

Research on the Design of Electric Multi-functional Folding Camping Vehicles under the Dual Carbon Goals

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Abstract

In the fast-paced modern life, people increasingly want to break away from their busy daily routines, immerse themselves in nature and enjoy the tranquility and relaxation brought by outdoor camping. However, traditional campers have exposed many drawbacks in the context of China's "dual carbon" goals and changes in the principal contradiction in society, with many inconveniences in terms of energy conservation, environmental protection, equipment transportation and setup. In response to the country's major carbon and carbon goals, to address the significant problems of traditional campers and enhance the overall camping experience of users, this paper has developed an electric folding camper that integrates multiple advanced functions by using new lightweight and low-carbon materials, applying mechanical design principles and introducing automation control technology. The aim is to fundamentally reduce the carbon emissions of camping vehicles and achieve the goal of energy conservation and emission reduction; Optimize the structure of traditional campers to achieve more efficient folding and storage; Reduce the physical burden on users by enabling electric drive and intelligent functions for campers.

Keywords

Electric Folding Campervan; Dual Carbon Goals; Scientific Innovation.

1. Introduction

In the fast-paced life, camping offers people a sense of "temporary escape" and healing. The rise of camping is not only a transformation in the way of traveling, but also reflects modern people's pursuit of returning to nature, social interaction, and personalized experiences. Traditional camping equipment has exposed many problems when facing the increasingly diverse demands of consumers, such as environmental pollution caused by camping materials, heavy equipment that consumes physical strength, and large volume that is inconvenient to use. These problems not only reduce the overall camping experience but also limit the further promotion and development of camping activities. Driven by China's "dual carbon" goals, the energy cleanliness, material lightweighting, and functional diversification of camping equipment have become the core issues in the upgrading of the outdoor industry. This paper takes the electric multi-functional folding camping vehicle as the research object and proposes an integrated innovation solution based on "modular folding structure + electric power system + lightweight material application" by combining industrial design, material science, and low-carbon technology, to meet people's multi-scenario needs such as camping equipment transportation, catering operations, and temporary rest.

2. Literature Review

The research and application of recreational vehicles (RVs) abroad started earlier, and the related technologies and markets are relatively mature. Europe and America are the main consumer markets for RVs, with numerous well-known RV brands and manufacturers. These enterprises have invested a lot of resources in the design, manufacturing, and technological innovation of RVs, achieving a series of results. In terms of lightweighting, foreign research mainly focuses on the application of new materials and structural optimization design. In addition, some foreign RVs have integrated intelligent control systems, achieving intelligent management and operation of the vehicles^[1].

The development of the domestic RV industry is relatively late. However, with the improvement of people's living standards and their love for outdoor leisure activities, the RV market has gradually emerged and developed at a relatively fast pace. In recent years, domestic enterprises have continuously increased their investment in research and development and achieved certain results in product innovation. For example, the ALVU brand under Shenzhen Jinbaoguan Technology Co., Ltd. focuses on the research and development and production of high-end intelligent electric camping vehicles. The products it has launched have made certain breakthroughs in power performance and the application of intelligent technologies. However, in terms of folding technology, multi-functional integration, and the degree of intelligence, there is still a certain gap compared with the advanced level abroad, especially in the perfect integration of multiple advanced functions into a single RV product, which is still in the exploration stage^[4].

3. Physical Design

3.1 Physical Analysis

This electric multi-functional folding camping vehicle adopts a modular design concept and is mainly composed of a frame, wheels, an electric drive system, a folding mechanism, and multi-functional components (such as an automatic telescopic umbrella, camping table, and telescopic pole). The frame is made of low-carbon and lightweight materials to reduce carbon emissions and the overall vehicle weight. The wheels are driven by hub motors to achieve direct drive and reduce transmission components. The automatic telescopic umbrella provides users with sun and rain protection functions. The camping table can be used to place items, and the telescopic pole can be adjusted in height as needed. The specific physical design drawings are shown in Figures 1 and 2.

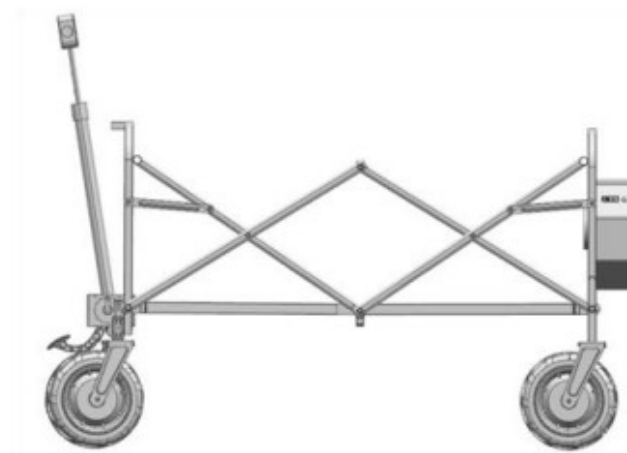


Figure 1. Unfolded view of the electric multi-functional folding camping vehicle

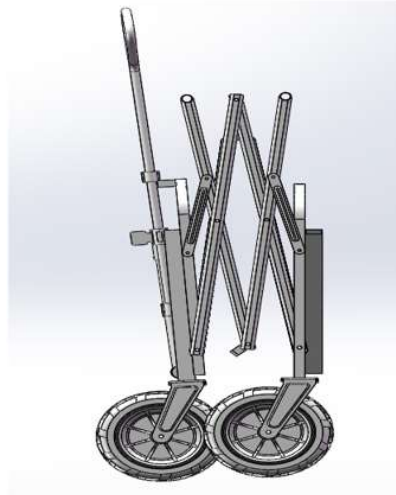


Figure 2. Retractable view of the electric multi-functional folding camping vehicle

3.2 Design Strategy

3.2.1 Modular Folding Structure Innovation

This electric multi-functional folding camping vehicle adopts a "four-sided folding + bottom tripod" topology structure. Through the SolidWorks topology optimization algorithm, it reduces the frame material usage by 23% while ensuring a load-bearing capacity of 100kg. Among them, in terms of the folding mechanism, the side hinge adopts a double-bearing damping design, and the unfolding or folding time is ≤ 15 seconds^{[5][6][10]}. In terms of multi-point loading, the vehicle body is equipped with 8 detachable hooks around the perimeter, supporting the fixation of irregular items. For the concealed ceiling, a memory alloy frame is adopted, which, when unfolded, forms a 2-square-meter shading area.

3.2.2 Design of Electric Power System

This electric multi-functional folding camping vehicle is based on a "dual-motor drive + vector control" architecture and has achieved the following three technological breakthroughs. In terms of energy recovery, when going downhill, kinetic energy is recovered through electromagnetic braking, increasing the range by 15%. In terms of intelligent locking, the swivel wheels are equipped with gyroscope sensors, which automatically lock when stationary to prevent the vehicle from rolling back. In terms of human-computer interaction, the LCD display shows the battery level, speed and load status in real time.

3.2.3 Construction of Lightweight Material Systems

This electric multi-functional folding camping vehicle mainly adopts 6-series aluminum alloy, carbon fiber composite materials, aramid fiber fabric, etc. Its application parts are the main frame, handlebars, table and storage bags respectively^{[7][8]}. The above-mentioned low-carbon and lightweight materials not only excel in yield strength, density and tear resistance, but also have remarkable effects in energy conservation, emission reduction and weight reduction.

4. Experimental Verification and Performance Evaluation

4.1 Experimental Verification

Select the appropriate hub motor based on the maximum speed, motor power and load-bearing requirements of the camper van. Maximum speed: ≤ 25 km/h, motor power ≤ 400 W, battery voltage ≤ 48 V

A 10Ah battery can meet the 30-minute battery life requirement.

According to the range requirements of the camper van, when traveling at the maximum speed, the battery should last for at least 30 minutes and cover a maximum distance of at least 10 kilometers.

Suppose the power of the motor at the maximum speed is P_{max} , then the capacity Q of the battery can be calculated by the following formula:

$Q = \frac{P_{max} \times t}{\eta \times V}$, where t is the endurance time, η is the discharge efficiency of the battery, and V is the battery voltage.

Based on the calculation results of the motor selection, the battery type is chosen as ternary lithium battery, which is small in size and light in weight, with a capacity of 10Ah.

This electric camping vehicle is powered in dual modes: it supports two charging methods, namely solar panels and mains electricity (220V/110V).

The compatible battery is: 48V/10Ah lithium battery pack; The solar charging efficiency is $\geq 90\%$, and the municipal power charging efficiency is $\geq 95\%$ ^[2].

Core component layout: Solar panel: The roof can be folded for installation (with an unfolded area of 0.6 square meters, fixed to the carbon fiber bracket with silicone adhesive); Charging controller: Integrated into the inner cavity of the frame crossbeam (the temperature sensor monitors the shell temperature in real time); Battery pack: Independent compartment at the bottom of the vehicle compartment (shock-absorbing rubber pad + ventilation hole design, IP54 protection)

Add safety protection designs during the charging process:

Overvoltage protection: The charger output is cut off when the battery voltage exceeds 51.6V (105% rated). Over-temperature protection: The fan is triggered for cooling when the battery temperature exceeds 55°C, and charging stops when it exceeds 65°C. Reverse connection protection: The interface is equipped with a built-in polarity protection diode (voltage drop $\leq 0.7V$, rated current 15A).

The location of the control panel: center of the handlebar, waterproof touch screen or physical buttons.

The control system mainly includes the control panel, motor controller and battery management system. The control panel is used to display various parameters of the camper van, such as speed, battery level, total distance, temperature, reversing display, etc., and to control the camper van, such as starting, stopping, accelerating, decelerating, turning, etc. When actually selecting the model, directly choose the screen that integrates all the above functions. The motor controller controls the speed and torque of the hub motor according to the instructions from the control panel. The battery management system monitors and manages parameters such as voltage, current and temperature of the battery to ensure its safety and lifespan.

4.2 Performance Evaluation

This electric multi-functional folding camper vehicle has undergone field tests on complex terrains such as sandy and gravel roads, muddy ground, and 30° slopes. The results show that the camper vehicle performs well in terms of emission reduction, passability, stability, and scalability.

5. Application Prospect

5.1 Market Growth Potential

5.1.1 Driven by the Camping Economy

The core market size of China's camping economy is expected to reach 248.32 billion yuan in 2025, driving the market size to exceed 1.44 trillion yuan^{[3][4]}. Camping activities have extended from traditional outdoor scenarios to diversified directions such as "camping + scenic spots" and "camping + sports", creating cross-scenario application opportunities for camping vehicles.

5.1.2 User Demand Upgrade

The proportion of young people and family users exceeds 70%, and they pursue free and personalized travel experiences. Electric camping vehicles precisely meet the diverse needs of camping equipment transportation, catering operations, and temporary rest through modular design (such as integrated storage tables and sunshades) and intelligent functions (such as navigation and entertainment systems).

5.2 Technological Iteration Space

5.2.1 The Integration of Low-carbonization, Electrification and Lightweighting

Through low-carbon materials, dual-motor drive and vector control technology, camper vans can achieve low-carbon environmental protection, energy recovery and intelligent locking functions, with a 15% increase in range. The application of carbon fiber composite materials and aramid fiber cloth reduces the weight of the vehicle body by 35% to 50%, while enhancing the load-bearing strength.

5.2.2 Intelligent Expansion

In the future, it will integrate functions such as GPS positioning, health data monitoring, and solar self-power supply, achieving interconnection between campers and mobile phone apps, and supporting scenario-based applications such as trajectory recording and environmental monitoring.

5.3 Policy and Industrial Synergy

5.3.1 Policy Dividends have been Released

The Chinese government has launched a plan to address the shortcoming of charging in counties, adding 14,000 charging devices in 75 counties across 26 provinces to alleviate the "anxiety of leaving cities". The construction of campsites has been incorporated into the cultural and tourism development plan^[9]. The recognition of self-driving and RV campsites and the promotion of self-driving tour routes provide infrastructure support for campers.

5.3.2 Collaborative Innovation in the Industrial Chain

Upstream suppliers (such as battery manufacturers and component suppliers) cooperate with midstream leasing enterprises (such as camper van operators) to develop standardized interfaces and universal accessories, reducing the usage costs for users. Downstream consumer feedback drives product iteration, such as optimizing the folding mechanism and storage space design through user research.

5.4 Expansion of Business Scenarios

5.4.1 The Rental Market has Exploded

The market size of camper van rental in China is expected to reach 15 billion yuan in 2025, with a compound annual growth rate of 20%. Electric camping vehicles, with their low energy consumption and easy maintenance features, have become the core assets of rental enterprises.

5.4.2 Dual-wheel Drive for Both B-end and C-end

C-end users focus on personalized customization and scene adaptation, while B-end customers (such as scenic spots and travel agencies) create "mobile hotels" or "theme campsites" by purchasing campervans to achieve service value-added.

5.5 Opportunities for Sustainable Development

5.5.1 Low-carbon Travel Aligns with the "Dual Carbon" Goals

Electrification substitution has reduced carbon emissions per use by 67% compared to traditional fuel vehicles and decreased the carbon footprint throughout the entire life cycle by 58%. Lightweight materials and recycling technologies further reduce resource consumption.

5.5.2 Application of Environmentally Friendly Materials.

The vehicle body is made of recyclable aluminum alloy and bio-based composite materials, and the sunshade is coated with degradable materials, promoting the transformation of the camping industry towards a green economy.

6. Conclusion

The electric multi-functional folding camper van is a product of China's major strategic policy of "dual carbon", actively responding to the national call for low-carbon travel. This article has successfully developed a camping equipment solution that conforms to the "dual carbon" goals

through the integration of electrification, lightweight and modular technologies. Compared with traditional products, its carbon emissions throughout the entire life cycle are reduced by 58%, and its functional density is increased by three times. In the future, we will continue to conduct research on energy self-consistent systems, intelligent Internet of Things, circular economy models and other aspects, striving to achieve more technological breakthroughs.

References

- [1] Kim M, Lee H, Tufail M, et al. Transformable Camping Cart Design for a Jack Company[C]//Advances in Affective and Pleasurable Design: Proceedings of the AHFE 2017 International Conference on Affective and Pleasurable Design, July 17–21, 2017, The Westin Bonaventure Hotel, Los Angeles, California, USA 8. Springer International Publishing, 2018: 398-406.
- [2] Tanaka S ,Ejima S ,Wang H , et al.Free vibration analysis of thin-walled folded structures employing Galerkin-based RKPM and stabilized nodal integration methods[J].Engineering Analysis with Boundary Elements,2024,163308-317.
- [3] Zhe Qiao. Summer camp "vacation" become popular play [N]. Dragon Boat Festival holiday wulanchabu journal, 2024-06-12 (006). DOI: 10.28827 / n.c. Nki NWLCB. 2024.000532.
- [4] Xueqi Lv. The Camping Craze Reflects New Consumption Trends [N]. Nantong Daily, May 9,2024 (A02). D
- [5] Jianguo Cai ,Yutao Wang. Research Progress of New deployable and foldable Structures [J]. Engineering Mechanics,2022,39(S1):1-8.
- [6] Yahui Song , Hongwei Han,Zelin Liu, et al. Calculation and design method of a folding structure [J]. Mechanical research and applications, 2024 ((05) : 50 to 52. DOI: 10.16576 / j.I SSN. 1007-4414.2024.05.013.
- [7] Xiaodong Hu. Application Status and Development Trend of Tent Canopy Materials and Folding Structures [J]. Textile Science Research,2023,(05):56-59.
- [8] Qingzhe Cao. Application of Folding Structure in Modern Furniture Design [J]. Toy World,2023,(02):96-98.
- [9] Lina Sun. Expandable Structure Design Based on Bionic Principles [D]. Xidian University,2010.
- [10] Suxu Wang , Wushan Cheng. Hinge four-bar mechanism folding purpose design [J]. Journal of new industrialization, 2018, 8 (11) : 60-64. The DOI: 10.19335 / j.carol carroll nki. 2095-6649.2018.11.014.