

Shield Machine and Shield Model Machine

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Abstract: With the rapid development of China's economy and technology, infrastructure construction is developing rapidly, and the development of underground space is gradually developing in the direction of the depth of the stratum. The shield construction environment is becoming more and more complex, and the excavation face instability accidents caused by improper construction parameter settings occur from time to time. Once the excavation face of deep shield tunnel is unstable, it is difficult to carry out rapid rescue on site. Therefore, it is of great significance to study the influence of different factors on the stability of excavation face under deep buried conditions and to evaluate the risk of excavation face instability. The shield model machine can make on-site simulation experiments and give on-site opinions. The shield machine, the full name of the shield tunnel boring machine, is a kind of special engineering machinery for tunnel excavation. The modern shield tunnel boring machine integrates light, machine, electricity, liquid, sensor and information technology. It has the functions of excavating and cutting soil, conveying soil, assembling tunnel lining, measuring and guiding correction. It involves geology, civil engineering, machinery, mechanics, hydraulic, electrical, control, measurement and other multi-disciplinary technologies, and it is necessary to carry out 'tailored' design and manufacture according to different geology, and the reliability requirements are extremely high. Shield tunneling machine has been widely used in subway, railway, highway, municipal, hydropower and other tunnel projects. The shield model machine is used to simulate the shield process of the shield machine and prevent dangerous situations during the shield process.

Keywords: Shield machine, earth pressure balance shield, shield model machine.

1. Research Status of Shield Machine at Home and Abroad

1.1. Research status of shield machine abroad

Throughout the development history of shield tunneling for more than 180 years, the improvement of shield tunnel construction method and shield tunneling machine is around : 1 Strata stability and ground subsidence control; 2 mechanization, automatic tunneling and tunneling speed; 3 Lining and tunnel quality, the three elements of the shield tunneling machine improvement and construction methods of the revolution. The traditional shield method considers these three elements independently, and takes stratum stability treatment as an auxiliary method of shield, mainly including lowering groundwater level method, improving foundation method, freezing method and air pressure method. The structure of the shield machine itself does not consider the impact on the stability of the stratum or the reduction and prevention of ground subsidence. The shield is generally an open-chest structure. However, even if any ground stabilization treatment method can suppress the influence on the ground, it is difficult to meet the various requirements of construction in the city, especially the ground settlement problem related to the safety of ground construction. Therefore, it is naturally developed to the next generation of shield ^[1]; closed-chest shield. One of the most significant characteristics of modern shield is to consider the three elements of shield method as a whole, and solve the problem of working face stability with shield tunneling machine equipment itself. The method of using compressed air to balance earth pressure is prone to air leakage, eruption, working face collapse and other accidents, and causes adverse effects on the environment such as land subsidence, especially in the formation with small cohesion and

permeability. This method is not competent. Naturally, the idea of using liquid instead of air to support the working face was first tested in Germany and the United Kingdom. In 1967, Japan completed this system, which produced a modern concept of slurry balance shield. Slurry balance shield is to balance the soil pressure by pressing the slurry into the cavity formed between the working face and the closed chest plate, maintain the stability of the working face, and use the slurry to transport the discarded soil cut down by the cutterhead. The advent of this method has greatly improved the stability of the working face. The scope of application of the shield method has been greatly broadened, and the shield tunneling machine has been unprecedentedly developed^[2].

However, the slurry balance shield requires a large-scale slurry separation and treatment system, which covers a large area, has a great impact on the environment, and has a high construction cost. The system is not ideal for tunnels constructed in the city. Then in 1974, Japan first successfully developed the earth pressure balance shield. This system sent the discarded soil cut by the cutterhead into the front-end closed chamber, stirred or injected additives to stir into plasticized discarded soil and combined with screw conveyors and other mechanisms. While maintaining a proper and stable pressure on the working face, it has been widely used because of its high screw transmission. Although the modern shield tunneling machine has made great improvements in component structure, driving mode, automatic control, measurement and control guidance, the principle and method of pressure balance in these working faces have been used up to now. Today's shields are basically based on the two modes of mud-water balance and earth pressure balance, or a combination of these two modes, or a combination of these two modes and open-chest type, forming a composite shield to meet the requirements of tunnel construction with variable stratum conditions.

The development of shield machine has always been closely related to the development of basic industry and the actual needs of underground engineering. Moreover, the key technologies of shield machine in different periods have been mastered by a few countries with developed industry in this period, such as Britain and Germany in the 19th century and Germany, Japan, the United States and France in the 20th century. With the development of economy and science and technology in these countries, a large number of underground projects have been put into construction, which has promoted the rapid development of shield technology. Shield tunneling technology is a comprehensive embodiment of various technical levels such as hydraulic technology, electromechanical control technology, measurement and control technology, computer technology and material technology. Over the past 180 years, shield tunneling technology has been continuously developed and improved with the development of these related technologies. The application of modern high-tech makes the ground subsidence control, propulsion speed control, measurement and control guidance, automatic lining of shield tunneling more and more easy^[3].

The modern shield tunneling machine integrates the three elements of the shield method well, and basically does not need the stability treatment of the surrounding rock and the secondary lining of the tunnel. In many cases, the comprehensive construction cost of the shield construction is much lower than that of the manual excavation construction, and the tunneling speed is much higher. In order to meet the diversified needs of urban tunnels, various forms such as super-large section shield, multi-circular shield, special-shaped section shield and spherical shield have been developed. Many improvements have also been made to the earth pressure balance technology. The development of bubble method and other soil modified materials has further broadened the scope of application of earth pressure balance shield, improved construction accuracy and reduced cost. At the same time, the automation of the shield greatly improves the construction safety, labor environment and labor intensity.

1.2. Domestic research status of shield machine

After years of development, China has a relatively complete industrial chain of shield machine design, research and development, and production, and has independent intellectual property rights. Through my review of the shield machine literature, it is found that the research and development and design of the shield machine mainly focus on two major difficulties, namely, the research on the cutterhead and assembly technology of the shield machine. The main reason is that in the actual work of the shield machine, tunneling and segment assembly are the most basic work requirements of the shield machine. In addition to these, the composition of the shield machine is also extremely complex, which involves mechanical, electrical, hydraulic, guidance, computer technology and other disciplines of comprehensive large-scale mechanical equipment. Therefore, it is not difficult to see that the study of shield machine needs to involve many disciplines, mainly including traditional machinery, electronics, geology, civil engineering, materials and other comprehensive technologies^[4].

2. Development and Prospect of Shield Machine

The shield machine has become a key technical equipment in transportation, mining, water conservancy and other engineering aspects, and has been widely used in many fields. With the continuous development of information, automatic control technology and microelectronic remote sensing technology, the multi-function of shield machine is becoming more and more intense. Therefore, these technologies have been intensively applied to the design and development of shield machine in the future, so that the shield machine can meet the complex geological conditions, and also make the shield machine more intelligent. The following is a few studies on the development of shield machine^[5].

2.1. To the direction of miniaturization and super large development

Nowadays, with the continuous improvement of the level of social productivity, the process of urbanization is accelerating, and the rapid development of urban construction has put forward higher and higher requirements for shield construction technology. Some scientists who stand at the forefront of technology are also following the pace of development of the times. In order to adapt to the changing requirements of the current tunnel engineering project, they are constantly standing at the forefront of technology and exploring the new development and progress of shield technology. At present, with the continuous development of urban rail transit, with the joint efforts of a large number of scientists, they are trying to build a shield machine with more technical level. The cross-sectional diameter of the shield machine is becoming more and more miniaturized and oversized.

2.2. To develop in the direction of high automation

With the improvement of intelligent automation level of various technologies in China, China has begun to develop automation technology in various fields. Shield construction needs more automation support. With the advantages of automation technology, the construction efficiency of tunnel engineering is improved, the construction quality is guaranteed, and a large number of human resources are saved, which brings guarantee for the life safety of construction workers. Nowadays, with the rapid development of computer technology, remote sensing and other fields in China, the shield machine can also use the rapid development of automation technology in the process of use, use sensors to detect whether various data are normal, and communicate with the computer system, and judge the next operation by the computer, which makes the shield machine develop in the direction of automation in time^[6].

2.3. Towards diversification

With the rapid development of science and technology, a variety of rail transits have emerged in the rapid development of urban construction. In the process of tunnel shield construction, various forms of shield machines have been derived for different cross-sections of different projects, such as rectangles, circles, and ellipses. It accelerates the adaptability of shield technology to the tunnel environment and promotes the development of shield technology in a diversified direction.

2.4. Diversified development of models

In the future, the shield machine will not be used in a single working condition, but with the continuous improvement and optimization of the shield machine, the use of the shield machine will also change greatly. In the future, the shape and size of the shield machine will change. At the same time, with the change of section size, size and shape demand, shield machine will also develop towards diversification. At the same time, the shield machine is no longer the overall structure, and is gradually replaced by a detachable modular structure, making the use of the shield machine more extensive^[7].

2.5. More automated and intelligent operation

Modern shield machine has not only realized the artificial form of shield operation, through continuous improvement of innovative design, modern shield machine has gradually realized the automatic, intelligent operation and production. For example, in today 's shield machine, there are a large number of advanced technologies, including cutterhead drive device, automatic control, remote sensing technology, detection technology, communication technology, etc., which makes the shield machine more intelligent. At the same time, with the development of small-scale shield machine, the application field of shield machine is also increasing, which can adapt to various complex environments and climates, and become more intelligent and flexible engineering operation machinery. The traditional shield machine is more dangerous whether in operation or in assembly. The reliability and safety of the shield machine are improved, so that the shield machine is accepted by more people and the scope of application will become wider.^[8].

2.6. Integrated and modular development of the whole machine

As far as the previous shield machine is concerned, due to the large size and inconvenient transportation of the shield machine, the decomposition transportation is usually adopted, and the assembly operation is carried out in the specific working environment. An ordinary large shield machine adopts a large number of steel structures. The large shield machine weighs thousands of tons, so whether it is production, manufacturing, transportation, assembly will encounter various problems, and the time span will also increase significantly, resulting in huge research and development design costs. In addition, the working environment of the shield machine is complex and harsh, and it often works in a deep underground, which brings serious wear to the machine. It also increases the difficulty of maintenance and repair, and has high requirements for material strength and wear resistance. With the continuous development of modern material technology, more and more new and new materials have been applied to the production and manufacturing of shield machines, which makes some key components of the originally awkward and huge shield machine adopt more durable and wear-resistant materials. The development of shield machines has achieved breakthroughs in many aspects. With the integration and modular design of the shield machine, the length of the rear support will be shorter, the height and width will be smaller, and the function will be more perfect^[6].

3. The Necessity of Shield Model Machine

The invention of shield starts from maintaining the stability of excavation face. Shield construction is widely used in underground tunnel construction because of its advantages of fast construction speed, construction integration, small environmental impact and strong stratum adaptability. One of the advantages of the shield method is that it has less impact on the environment, which is more significant in the environment with poor surrounding rock such as soft soil tunnel. However, for the shield method, whether the stability of the excavation surface can be guaranteed is very important for the shield construction. In the process of tunnel excavation, maintaining the stability of the excavation surface is the most important factor to ensure the safety of construction. In shield tunnel, the instability of excavation face has become a common disaster affecting tunnel excavation. According to the relevant literature statistics, in recent years, the collapse of the shield tunnel accounted for 47 % of the total accident, and the instability of the excavation surface is the main cause of the collapse accident^[8].

Obviously, the instability of the excavation surface not only affects the safety of tunnel construction, affects the construction progress, but also causes the safety of life and property to the construction personnel. The large buried depth tunnel will increase the possibility of adverse geology in both the depth along the depth direction and the width along the axis direction of the tunnel. During the construction of deep-buried shield tunnel, the failure and deformation law of the excavation face of deep-buried tunnel is completely different from that of shallow-buried tunnel, and the design theory and construction experience of deep-buried shield tunnel are insufficient, which brings great construction difficulty and safety hazards to the construction of deep-buried shield tunnel.

With the increase of buried depth of tunnel, the balance mechanism and stability of excavation face caused by high earth pressure will be very different from that of excavation face under conventional buried depth. The stability control of excavation face of deep buried shield has become a key problem to prevent environmental disasters in shield construction. Therefore, in order to finally realize the prevention and treatment of the collapse accident of the deep-buried shield tunnel, ensure the safe construction of the tunnel and protect the surrounding environment of the tunnel, the shield model machine shows its advantages. The simulated field environment cooperates with the numerical simulation to make reasonable guidance for the real shield, so as to prevent and study the stability of the tunnel face.

4. Suggestions on the Development of Shield Machine Manufacturing in China

Formulate shield machine manufacturing standards and norms, improve the market supervision mechanism and means. Build a three-in-one shield machine manufacturing standard system of the country, industry and enterprise. Relying on domestic shield machine manufacturing enterprises, construction enterprises and industry associations, accelerate the formulation of standards for shield machine manufacturing, detection and damage assessment, key technologies, product quality and production management standards, and ensure the rapid improvement of product

quality characteristics.

With the application and development of high-tech, the high-tech content of shield control technology is getting higher and higher, the degree of automation is constantly improving, and the measurement and positioning are becoming more and more accurate. Laser guidance technology, remote control technology and gyroscope positioning system have been widely used in shield construction technology. In the process of shield construction, the surface subsidence control technology in the construction area is becoming more and more mature, and the quality of tunnel construction is becoming more and more perfect. The application of texture in tunnel construction can safely cross tall buildings underground. With the development and utilization of underground space and the construction of urban municipal comprehensive pipelines. The section size of shield has the tendency to develop in two directions: small and super large. The shield with a diameter of 18 m is being developed, and the micro shield has been popularized and applied in the project.

References

- [1] Zhou Xinyuan Li Enzhong Zhang Wei, Shi Peijing, Xu Binshi Research on the current situation and development countermeasures of China's shield machine remanufacturing industry Modern manufacturing engineering,2019 (08):157-160+147.
- [2] The current situation of Kang Xiaolin 's shield machine construction technology is the first prospect of urban construction theory research (by sub-version)2018130.113
- [3] Yuan Dajun, Shen Xiang, Liu Xueyan, et al. Study on the stability of excavation face of slurry shield [J]. China Journal of Highways, 2017,30 (08):24-37.
- [4] Wei Liangwen, Zhang Qinghe, Sun Tongli, et al. Research progress on the stability of shield tunnel excavation face Journal of Chongqing Jiaotong University (Natural Science Edition) 2007,(06):67-72.
- [5] Zhang Qinghe, Zhu Hehua, Huang Hongwei Underground Engineering [M]. First edition. Shanghai: Tongji University Press, 2005
- [6] Xue Beifang Present Situation and Development Strategy of Shield Tunnel Boring Machine in China [J] Modern Tunnel Technology 1999 (6).26-31.
- [7] Yang Huayong, Research on Development Strategy of Guofang Shield Tunneling Machine [C]/2003 Shanghai International Tunnel Engineering Symposium. Shanghai Tongji University Press, 2003.
- [8] Overview of Wu Keli Tunneling Machinery Development at Home and Abroad [J] Heavy Industry and Lifting Technology 2005 (1):29-32.