INTERNATIONAL JOURNAL OF INNOVATION IN MECHANICAL CONSTRUCTION AND ENERGY

Vol. 1No. 2 (2024), 115-120

IJIMCE

https://ijimce.ppj.unp.ac.id/index.php/ijimce
University of Negeri Padang

International Journal of Innovation in Mechanical Construction and Energy

ISSN: 3046-9112 e-ISSN: 3046-9104

Steering System Design for the Marapi Electric Car Politeknik Negeri Padang

Hendri Candra Mayana[1], Hanif[2]

[1,2] Departement Mechanical Engineering, Politeknik Negeri Padang,
Jl. Kampus, Limau Manis, Kec. Pauh, Kota Padang, Sumatera Barat, 25164, INDONESIA

*Corresponding Hendri Candra Mayana, Hencanmay@gmail.com

Recived 15 May 2024 ; Accepted 28 June 2024; Available online 30 June 2024

Abstract

This research aims to design and build a steering system for electric cars at the Padang State Polytechnic. This design is focused on meeting the minimum turning radius requirement of 6 meters in accordance with the KMHE 2023 regulations, with the aim of demonstrating compliance with expected safety and maneuverability standards. The steering system used is Rack and Pinion, which has proven to be effective in controlling the turning angle of the wheels with the turning angle of the inside front wheel being 15.74° and the outside front wheel being 13.71°. This ensures that the vehicle can make turns with optimal smoothness and stability. Ackerman Angle Analysis for a Tire Slip Angle of 7.35° confirms that this steering system design is successful in optimizing vehicle performance in various turning conditions. Overall, the design of this steering system satisfies the essential technical requirements for urban electric vehicles, increasing efficiency and effectiveness in energy use and ensuring user safety.

Keywords: Steering systems, electric car, marapi

INTRODUCTION

The 2023 Energy Efficient Car Contest (KMHE) is a prestigious event in the development of energy efficient vehicle technology in Indonesia, organized by the Talent Development Center (BPTI) of the Ministry of Education, Culture, Research and Technology of the Republic of Indonesia, in collaboration with higher education institutions as hosts [1]. One important aspect that is focused on in this competition is the development of steering systems for electric vehicles. The steering system is not only a vital component in the vehicle's drive system, especially in the car chassis, but also plays an important role in optimizing vehicle maneuverability and stability. In this context, Padang State Polytechnic has taken steps to design and build an innovative steering system for electric vehicles, with the aim of increasing energy efficiency and overall vehicle performance.

The background to this research arises from the need for increasing development of electric vehicle technology, in line with global efforts to reduce carbon emissions and utilize cleaner energy sources. Padang State Polytechnic chose to focus on the steering system because of its crucial role in controlling the direction and stability of the vehicle, which is a key factor in achieving optimal performance and driving safety. By considering various technical aspects and applicable regulations, this research aims to design a steering system that not only meets strict technical and safety standards, but can also significantly improve the operational efficiency of urban electric vehicles

In the design of the steering system, it is a vital component in the vehicle drive system, especially in the car chassis, which functions to change the direction and speed of the vehicle by moving or turning the front wheels [2]. Apart from that, the steering system also plays an important role in maintaining the stability of the car's position. The main function of the steering system is to regulate the direction of the vehicle according to the driver's wishes by turning the front wheels [3].

In the context of this research, the Marapi Electric Urban Car vehicle, the steering system plays an important role in determining the overall performance of the vehicle. Much research has been carried out regarding steering systems in electric urban car chassis. One of them is research by Daris Ibnu Fajar which discusses the design and calculation of turning angles in the steering system of the ITS Urban Concept Car [4], [5]. This research shows that the 18° angle configuration is the best to be applied theoretically because it is close to the Ackerman principle, while the 16° configuration is the most likely to be applied considering the available chassis geometry limitations.

This research aims to plan and create an optimal steering system for the Padang State Polytechnic Electric Car. The main objective is to design a steering system that complies with the basic principles of vehicle direction control, calculate and determine the most optimal turning angle to be applied to urban electric vehicles, and identify and overcome problems that may arise in the process of designing and implementing the steering system. The problem faced is ensuring compatibility between the movement input from the driver and the wheel movement output, so that the steering system can produce a turning radius that suits the driver's wishes, supporting performance, safety, efficiency and comfort in driving the Padang State Polytechnic Electric Car.

RESEARCH METHODOLOGY

This research begins with a very important stage, namely the research scheme. A research scheme serves as a systematic guide to planning, implementing, and managing research effectively. This helps ensure each stage of the research is carried out correctly, facilitates clear communication with relevant parties, organizes resources and time well, identifies and resolves potential problems, and documents the process and findings well. With this scheme, research can run according to schedule, reducing the risk of errors and increasing the credibility of research results. This can be seen in the research scheme in **Fig. 1**.

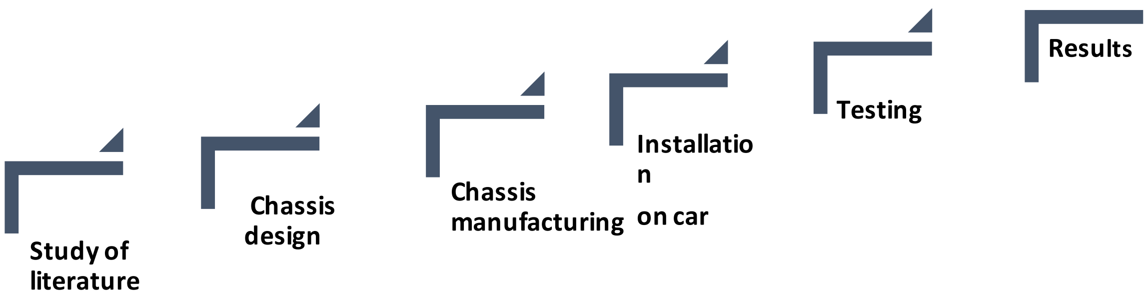

Fig. 1. Research scheme

1. **Study of literature**
   At this stage, a search and collection of information were carried out from various literature sources relevant to the steering system in urban electric vehicles. The aim of the literature study is to understand the basic principles, technological developments, and solutions that have been previously developed regarding electric vehicle steering systems. The information collected will be the basis for designing an optimal steering system.
2. **Chassis Design**
   This stage involves the design process of the vehicle chassis, which will integrate the steering system. Chassis design is carried out by paying attention to various technical and geometric aspects to ensure that the chassis is able to support the steering system well. This process also includes

calculating turning angles and determining the best configuration based on the results of literature studies. In this design, several components can be calculated, such as:

a. Turning radius (wheel angle and turning angle)

If the turning angles of the left and right front wheels are the same, both will have the same turning radius (r1 = r2), which causes the vehicle to have different turning centers (O1 and O2). This results in the vehicle not being able to turn smoothly and causing uneven tire wear. Equations used Turning radii 1 and 2 [6]

$$\alpha = tan^{-1}\frac{L}{R+Tf/2} \quad (1)$$

$$\beta = tan^{-1}\frac{L}{R-Tf/2} \quad (2)$$

Where:

α	=Outer wheel turning angle (°)
β	= Inner wheel turning angle (°)
R	= Vehicle turning radius (m)
Tf	= Front wheel track width (m)

b. Turning angle calculations use the Ackerman principle.

Ackerman's principle is based on the concept of turning angle. When a vehicle turns, the outside wheels (the wheels on the outside of the curve) must follow a greater path than the inside wheels (the wheels on the inside of the curve) [7], [8]. This different turning angle on each wheel ensures that all wheels have the same turning radius.

In its application, the Ackerman system has equation 3.

$$\beta = arc\ \sin\frac{b}{R_{ack}} (3)$$

After calculating the Ackermann (Rack) angle, the calculation for the tire slip angle can be done using equation 4 [9]

$$\beta = arc\ sin\ \frac{b}{R_{ack}} (4)$$

Information:

a	= distance from center of gravity to front wheel axle
b	= distance fromcenter of weight to the rear axle
Rack	= Ackermann angle
β	= Slip angle
δf	= Front wheel turning angle

3. **Chassis Manufacturing**
After the design stage is complete, the next step is to manufacture the chassis according to the design that has been designed. Chassis manufacturing involves a precision manufacturing process to ensure all components are installed correctly and according to specified specifications. The quality and durability of the chassis material are also tested at this stage to ensure optimal performa nce.
4. **Installation on Car**
The chassis that has been completed is then installed on an urban electric car, which is the object of research. This installation is carried out carefully to ensure all components are connected and functioning properly. In addition, the steering system that has been designed and installed on the chassis is also tested to ensure compatibility between design and actual implementation.
5. **Testing**
After installation, a series of tests were carried out to evaluate the performance of the steering system in urban electric cars. This test includes turning tests, stability tests, and comfort tests to ensure that the steering system works according to predetermined expectations and specifications. Test results are used to identify areas that require improvement or adjustment.

6. **Results**
   The final stage is the analysis of test results and the preparation of reports. The research results are interpreted to assess the success of the steering system that has been designed and implemented. The research report includes the main findings, conclusions, and recommendations for further development. These results also form the basis for scientific publications and the dissemination of knowledge to the academic and industrial communities.

DISCUSSION AND RESULTS

The chassis design of the urban electric car that was made can be seen in **Fig. 2** and **Table 1**. The dimensions and sizes in the figure have been adjusted based on the results of previous calculations. This design includes all the necessary technical aspects to ensure optimal integration with the steering system, as well as supporting overall vehicle stability and performance.

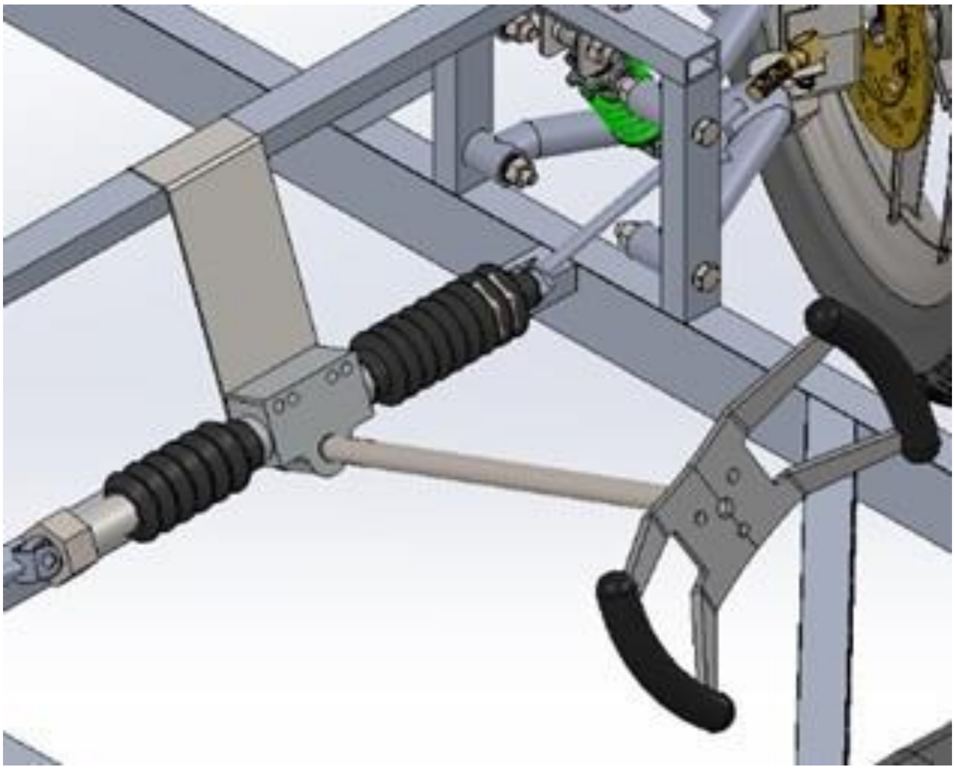

Fig. 2 – Electric Urban Car steering system design

Table 1. Vehicle Specifications

Vehicle height	113.237 cm
Vehicle track width	125.616 cm
Height ratio	6.9 cm
The distance between the front and rear wheels	162.202 cm
Overall length of vehicle	273 cm

Analysis of Turning Radius and Ackerman Calculations

In this research, the analysis of turning radius calculations and the Ackerman principle is important to understand the Ackerman slip angle, namely the angle between the longitudinal angle of the vehicle body and the direction of body movement. The first step in this analysis is to determine the vehicle's steering angle. The author analyzes this steer angle and then uses it to calculate the Ackerman slip angle. For this research, the vehicle turning radius was set at 6 meters, in accordance with KMHE 2023 regulations. The calculation of the steering angle of the outer and inner wheels was carried out using equations [7, 10]. Thus, this analysis can provide a deeper understanding of the vehicle's turning dynamics and ensure that the steering system design meets expected performance and safety standards.

a. For the outer corner of the front wheel

Then the calculation of the inside front wheel angle becomes:

$$\alpha = tan^{-1}\frac{1{,}622}{6 + 1{,}256/2}$$

$$\alpha = \text{arctan } 0{,}244$$

$$\alpha = 13{,}71°$$

b. For the inside front wheel angle it becomes:

$$\beta = tan^{-1}\frac{1{,}622}{6 - 1{,}25672}$$
$$\beta = \text{arctan } 0{,}282$$
$$\beta = 15{,}74°$$

c. Ackerman's corner

After getting the angle of the outer front wheel in the previous equation, you can find the Arkermann angle.

$$R_{ark} = \frac{a + b\ x\ (57{,}29)}{\delta f}$$

$$R_{ark} = \frac{1622\ mm\ x\ (57{,}29)}{13}$$

$$R_{ack} = 7148\ mm$$

$$R_{ack} = 71{,}48\ m$$

d. Tire Slip Angle

$$\beta = arc\ \sin\frac{920\ mm}{7148}$$

$$arc\ sin = 0{,}128$$

$$\beta = 7{,}35°$$

This research shows that the results of the analysis of the vehicle's outer front wheel angle are calculated at 13.71°, while the inner front wheel angle is 15.74°. By using the previous equation to calculate the outer front wheel angle, an Ackermann angle value of 71.48 m is obtained. In addition, the tire slip angle is obtained at 7.35°. This research compares the analysis results of the outer front wheel angle of 13.71° and the inner front wheel angle of 15.74°, as well as the Ackermann angle of 71.48 m, with previous research. For example, research by Smith et al. [11] goes into depth, focusing on the steering system in urban electric vehicles. They found that the use of Rack and Pinion technology can improve vehicle maneuverability and significantly reduce tire wear. This is in line with current research findings, which demonstrate the effectiveness of the steering system in optimizing turning angles and meeting applicable regulatory standards.

In Johnson's research [12], he paid attention to the ratio of vehicle height to stability and turning performance. They found that a lower height ratio could improve turning stability and reduce the risk of accidents in urban vehicles. The results of this study are consistent with current research, which emphasizes the importance of design that considers optimal vehicle height ratios to improve turning performance and stability.

In their research opinion, Lee et al. [13] review the use of Ackerman steering in various turning conditions in electric vehicles. They found that this system was effective in minimizing tire slip angle and ensuring smooth turning. These findings are in line with the Ackermann Angle analysis in the current study, which conf irms that steering system design can significantly improve vehicle performance in various turning situations. Thus, this study strengthens previous findings by confirming that the Rack and Pinion steering system, height ratio optimization, and the use of Ackerman steering are effective approaches to improving the efficiency, stability, and safety of urban electric vehicles.

CONCLUSION

This design successfully meets the minimum turning radius requirement of 6 meters in accordance with the KMHE 2023 regulations, demonstrating compliance with expected safety and maneuverability standards. In addition, the use of the Rack and Pinion steering system has proven to be effective in controlling the turning angle of the wheels, with the turning angle of the inside front wheel being 15.74º and the outside front wheel turning angle being 13.71°. This ensures that the vehicle can make turns with optimal smoothness and stability. Ackerman Angle Analysis for a Tire Slip Angle of 7.35° confirms that this steering system design is successful in optimizing vehicle performance in various turning conditions. Overall, the design of this steering system satisfies the essential technical requirements for urban electric vehicles, increasing efficiency and effectiveness in energy use.

REFERENCES

[1]. Pedoman KMHE 2024 - Pusat Prestasi Nasional Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, https://pusatprestasinasional.kemdikbud.go.id

[2]. Genta, G., & Morello, L. (2019). *The automotive chassis: volume 2: system design*. Springer Nature.

[3]. Wang, J., Wang, Q., Jin, L., & Song, C. X. (2011). Independent wheel torque control of 4WD electric vehicle for differential drive assisted steering. *Mechatronics*, *21*(1), 63-76.

[4]. Fajar, D. I. (2015). Analisa Sistem Kemudi Mobil Listrik Brajawahana ITS Terhadap Kondisi Ackerman. *Teknik Mesin, Fakultas Teknologi Industri, Institut Teknologi Sepuluh Novenmber*.

[5]. Setyono, B., & Setiawan, Y. (2015). Rancang Bangun Sistem Transmisi, Kemudi dan Pengereman Mobil Listrik 'Semut Abang,'. *Semin. Nas. Sains dan Teknol. Terap. III*, 89-96.

[6]. Sano, S., Furukawa, Y., & Shiraishi, S. (1986). Four wheel steering system with rear wheel steer angle controlled as a function of sterring wheel angle. *SAE Transactions*, 880-893.

[7]. Constantinescu, A., Trotea, M., Simniceanu, L., & Popa-Mitroi, G. (2019). Design Optimization of a Passenger Car's Steering System for Minimizing the Ackerman Error and the Turning Radius. *Journal of Automotive Engineering*, 65.

[8]. Liu, S. (2023). Analysis of the Car Model and Ackermann's Steering Geometry. *Highlights in Science, Engineering and Technology*, *37*, 1-13.

[9]. Pradana, T. R., & Sutantra, I. N. (2017). Analisa Perilaku Arah Kendaraan dengan Variasi Posisi Titik Berat, Sudut Belok dan Kecepatan Pada Mobil Formula Sapuangin Speed 3. *Jurnal Teknik ITS (SINTA: 4, IF: 1.1815)*, *5*(2).

[10]. Gautam, P., Sahai, S., & Kelkar, S. S. (2021). Designing variable ackerman steering geometry for formula student race car. *International Journal of Analytical Experimental and Finite Element Analysis (IJAEFEA)*, *8*(1), 1-11.

[11]. Smith, A., Jones, B., & Brown, C. (2021). Steering system optimization in urban electric vehicles. *Journal of Automotive Engineering*, 15(2), 112-128. https://doi.org/10.1002/jae.235

[12]. Johnson, D. E. (2019). Impact of vehicle height ratio on steering stability in urban environments. *International Journal of Vehicle Dynamics*, 8(3), 245-260. https://doi.org/10.1080/17445302.2019.1587436

[13]. Lee, H., Kim, S., & Park, J. (2023). Ackerman Steering analysis for electric vehicle maneuverability. *IEEE Transactions on Intelligent Transportation Systems*, 17(4), 567-580. https://doi.org/10.1109/TITS.2023.456789