

# Development of the zinc-air power battery on electric bicycles in China

Zhu Mei<sup>1</sup>, Xu Xianzhi<sup>2</sup>, Song Hui<sup>2</sup>, Li Fen<sup>2</sup>

(1. School of Engineering, Anhui Agricultural University, Hefei 230036, China;  
2. Department of Mechanics and Mechanical Engineering, University of Science and Technology of China, Hefei 230027, China)

---

**Abstract:** Electric bicycles powered by lead-acid batteries have developed very fast for several years in China. Because the inconvenience caused by the service performance and the inconsistency to the environmental protection policy of the lead-acid battery, the zinc-air power battery was proposed to solve the problem in this paper. The advantage and the feasibility of developing zinc-air power batteries in China have been illustrated in the paper. And, it is represented that development of electric bicycles powered by the zinc-air power battery also can accelerate this kind of battery's development in other electric vehicles, which is favorable to economic development and environmental protection.

**Key words:** zinc-air battery; electric bicycles; energy policy; China

## 1 Introduction

### 1.1 Development of electric bicycles in China

Electric bicycles have greatly developed since 1990s in China. In 2005, the output of whole electric bicycles exceeded 9 000 000, and 2 000 000 ~ 3 000 000 were exported, up from several thousand in 1998<sup>[1]</sup>. This growth is expected to continue for years to come, pending any heavy regulation. In most cities, electric bicycles have been the main vehicles replacing regular bicycles and motorcycles. Though the development of electric bicycles have met many difficulties, especially in individual cities it is limited on road, it also have good developing trend. The basic reason is it meets the necessity of consumers. Survey data from three major cities in China indicate that today's bicycle users (450 million) will most likely purchase an electric bicycle as their next mode of transport<sup>[2]</sup>. So, for the low and middle classes of China, electric bicycles are thought as faster, more comfortable transportation options and are popular.

### 1.2 Electric bicycles powered by lead-acid battery

For electric bicycles, battery is one of the core parts. It also can constrain the development of electric bicycles. Now, lead-acid battery is the main power source of electric bicycles, especially in Chinese market<sup>[3]</sup>. As the development of electric bicycles, the shortcomings of the lead-acid battery are more and more notable. Firstly, the road haul of the bicycles powered by lead-acid batteries is short which widely

limit consumers' radius of action. At some times, consumers worry about there is no enough capacity of batteries supplying power for long time riding. Though colloidal lead-acid battery and new kind of lead-acid battery with higher capacity (48 V, 20 A · h) have been applied, they can not thoroughly solve the problem of the short road haul. Secondly, many consumers complained inconvenience of using electric bicycles powered by lead-acid batteries. Some consumers need to take so heavy battery up and down for charge every day. They have to bear heavy work on using the lead-acid battery. Thirdly, metal lead pollution is more and more serious as the application of the lead-acid battery. Many used batteries have not been properly treated because of lacking of perfect recovery law and maximizing profit for some battery merchants. The smelting and recovery of the lead are also have environmental pollution, which is unfavorable to long-term development. Though advances in lead-acid battery technology over the past decade have made electric bicycles affordable, efficient, and practical, most consumers are also keen to purchase new kind of electric bicycle powered by batteries with more excellent performance<sup>[2]</sup>.

### 1.3 Environmental protection policy of China

In the paper<sup>[4]</sup>, we can see China is getting serious about improving its environmental landscape. The paper illustrated the change of development policy of China. Now, China pays much attention to concordance of economic development and environmental pro-

---

Received 27 January 2008

tection which is agreeable to build “harmonious society” proposed by President Hu and Prime Minister Wen. Our leaders have realized the past energy policy had caused environmental landscape which is unfavorable to the development of China. Energy conservation and environmental protection have been incorporated into China’s overall economic development framework. Development of renewable energies is an important energy policy which is a good way to solve the inconsistency of economic development and environmental protection. Batteries are thought as replacement for fossil energy to decrease environmental pollution and relieve energy crisis. Batteries will be main energy form for vehicles.

## **2 Zinc-air power battery is a good replacement of lead-acid battery**

### **2.1 Benefits of zinc-air power battery**

Metal/air batteries are one of the more promising alternatives to conventional power sources. These batteries have tremendous potential because they are efficient, environmentally safe, and completely renewable. Metal/air fuel cells can be used for both stationary and mobile applications.

Zinc as an anode fuel has an advantage over other metals due to its unique set of attributes which include a low equilibrium potential with respect to hydrogen, electrochemical reversibility, stability in aqueous electrolytes, high specific energy, high volumetric energy density, abundance, low cost, environmental compatibility, and ease of storage and handling<sup>[5,6]</sup>.

Zinc-air power batteries are usually designed as mechanically rechargeable, that is, recharge process is changing a new zinc anode. The main benefit of this design is batteries can be used as primary battery without worrying about the deforming of counter electrodes caused by deep discharge for most secondary batteries. Another benefit is the life length of batteries is decided by air cathodes. As long as the air cathode can work, the batteries can be continuously used only by changing zinc anode. There are many benefits of zinc-air power battery technology over lead-acid batteries. These benefits include very high specific energies, high energy densities, and the de-coupling of energy and power densities. Further, these systems provide rapid on-site refueling that requires only a standard electrical supply<sup>[7]</sup>. In spite of these benefits, zinc-air power battery is pollution-free compared with the lead-acid battery.

Comparing to Li-ion batteries, zinc-air power batteries also have many benefits, especially in Chinese market. Though the Li-ion battery is the dominant bat-

tery in Japan and Europe electric bicycles market, it has small market in China. From one manufacturer’s perspective, Li-ion batteries are still dangerous, costly for application in electric bicycles. Most consumers could not accept it now. But for zinc-air power battery, it is safe and cheap, like lead-acid battery.

### **2.2 Advantage for developing zinc-air power battery in China**

In China, the mature market of electric bicycles is the maximal advantage for developing zinc-air power battery. Market benefit promotes technology advance. In turn, the battery advance also improves to expand the electric bicycles market. Demands of consumers improve development of products. Firstly, in China, consumers need electric bicycles. Though minority cities limit its development, most people think it is a kind of convenient vehicle because of its service performance and price. Secondly, lead-acid batteries limit development of electric bicycles including two aspects. Considering environmental protection point of view, lead pollution is a heavy incipient fault. Especially, in China, recovery work of spent lead-acid batteries is not thoroughly put into effect. So the damaging of lead application is serious. From service performance point of view, short road haul and long charge time of lead-acid batteries are main limits, which is decided by the self-shortage of lead-acid batteries. Consumers need a new kind of electric bicycle to realize long road haul and convenient charge style. Considering the self-performance of zinc-air batteries, it is also a good choice for electric bicycles in China. Firstly, it is friendly to environment. In spite of its excellent service performance, its charge style is also fitful to the development of electric bicycles. Because charging process of zinc-air power batteries is replacing the used Zn with fresh Zn, which is likened to refueling a vehicle with gasoline. Compared with the charging process of lead-acid batteries, this saves much waiting time of consumers. The more important meaning is it takes the revolution of the battery manufactory. Firstly, the power battery can be designed as primary battery without considering consistency of batteries in charging process. Secondly, the working consistency of power batteries is controlled by the product quality control in mechanically rechargeable process. This design of the charge style also accelerates the construction of the regeneration factory and the development of the regeneration service, which can provide some employment opportunities in China. It is helpful for decreasing the jobless rate at the current situation of our country. According to the analysis above, China has good developing environment of electric bicycles powered by zinc-air power batteries. It is

a good promotion.

### 2.3 Feasibility of developing zinc-air batteries in China

Developing new energy is a definite direction of energy policy worldwide. Li-ion battery, Ni-H battery, and other batteries are researched to use in many aspects including in electric vehicles. But, for electric bicycles, they are not suitable. Main reason is high price. For the zinc-air power battery, the price is correspondent to that of lead-acid battery, even much lower, so consumers can accept it. Many consumers of electric bicycles are people with middle and low earning. They can not accept electric bicycles powered by new batteries with high price though the performance is absolutely superior to that powered by lead-acid battery. But, for zinc-air power battery, it can obviously increase road haul of bicycles and only take several minutes to complete charge process, the more important is the price is also as cheap as lead-acid battery. So, developing zinc-air power battery is feasible.

On the other hand, metal zinc is less pollution. Zinc-air power battery is thought as "green energy" of 21<sup>st</sup>[8,9]. In the battery, reactants are zinc and oxygen, catalyst are activated carbon, electrolyte is potassium hydroxide (KOH), reaction product is zinc oxide (ZnO), all these materials have no harm to environment, including the process of refining zinc and the process of regenerating zinc also have little pollution to environment. So, zinc-air power batteries agree to environmental protection policy of China.

Furthermore, metal zinc source is very abundant in our country. And in zinc-air battery, zinc also can be electrolyzed for reusing, which is a circular recovery process. The application of zinc-air battery can accelerate the circular economy construction of China.

### 2.4 Acceleration function to other electric vehicles powered by zinc-air power battery

Development of electric vehicles gets worldwide approval. Battery is a key part of electric vehicles. Our country also has actively developed electric vehicles including kinds of batteries. It has little landscape on electric vehicles development between China and other developed countries, so this is a good developing chance for our country.

Zinc-air power battery is a kind of promising battery. Fritz R. Kalhammer<sup>[10]</sup> has analyzed that only zinc-air battery (zinc-air fuel cell) is suitable to be used on electric vehicles because of its high specific energy. So, developing zinc-air power battery used in electric vehicles is a right direction, which can be accelerated by the development of the zinc-air power battery used in electric bicycles.

Combining the current situation of China, we suggest we should actively develop electric bicycles powered by zinc-air power battery instead of lead-acid battery. Firstly, not only because the market of electric bicycles is mature, but structure of electric bicycles are relatively simple, so it is easy to realize alternative from lead-acid battery to zinc-air battery. Secondly, zinc-air battery is a kind of regenerative battery because zinc can be recycled through electrolysis process. It also can be deemed as a kind of service-type battery. Because during the application of zinc-air power battery, the regeneration service and the charge service are necessary, that is, the social service system is the basic of this battery industry. It must ensure consumers can get fast charge service and the used batteries can be regenerated in time. So, when we are developing the zinc-air power battery used in electric bicycles, at the same time, we are accelerating to build the social service system of the battery that is also the foundation for other electric vehicles powered by zinc-air power batteries. Synthesizing the illustration above, we can generalize that developing zinc-air power battery used on electric bicycles agrees to the current situation of China. And during the development, there are three favorable factors: relative simple technique barrier of battery application, motivation of electric bicycles' mature market and chance for building perfect social service system. All these are helpful for accelerating the development of electric vehicles powered by zinc-air power battery.

## 3 Summary

Electric vehicles technology is an effective method to solve problem of economic development and environmental protection. Battery constrains development of electric vehicles. Comparing to other kind of batteries, zinc-air power battery is a good choice for replacing lead-acid battery used in electric bicycles according to Chinese situation. Considering of the battery's performance, environmental protection policy of our country, developing zinc-air power battery is feasible and beneficial. Besides these, we also get it is a good transition for zinc-air power battery application from electric bicycles to other electric vehicles. Not only from technology point of view, but also from capability of social complement on supplying zinc-air battery service point of view, it is necessary.

## References

- [1] Cherry C, Cervero R. Use characteristics and mode choice behavior of electric bike users in China[J]. *Transport Policy*, 2007, 14(3): 247-257.
- [2] Weinert J, Ma C, Yang X, et al. The Transition to Electric bicy-

- cles in China and Its Effect on Travel, Transit Use, and Safety [M]. Washington, DC: Transportation Research Board, 2006.
- [3] Weinert J, Ma C, Cherry C. The transition to electric bicycles in China: history and key factors for rapid growth [J]. Journal of Transportation Special Issue: Motorization in Asia, 2007, 34(3): 26.
- [4] Zhang Z X. China is moving away the pattern of “develop first and then treat the pollution” [J]. Energy Policy, 2007, 35 (7): 3547-3549.
- [5] Linden D, Reddy D B. Handbook of Batteries(3rd Ed.) [M]. New York: McGraw Hill, 2002. 47-50.
- [6] Zhang X G. Corrosion and Electrochemistry of Zinc [M]. New York: Plenum Press, 1996. 5-10.
- [7] Smedley S I, Zhang X G. A regenerative zinc-air fuel cell [J]. Journal of Power Sources, 2007, 165 (2):89 7-9 04.
- [8] Goldstein J, Brown I, Koretz B. New developments in the electric fuel limited zinc/air system [J]. Journal of Power Sources, 1999, 80: 171-179.
- [9] Will F. Proceedings of the 13<sup>th</sup> Annual Battery Conference on Applications and Advances Long Beach [C]. CA, 1998.
- [10] Why Choose Zinc-air [OL]. <http://www.powerzinc.com/en/te01.asp>.

### Author

Zhu Mei, female, born in 1977, graduated from University of Science and Technology of China with a doctor degree, and is a lecturer of School of Engineering, Anhui Agricultural University. Her main research is about the zinc-air power battery, including performance of the air cathode, electro-analysis of metal zinc, integration and regeneration of the batteries. Besides, she also works for the practicability and industrialization of the zinc-air power battery. She makes efforts to improve the application course of the battery in electric-vehicles. She can be reached by E-mail: zhumei @ ustc. edu. cn

Foundation item: Imbursed by Anhui Exploitation Fund of Person with Ability( 2006Z029).

---

( cont. from p. 51 )

### Author

Jiang Hongkui, male, born in 1974, graduated from Lanzhou Jiaotong University with a mater degree, and now is a teacher in College of Traffic and Communications, Zhejiang Normal University. He can be reached by E-mail: jhkass@163.com

---

Foundation item: The project supported is by Foundation of Education of Zhejiang Province, China ( No. 20060470 ).