



Exploration of Innovative Modular Design for High-Speed Train Seats

Chenhui Wu^{1,*}, Jian Li¹, Siqun Ma², Huilin Yang¹ and Chenxiao Hu¹

¹School of Art, Dalian Jiaotong University, Dalian 116028, China

²School of Locomotive and Rolling Stock Engineering, Dalian Jiaotong University, Dalian, 116028, China

*141021168@qq.com

Abstract. With the continuous pursuit of travel efficiency and comfort, high-speed trains play an increasingly important role in people's lives as a fast, safe, and environmentally friendly mode of transportation. As the most direct point of contact for passengers on high-speed trains, seats are particularly important for passenger comfort and experience. Therefore, high-speed train seats are also one of the key focuses in the development of high-speed trains. With the continuous advancement of technology and diversification of market demands, high-speed train seats will evolve towards modularization and intelligence to achieve flexible configuration and intelligent adjustment, thereby improving seat design efficiency and user experience. This paper comprehensively summarizes the current status of research on innovative modular design for high-speed train seats, providing reference and guidance for further research and development in this area to better promote the development of high-speed train seats.

Keywords: High-Speed Train; Seats; Modular Design.

1 Introduction

As technology continues to advance and people's pursuit of quality of life improves, their demands for travel efficiency and comfort are also increasing^[1]. The seat, as one of the most important components in high-speed trains, directly affects passengers' travel experience and comfort.

Therefore, the design of high-speed train seats not only needs to meet the comfort requirements of high-speed trains, but also needs to consider people's needs for beauty, safety, and efficiency from multiple perspectives. At present, the seat configuration scheme of China's high-speed trains will be designed accordingly according to different train models and grades. The seat configuration usually takes into account the comfort and safety of passengers while considering operational efficiency and cost control. Generally, different seat options such as first-class seats, business seats, and economy seats are provided. First-class seats are usually configured in the front of the train, providing more spacious and comfortable seats and personalized services; business seats provide comfortable seats and relatively private spaces; economy seats are the most basic and

© The Author(s) 2024

Z. Chen et al. (eds.), *Proceedings of the 2024 International Conference on Humanities, Arts, and Cultural Industry Development (HACID 2024)*, Advances in Social Science, Education and Humanities Research 861,

https://doi.org/10.2991/978-2-38476-281-1_27

economical option. However, due to the limited types of seats in China's high-speed trains, it is difficult to meet market demand. Therefore, flexible configuration and intelligent adjustment of seats will be one of the important trends in the development of high-speed train seats in the future.

2 Modular Design Concept and High-Speed Train Seat Design

2.1 Overview of Modular Design

Modular design is a design method that uses the principle of modularity to design products, in which the product is divided into a series of modules according to certain technical rules, then these modules are rearranged and reconfigured, and finally a product design with specific functions is formed. The core idea of modular design is to divide, combine, and reconfigure product modules to obtain the various functions and structures required for the product. Modular design mainly consists of three parts: module division, module structure, and module interface. Module division is achieved by decomposing and rearranging the product to obtain modules with different functions. Module structure is the combination of product modules to obtain different functional modules. Module interface is the combination of functional modules with different functions to meet the needs of different users^[2].

Through modular design, the design can be more flexibly innovated by combining different module units to achieve diverse seating designs. Modular design can independently design and adjust the seat's functions, structure, and materials to better meet the user's individual needs, bringing many advantages in the production, maintenance, and replacement of the seat. It is an important design concept worth exploring and applying in the field of high-speed train seat design.

2.2 Modular Design of High-Speed Train Seats

Modular design refers to the design method of combining modules with similar functions in the product and system to form a design with strong adaptability and scalability. The high-speed train seat adopts the modular design concept, dividing the seat function modules into independent parts, and realizing the flexible arrangement of the seat through the relationship and combination of the modules, to meet the needs of passengers.

Compared with traditional seat design, modular design of high-speed train seats has the following advantages:

Improve seat configuration efficiency: Modular design can optimize the complex seat functions and achieve quick adjustment of seat configuration under different needs.

Reduce costs: Modular design can reduce the focus on product details, and modular design has reusability, reducing the need for redesign and manufacturing, which can effectively improve design efficiency and reduce manufacturing costs.

Meet individualized needs: By flexibly configuring the functional modules of the seat to meet the different physical characteristics, preferences, and needs of passengers, it can better improve comfort and meet the needs of passengers. It can also leverage

intelligent technology to achieve higher levels of seat adjustability and personalized needs.

Improve scalability: Modular design can easily add new modules to existing designs, with extremely high scalability, which will better meet customer needs.

Improve production efficiency: By integrating and optimizing the functional modules of the high-speed train seat in the design stage and decomposing the product into independent modules that can be produced separately, the production efficiency and speed of the product can be improved.

Applying the modular design concept in the design of high-speed train seats brings higher flexibility and customizability to the seat design, improves the comfort of the seat, optimizes the functionality and suitability of the seat, and reduces the maintenance cost and update cycle of high-speed train seats. Through the flexible combination of different modules, passengers can customize their own seats according to their needs and preferences, thus obtaining a more comfortable and personalized travel experience.

At present, China is still in the initial stage of modular innovation design for high-speed train seats. With the continuous development and progress of China's high-speed rail industry and the continuous improvement of people's living standards and travel needs, there will be more and more high-speed train products in China that adopt the modular design concept in the future.

2.3 High-speed Train Seat Function Modules

From the perspective of seat functions, there are four main function modules:

1. **Seat body:** The seat body is the most basic functional module of high-speed train seats, and passengers can adjust the height and backrest angle of the seat to meet their needs for comfort in different sitting positions.

2. **Armrest:** The armrest is a part of the seat that is often in contact with passengers. Passengers can support their head and hands in the most comfortable position by adjusting the height and length of the armrest.

3. **Information and entertainment system:** The information and entertainment system mainly includes screens, speakers, and Bluetooth devices, providing passengers with rich information services and entertainment functions.

4. **Sleep System:** The sleep system mainly consists of the seat cushion and backrest, which is the part that passengers come into contact with most frequently and determines the level of comfort during their journey.

3 Enhancing Comfort in High-Speed Train Seats: Key Technologies

3.1 Comfort Demand Analysis

Comfort is one of the most important influencing factors in the design of high-speed train seats. Long-time riding can cause significant pressure on the human body. Scientific and reasonable seat design should be able to alleviate riding fatigue and enhance riding comfort. The comfort of seats is mainly reflected in the following aspects:

(1) **Seat Materials and Fillings:** The materials of high-speed train seats should have good elasticity and support to ensure the comfort of passengers when riding. The breathability of the materials is also a key factor in ensuring comfort^[3]. Materials with good breathability can reduce the discomfort of passengers during long rides.

(2) **Seat Support:** Support is one of the core considerations for the comfort of high-speed train seats and directly affects passengers' travel experience. First, the backrest should closely fit the natural curve of the human back and provide uniform support. For example, the backrests of some high-end train seats adopt a design that conforms to the physiological curvature of the human spine, which can effectively reduce back fatigue. For passengers of different body types, the degree of fit of the backrest may vary. Therefore, an adjustable backrest can better meet individualized needs. Second, the seat cushion needs to reasonably distribute the pressure borne by the buttocks and thighs to prevent excessive local pressure. For instance, using sponge materials with memory function can automatically adjust the pressure distribution according to the passenger's weight and sitting posture. The length and width of the seat cushion should also be appropriate to fully support the entire buttocks and thighs. The seat cushion should have a certain degree of elasticity to provide buffering effect and also have sufficient hardness to maintain support. If it is too hard, it will cause discomfort. If it is too soft, it is easy for people to sink in and affect blood circulation. Third, the height and angle of the armrest should be adjustable according to the needs of passengers to provide appropriate support for the arms during rest. For example, when reading or using electronic devices, the armrest can be adjusted to the appropriate position to reduce arm fatigue. Fourth, the position of the headrest should accurately support the head and avoid excessive forward or backward tilting of the neck. An adjustable headrest can better adapt to the sitting posture and rest needs of different passengers. The headrest should have moderate softness to provide a comfortable touch while maintaining a certain degree of support.

(3) **Seat Adjustment Function:** Passengers can adjust the inclination of the seat according to their preferences and rest needs to find the most comfortable posture. During long-distance travel, being able to adjust the seat to a nearly flat state greatly improves comfort. Adjustable seats can provide good support for passengers of different heights and reduce leg fatigue.

3.2 Seat Material Selection

The comfort of high-speed train seats largely depends on the materials used. The selection of materials for high-speed train seats should consider factors such as passenger comfort, replaceability, and environmental friendliness to ensure the overall performance of the seats.^[4]

Materials for high-speed train seats should have good elasticity and support to ensure passenger comfort during travel. Breathability is also a key factor in ensuring comfort, as materials with good breathability can reduce discomfort for passengers during long journeys.

Additionally, material selection should consider the replaceability and ease of maintenance characteristics. By decomposing high-speed train seats into multiple independent modules through modular design, it becomes easier to manufacture, maintain, and replace them using materials that are easily replaceable and maintainable—greatly enhancing seat durability while reducing maintenance costs. Environmental sustainability is another important consideration in material selection for high-speed train seats. Choosing sustainable materials such as recyclable or biodegradable ones helps reduce resource consumption and environmental impact—aligning with green design objectives.

3.3 Human Factors Engineering Design

Innovative design of high-speed train seats incorporates human factors engineering—a crucial research area focused on determining passengers' body structure, posture, and movement characteristics when seated on high-speed trains from an ergonomic perspective. This approach aims to design seats that meet ergonomic standards to enhance passenger comfort during extended periods of travel. In modular seat design, seat shape and curvature must align with physiological characteristics while providing proper support for passengers' spine, neck, and buttocks positions^[5]. Seat cushions and backrests should conform to body curves to alleviate pressure points caused by prolonged sitting discomfort effectively. Furthermore, considering passengers' activity space and convenience on the bullet train is essential; therefore adjusting seat functions needs to be simple yet effective so that passengers can adjust height angles or positions according to their preferences easily—ensuring optimal seating experience. Additionally, seat material texture must meet requirements for comfort and ventilation—preventing excessive sweating or bodily discomfort due to seating material during high-speed rail travel.

3.4 Modular Seat Safety Considerations

Enhancing safety while optimizing user experience is an indispensable aspect of designing high-speed train seats. Advanced material technology plays a critical role in ensuring sufficient load-bearing capacity along with impact resistance capabilities within the seat's construction. Intelligent safety systems integrated into seat designs include emergency braking devices coupled with sensors sensitive enough even airbags

designed specifically against collisions—all working together towards improving protective performance during accidents^[6]. Optimizing seat structures by minimizing sharp edges reduces potential injury risks among passengers—an essential element alongside considerations about user experience—to guarantee comfortable seating experiences within safe environments aboard fast-moving trains. These advancements underscore how technological innovation combined with thoughtful engineering considerations significantly contribute toward creating safer yet more comfortable traveling experiences onboard modern-day bullet trains across various terrains worldwide!

4 Conclusion

The research on the modular design of high-speed train seats is a relatively complex system engineering, the current research results are not comprehensive and in-depth, and there are still many problems and deficiencies in practical application. The "Technical Platform Guide for Modular Design Products of High-speed Trains" (T/CCTAS 87-2023) group standard issued by the China Association of Communications and Transportation has been implemented since December 31, 2023, which indicates that the modular design of high-speed trains in China is developing towards standardization and standardization. In the future, the design of high-speed train seats will pay more attention to ergonomics and personalized customization, while improving the ride experience and comfort, according to the needs and preferences of different passengers to customize the seat function and appearance, to bring passengers a more comfortable travel experience.

References

1. Lü Wanshu. Research on Optimization Design of High-speed Railway Passenger Seats [D]. Shenyang Aerospace University, 2014.
2. Xu Xiaoyun, Xie Qiurui. Research on Product Design Based on Modular Design Principle [J]. Art View, 2017, (09):120-12.
3. Jiang Xingyue. Research on Green Modular Design Method of Automobile Seats [D]. Inner Mongolia University of Technology, 2019.
4. Fu Zedidi. Research on the Design of High-speed Train Business Seat Based on Ergonomics [D]. Changchun University of Technology, 2022.
5. Singh P., Raina S., Pandey K., Bansal S. Effect of Fabric Type and Construction on Automotive Seating Comfort [J]. SAE Technical Paper 2013-01-0654, 2013
6. Laurent V, Then C, Silber G. Human modeling and CAE based subjective seat comfort score correlation [J]. SAE Int J Commer Veh 2014;7(1):295-304.

Open Access This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

