, with a front spring constant of 57.7 N/m. Constant values have been calculated and put together, revealing that the maximum capacity of the shock to support the suspension load is 365.8 kg. The study also found that the highest damping constant was observed in the 120.4 kg load case, with values of 285.41 Ns/m in low mode and 196.6 Ns/m in medium mode.

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