Proceedings of Urban Intelligence: Machine Learning in Smart City Solutions - CONFSEML 2024
DOI: 10.54254/2755-2721/65/20240491

The analysis of the optimization direction of conventional mechanical bicycle

Can Jin

Union College, Schenectady, New York, United States, 12308

jinc@union.edu

Abstract. With the rise of environmental awareness and the intensification of urban transportation problems, bicycles have regained attention as a green and efficient way of traveling. This thesis explores and analyzes the direction of optimizing the conventional mechanical bicycle in modern society. Using a summary review approach, the thesis focuses on the optimization potential of bicycles in terms of integrating frame design and ergonomics, personalized design, enhancing cycling efficiency, and refining products. Among other things, this thesis emphasizes the importance of frame shape design, dimensional adaptation, postural optimization, dynamic adaptation, lightweight design, aerodynamic efficiency enhancement, and product development for specific market segments. In addition, this thesis discusses the use of technology integration such as built-in Global Positioning System tracking, electronic displays, and other high-tech elements in bicycle design. Through this analysis, this paper finds that there is still a lot that can be changed in today's bicycles and that the market for bicycle sales will expand even further.

Keywords: Mechanical bicycle, Optimization strategy, Environmentally Friendly mobility

1. Introduction

In modern society, a bicycle is not only a means of transportation, but also a symbol of health and leisure lifestyle. With the enhancement of environmental protection awareness and the increasingly serious problem of urban traffic congestion, bicycle as a green and efficient way of traveling has once again attracted widespread attention. However, with the diversification of user needs and the rapid development of technology, traditional mechanical bicycles are facing unprecedented challenges and opportunities.

In this context, it is particularly important to optimize the design and function of traditional mechanical bicycles. This involves not only the comprehensive application of material science, mechanics, and ergonomics, but also the accurate grasp of market trends and the prediction of future travel needs. Effective optimization can not only enhance the riding experience and reduce energy consumption, but also provide strong support for the sustainable development of the bicycle industry [1].

This paper aims to analyze and discuss the direction of optimization of conventional mechanical bicycles in modern society, focusing on frame design, material application, ergonomic integration, and adaptability to specific market segments. Through comprehensive analysis, this thesis aims to propose a series of practical optimization strategies, to ensure the performance of bicycles while improving their

DOI: 10.54254/2755-2721/65/20240491

environmental friendliness and user experience, thus promoting the progress of the whole bicycle industry.

2. Directions for optimizing conventional mechanical bicycles

2.1. Frame shape and geometry

2.1.1. Application of ergonomics. The use of ergonomics in bicycle frame design is critical, to scientifically reduce rider fatigue and muscle damage while enhancing riding comfort and safety. The core of this field includes size adaptation, postural optimization and dynamic adaptation. Size adaptation refers to the customization of frame sizes according to different riders' body dimensions (e.g. height, arm span, leg length) and is the basis for ergonomic applications. A suitable frame size not only minimizes riding discomfort but also successfully guards against long-term riding-related physical ailments. For instance, motorcyclists may assume abnormal riding postures due to frames that are excessively big or tiny, which puts more strain on their muscles and joints [2].

Additionally, ergonomics highlights the connection between riding posture and frame design. The frame's angles and curves should be in line with how the human body naturally positions itself when riding, to minimize needless physical strain. Designers can modify the angle and curve of the frame to lessen pressure points during riding and avoid muscle fatigue and injury by researching the impact of various riding postures on various body regions.

Frame design must consider the dynamic changes in body components that occur during riding. This means that the way body parts interact with the frame during cycle dynamics is just as crucial to consider when constructing a frame as anthropometric data under static conditions. For instance, it's important to take into account the frequency and amplitude of the rider's pedal movements to make sure the frame construction has enough flexibility and support to minimize vibration and friction when cycling, which lowers fatigue and the chance of injury. The human flexibility of the bicycle frame and riding comfort can be significantly increased by making extensive use of these ergonomic concepts, giving the rider a safer and healthier riding experience.

2.1.2. Personalized design. The optimization of frames for conventional mechanical bicycles has made individualized riding quite popular. The market's varied demands for bicycle functionality and design are reflected in this trend. Personalized design accurately addresses a range of utilitarian needs in addition to being an artistic innovation in frame look [3].

The term "aesthetic diversification" describes how modern consumers' heightened standards for bicycle aesthetics are driving frame design variation. Various design styles, ranging from retro to modern, cater to the specific needs of various types of bikers. Apart from hues and designs, the contours and angles of the frame also turn into crucial components for conveying uniqueness. Bicycle makers are able to appeal to a broader spectrum of consumers by personalizing the distinctive appearance design, particularly young and stylish users [4].

On the other side, functional customization describes how a frame's unique design is mirrored in its functionality as well as its appearance. Different user groups-such as professional racers, urban commuters, and recreational cycling enthusiasts-have different functional requirements for bicycles. Therefore, frame design needs to be optimized for these different needs. For example, for racing bicycles, frame design emphasizes lightweight and high strength, while for urban commuters, frame design focuses more on comfort and durability [5].

Technology integration can also be applied. With the advancement of technology,

personalized design has begun to integrate more high-tech elements. For example, the addition of intelligent elements such as built-in Global Positioning System tracking and electronic displays not only improves the convenience of riding, but also increases the attractiveness of the bike. In addition, for riders with special needs, such as those with special physical conditions, frame design can integrate

DOI: 10.54254/2755-2721/65/20240491

more auxiliary functions, such as adjusting seat support or special handlebar design, to provide a better riding experience.

In summary, personalized design plays a crucial role in the optimization of bicycle frames. It not only meets the growing diversified demands in the market, but promotes the innovation and development of bicycle design. By continuously exploring and implementing personalized design, bicycle manufacturers can better serve different user groups while driving the whole industry forward [6].

2.2. Increase in riding efficiency

2.2.1. Lightweight. Lightweighting is one of the most important directions to improve the riding efficiency of traditional mechanical bicycles. By reducing the total weight of a bicycle, it not only improves acceleration performance and climbing efficiency, but also reduces rider fatigue and makes long-distance riding easier. In the bicycle industry, lightweight is mainly achieved through the use of advanced materials and improved manufacturing processes.

Because of its superior strength-to-weight ratio, carbon fiber is the perfect material for bicycles that are lightweight. In addition to being lightweight, carbon fiber offers a high strength and stiffness to endure the strain of intense riding. When designing high-performance bicycles, it has been usual practice to incorporate a lot of carbon fiber in important parts like the handlebars, rims, and bicycle frames. The application of this material is gradually being extended to recreational and commuting bicycles in addition to race-class bicycles. Bicycle manufacturing procedures are changing in tandem with technological advancements. For instance, lighter and more precise bicycle components can be produced through the use of 3D printing and precision casting technologies. By using these technologies, bicycle weight is decreased while maintaining increased customization and design freedom. The bicycle industry also makes use of the modular design concept, which makes it easy to upgrade or repair specific parts of a bike while keeping the bike's overall weight low [7].

Achieving lightweight also requires optimizing frame and component designs in addition to materials and production techniques. In order to optimize the structure and use less material while maintaining the necessary strength and stiffness, designers can precisely simulate a bicycle's performance under various conditions using Finite Element Analysis (FEA) and Computational Computer-Aided Design (CAD). By using this method, designers can obtain the highest possible level of frame and component lightweight by removing unnecessary materials. In keeping with the sustainability idea, lightweight not only enhances the bike's performance and the rider's pleasure, but it also has a smaller environmental impact. Lightweight design and manufacture will continue to be crucial to the development of new materials and production methods in bicycles.

2.2.2. More aerodynamic. Another important area in bicycle design to focus on to greatly increase riding efficiency is aerodynamic efficiency. When riding a bicycle with increased aerodynamics, air resistance is effectively decreased, allowing for higher speeds and less energy consumption. An essential part of this process is wind tunnel testing, which is a useful tool for assessing and improving the aerodynamic performance of bicycles and their riders.

Wind tunnel testing simulates the airflow of a bicycle at various speeds and angles, giving designers precise data and feedback. Understanding and improving the aerodynamic behavior of bicycles and riders in everyday riding situations requires knowledge of this information. Using this information, designers can modify the frame, wheels, handlebars, and other parts of the bike to cut down on air resistance and increase overall aerodynamic efficiency. Particularly when designing bicycles for competition, wind tunnel testing is crucial. Race bicycles are superior because they can maintain the lowest aerodynamic resistance during high-speed riding thanks to rigorous aerodynamic analysis and adjustments [8]. Wind tunnel testing is not just used for expensive race bikes, though. Wind tunnel testing is being used by an increasing number of recreational and daily-use bicycles to optimize their design as the technology becomes more widely available and more affordable.

DOI: 10.54254/2755-2721/65/20240491

Wind tunnel testing is used to assess and improve riders' gear, including clothes and helmets, in addition to the frame itself. A rider's air resistance can be greatly reduced by wearing tights and helmets that fit properly, which can increase riding efficiency. This all-encompassing aerodynamic optimization not only improves the performance of the bike, but also enhances the comfort and experience of the rider. All in all, the application of wind tunnel testing in the bicycle industry marks the development of bicycle design in a more high-tech and specialized direction. It not only improves the race performance of high-performance bicycles, but also provides a more efficient and comfortable riding experience for everyday riding. With the further development of the technology and the popularization of the application, the continuous innovation and change of bicycles in aerodynamic design can be expected in the future [9].

2.2.3. Reduction in kinetic energy loss. Reducing kinetic energy loss is a key component in improving bicycle riding efficiency. Optimizing the use of kinetic energy in bicycle design not only increases cycling speed, but also reduces the energy expenditure of the cyclist. This goal is mainly achieved by selecting suitable materials and optimizing the geometric design of the bicycle.

A. Materials. In bicycle manufacturing, the selection of materials with a high modulus of elasticity can significantly reduce kinetic energy loss. These materials, which include composites and sophisticated alloys, offer good energy absorption and release characteristics that lessen dissipation of energy during riding. For instance, lightweight frames and components that efficiently transfer the rider's pedal power can be made by utilizing carbon fiber and specific high-strength alloys.

Reducing the loss of kinetic energy also involves the use of materials that absorb stress. These materials lessen the energy lost on inefficient riding techniques by absorbing vibrations from the road surface. For instance, handlebar grips, shock-absorbing forks, and flexible saddle materials all improve riding's energy efficiency [10].

B. Geometric design. Bicycle frames with streamlined designs have an impact on kinetic energy utilization in addition to aerodynamic efficiency. Kinetic energy loss can be minimized by minimizing air resistance and friction through the optimization of the frame and its constituent parts. In order to use kinetic energy more efficiently, for instance, smoother frame surfaces, optimized wheel profiles, and smaller overall design are all beneficial.

Riding dynamics must also be considered in the geometric design. This entails modifying the handlebar height, seat position, and wheel spacing to guarantee that the user can transfer power effectively while riding. Geometry design plays a crucial role in guaranteeing that riders are in the correct posture to minimize kinetic energy loss.

The bike can make better use of the power generated by each pedal stroke by combining fine geometry design with high-efficiency materials, which lowers inefficient energy use. This raises the comfort and enjoyment of riding the bike in addition to improving its overall performance. We may anticipate greater advancements in bicycle design and innovation to minimize kinetic energy loss as material science and design technologies continue to progress.

2.3. Refinement products

2.3.1. Women's market for bicycle. Product refinement in the bicycle business for the women's market exemplifies the sector's recognition and adaptation to the varied needs of its users. Female bikers necessitate bicycles that are specifically tailored to accommodate their distinctive body structure, distribution of strength, and riding preferences. The meticulous product development is evident in both the bike's functioning and its attractive design.

Bicycles developed specifically for women incorporate customized frame geometry, saddle shape, and handlebar layout. These designs frequently consider the physical attributes of female riders, such as shorter torso lengths and particular pelvic structures, in order to offer a riding experience that is both more pleasant and efficient. Women's bicycles often include shorter top tube lengths and lower crossbars,

DOI: 10.54254/2755-2721/65/20240491

facilitating simpler boarding and disembarking. Additionally, these bicycles may have saddle designs that are specifically tailored to accommodate women's body proportions [11].

Women's bicycles are specifically built to be lightweight while still maintaining sufficient strength, taking into account the smaller weight and differing strength distribution of female riders. The bike's lightweight construction enhances maneuverability and minimizes the rider's physical effort.

Regarding the outer design, women's bicycles typically exhibit a greater number of attractive components and personalized characteristics. This encompasses the utilization of vibrant hues, refined contours, and distinctive motifs to fulfil the aesthetic requirements of women who engage in cycling. Simultaneously, these bicycles are crafted with practicality as a priority, incorporating features like baskets for convenient storage of personal items and ergonomically shaped handlebars to cater to the practical requirements of women throughout their everyday commutes and leisurely rides.

With the growing population of female bikers, bike manufacturers are now diversifying their market by offering specialized bikes designed specifically for women, tailored to various forms of riding such as urban commuting, off-road adventures, and leisurely cycling. This segmentation is not only based on functional considerations, but also on understanding and respecting the diverse needs of female consumers.

In summary, the segmentation of the female market for bicycles reflects the industry's emphasis on inclusiveness and diversified needs to provide female riders with a more comfortable, safe, and personalized riding experience through specialized design and innovation [12].

2.3.2. Prospects for the development of electrically assisted bicycles. Electrically assisted bicycles, also known as e-bikes, have gained significant growth and popularity in the global market in recent years. These bicycles integrate the agility of a conventional bicycle with the electric propulsion of an e-bike, offering riders an effective, convenient, and eco-friendly mode of transportation. The significant progress and growing popularity of electrically assisted bicycles can be attributed mostly to the advancements and emerging trends outlined in reference [13].

Initially, due to the progress in battery technology, the distance that electric-assisted bicycles can go has been substantially enhanced. Contemporary lithium batteries provide both a low weight and a substantial energy density, enabling them to sustain power for bicycles over extended periods. As a result, electrically assisted bicycles are gaining popularity among individuals who travel long distances and those who pedal for enjoyment.

Furthermore, the surge in environmental consciousness has significantly contributed to the increasing popularity of electric-assisted bicycles. With the growing awareness of sustainable transportation options, a growing number of individuals are opting for electric-assisted bicycles as an eco-friendly means of travel. Electric-assisted bicycles, particularly in urban areas, diminish reliance on fossil fuels and aid in mitigating traffic congestion and air pollution [14].

Furthermore, electrically assisted bicycles have notable benefits in terms of enhancing the convenience and enjoyment of cycling. Electrically assisted bicycles offer supplementary power assistance to facilitate cycling for individuals who encounter steep inclines or desire to alleviate the exertion of trip. This not only appeals to amateur leisure bikers, but also offers additional cycling options for the elderly and individuals with low physical endurance [15].

The diversity of electrically assisted bicycles has been propelled by technological progress and the increasing market demand. Currently, there is a wide variety of electrically assisted bicycles available for purchase, catering to various user demographics such as urban commuters, mountain bikers, and individuals seeking folding bicycles. Due to the ongoing technological advancements and increasing consumer consciousness, electrically assisted bicycles have gained significant popularity. Overall, the development prospect of electrically assisted bicycles is very optimistic. They not only provide an environmentally friendly and efficient way to travel, but also continue to improve the user experience through technological innovation, becoming an important part of modern travel culture. As the global demand for sustainable transportation solutions increases, electrically assisted bicycles will continue to occupy a significant position in the market and continue to drive innovation in transportation.

DOI: 10.54254/2755-2721/65/20240491

3. Conclusion

This thesis summarizes and discusses the optimizations that can be made to the bicycle in terms of design, geometry, and sales market. Overall, bicycles have huge room for improvement in the future, and the sales market of bicycles will be further expanded, and future bicycles will be safer, lighter, and faster. In addition, this thesis has not discussed the role of bicycles in saving energy reducing carbon, and protecting the planet. This paper predicts that the direction of the global ambition to reduce carbon emissions will bring great changes and reforms to the bicycle sales market.

References

[1] XinWei Dou. Analysis of the application of ergonomics in machinery manufacturing design[J]. Hubei Agricultural Mechanization, 2019(14):1.

[2] XiaoFan Wu. Research and Application of Bicycle Design Methods Based on Ergonomics [D].Tianjin University,2008.DOI:10.7666/d.y1530398.

[3] SongZan Li. Application of ergonomics in bicycle design[J]. China Bicycle, 2000(10):2.DOI:CNKI:SUN:GZXC.0.2000-10-016.

[4] YuanCang Xu, YingMei Yuan. Ergonomic analysis and design of bicycle transmission[J]. Journal of Shaanxi University of Science and Technology: Natural Science Edition, 1993(1):7.DOI:CNKI:SUN:XBQG.0.1993-01-008.

[5] Lei Zhang, LiFang Yan, YangMing Liu. Research on ergonomics analysis and measurement method of bicycle saddle design[J]. Packaging Engineering, 2012, 33(6):4.DOI:CNKI:SUN:BZGC.0.2012-06-033.

[6] HaoRan Li. Research on the Application of Ergonomics in Folding Bicycle Design [D]. Sichuan Normal University [2023-11-27].DOI:CNKI:CDMD:2.1016.096255.

[7] ZhengJiang Zhang. Research on the application of innovative design in modern packaging machinery[J]. Digital Design, 2019, 000(009):266-267.

[8] Wei Zhang. Exploration of the use of automation technology in mechanical design[J]. Engineering Technology: Digest Edition.00019-00019[2023-11-27].

[9] YiZhen Peng, LianLin Peng. A method for improving the efficiency of a bicycle drive:CN202111624791.1[P].CN202111624791.1[2023-11-27].

[10] DongHua Wu. Application of ergonomics in cycling--Effects of ergonomic adjustment of cycling saddle and handlebar on optimizing cycling actions[J]. Journal of Nanjing Institute of Physical Education:Natural Science Edition, 2013(1):5.DOI:CNKI:SUN:NTXZ.0.2013-01-006.

[11] Jin Dong. Research on Marketing Strategy of Private Bicycle Enterprises--Taking Tianjin Fujitec Bicycle Co. Tianjin University [2023-11-27].

[12] XiaoJun Nie, LiZhong Wen, ZhiXing Wu. Analysis of Electric Bicycle Market in Nanning[J]. Journal of Guangxi Normal University: Philosophy and Social Science Edition, 2010(S2):4.DOI:CNKI:SUN:SYXI.0.2010-S2-005.

[13] SuYa Tang. Development status of electric power assisted vehicle and its market prospect[J]. Micromotor, 1997, 30(4):3.DOI:CNKI:SUN:WDJZ.0.1997-04-007.

[14] AnGong Hunag. On the Development and Future of Intelligent Status of Electric Bicycle[J]. Chinese Science and Technology Journal Database Social Sciences:00009-00009[2023-11-27].

[15] Zi Mai. E-bike - the road ahead is winding and the market outlook is bright[J]. Modern Home Appliances2003(1):1.DOI:CNKI:SUN:XDJD.0.2003-01-027.