



Force transmission characteristics for the non-equidistant arrangement thrust systems of shield tunneling machines

Deng Kongshu^{a,b}, Tang Xiaoqiang^{a,*}, Wang Liping^a, Chen Xu^a

^a Department of Precision Instruments and Mechanology, Tsinghua University, Beijing 10084, China

^b China Railway Track Systems Group Co., LTD, Changsha 410100, China

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ABSTRACT

Earth Pressure Balance shield tunneling has been successfully adopted for urban tunneling and has resulted in increases in working speed, savings of man-hours and improved safety. Based on the ellipse eccentricity, the ellipse matrix equation for non-equidistant systems has been constructed. Through the analysis of the matrix, the characteristics of force ellipse eccentricity were investigated in detail. The distinction from the equidistant system was studied by applying the force ellipse to the thrust systems of shield machines in engineering applications. It provides a new arrangement for the thrust system hydraulic cylinders, under large change-of-direction forces or uneven geological bodies, which may prevent the segments from cracking due to an over-offset load.

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1. Introduction

In recent years, Earth Pressure Balance (EPB) shield tunneling has been successfully used for urban tunneling construction under various ground conditions. At present, it can be considered as the most commonly used mechanized tunneling technology, even challenging the role of the Slurry Shield both as far as machine size and geo-mechanical fields of applicability are concerned [1]. The EPB shields, which was first developed in Japan, has resulted in an increase in working speed, savings in man-hours and improved safety [2–4].

Fig. 1 shows a simplified diagram of an EPB machine. During the excavation process the rotating cutter excavates the soil which passes into the pressurized head chamber, the machine is then advanced by jacks on the thrust system that applies pressure on the segments [5–7]. The screw conveyor removes the excavated soil from the head chamber. The shield thrust system in the machines, driven by the hydraulic system providing significant force, is a key part of the shield. It does not only perform the task of driving the machine ahead in the process of tunneling, but also controls the attitude of the machine to ensure that the shield can advance along the expected path aligned for constructing the planned tunnel line [8].

In the anisotropy of excavation interface rocks, however, the inconsistencies of resistance surrounding the machine and its own weight create a complicated working situation. Under such special conditions, the offset load on segments would be easily generated. Consequently, problems caused by meandering routes, ground subsidence and machine failure would be more likely to arise.

Therefore, this is of primary importance to study the analysis and the design of the thrust system [9].

For the current driving system of the machine, the hydraulic cylinders are in parallel with the axis of the shield and are spaced equidistant along the circumference. In fact, the structure could produce a huge change-of-direction load in the passage of tunneling due to the curved excavation and the heterogeneous geologic conditions. Consequently, in some special cases, the hydraulic cylinders should be distributed by non-spacing [10].

Most of current studies about thrust systems focus on the control methods and the tunneling parameters of the hydraulic driving system with the requirements for a system in given geological and tunnel parameters [11–13]. However, the structures in usage for studies are usually a uniform distant driving system, which are less involved in the non-spacing structure [14]. The article firstly presents the non-spacing structure under special conditions and the optimization mechanical model. Then, the article investigates the law of force transmission for the non-uniform system in more detail. Finally, through an engineering application, a comparison in the force transmission characteristics between spacing systems and non-spacing systems will be given. The result could provide a theoretical foundation and support for the design of the non-spacing thrust systems in shield tunneling machines under special conditions.

2. Mechanical model of non-uniform driving system

2.1. External loads applied on the thrust system

The deviation from the driving route and the expected one is an important indicator for construction quality in engineering. Therefore, to adjust the posture of the machine in time, there requires a real-time

* Corresponding author. Tel.: +86 10 62792678.

E-mail address: tang-xq@mail.tsinghua.edu.cn (T. Xiaoqiang).