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A preliminary study on the simulation of a curved TBM excavation

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ABSTRACT

This study aims to simulate the curved excavation by TBM steering system based on the TBM steering mechanism. The concept and mechanism of the TBM steering system were briefly introduced. Based on the mechanism of TBM steering system, the curved excavations were simulated by Python at an initial stage.

1. INTRODUCTION

As the tunnel alignment is often designed as a combination of straight and curved lines, the TBM steering system should be well taken into consideration in order to cover the various operational ranges of curves successfully.

Shen et al.(2011) introduced the geometric and mathematic theoretical models to determine the three-dimensional orientations of a TBM during the TBM advance. Chanchaya and Suwansawat (2014) introduced three operational factors (articulation angle, shield jack length difference, and copy cutter stroke) necessary for the curved excavation. Festa et al.(2015) presented the kinematic behavior of a TBM in soft ground. They described the TBM shield position and orientation with two reference points. Kang et al.(2017a) conducted a numerical simulation to evaluate the structural stability of the TBM shield during the tightly curved excavation. Also, Kang et al.(2017b) carried out the 1:17.7 scale model experiment to identify the behavior of the thrust pressure depending

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on the different shield jacking force systems and articulation angles for the curved excavation. However, these previous studies show the limitations for designing the TBM steering system in detail.

2. OVERVIEW OF TBM STEERING SYSTEM

For the TBM steering, the thrust jack and articulation jack are used. There are two types of articulation systems: 'V-type' and 'X-type'. The 'X-type' system used in this study is more suitable for the extremely tight curved excavation because it has more advantages of articulation sealing and water-resistant works during the articulation (Kang et al., 2017a; Kang et al., 2017b).

The thrust systems are divided into two systems: reaction force at the front shield and reaction force at the middle & tail shield. Generally, the latter used in this study is more appropriate for the curved excavation as that system can supply the constant thrust force to the segment ring regardless of the rotation of the front shield (Kang et al., 2017a). In curved excavation, articulation jacks are used first to adjust the advanced direction. After that, shield jacks are extended to move the TBM forward in the target direction. Because of these articulation jack operations and thrust jack operations, reference points can be changed; refer to Fig. 1.

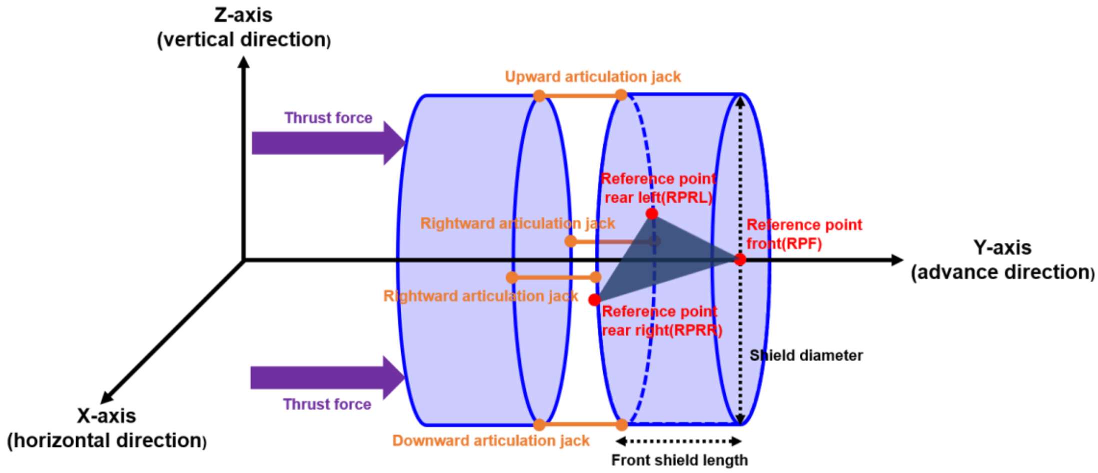

Fig. 1 Drawing of TBM steering system with TBM position.

3. EXAMPLE OF CURVED EXCAVATION SIMULATION IN PYTHON

Based on the concept of TBM steering system, mathematical models were created, and the curved excavation was simulated by Python. As for the example simulation of input parameters, shield diameter is 8,000 mm, the length of the front shield is 3,000 mm, the width of segment ring is 1,500 mm, the speed of shield jack is 10 mm/sec, and the total process cycles are 100 rings. The shield TBM traveled in the top-right direction with the horizontal and vertical articulation angle of 0.57° per cycle and the target planned alignment. Once the shield jacks are extended until the length of the shield jack is equal to a segment length, one process cycle is complete. This cycle is continuously repeated until the simulation is complete. Fig. 2 shows the simulation result of curved excavation in the top-right direction. Fig. 2(a) shows the simulation at 50 cycles, and Fig. 2(b) shows the simulation at 100 cycles. The blue lines mean the planned route, the pink lines mean the projection area of planned route, the green dot lines mean the projection line of reference points. Three reference points in the form of red triangle travel along with the route nearly completely during the simulation time.

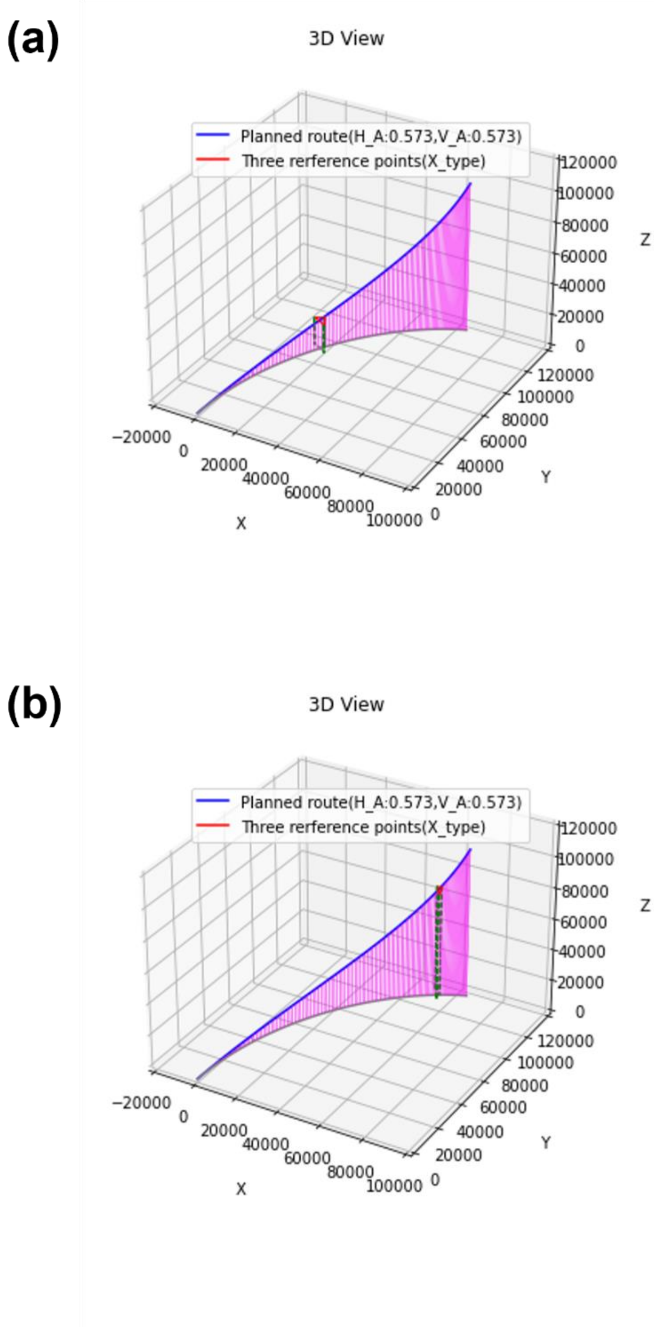

Fig. 2 Example simulation results of curved excavations in the top-right direction: (a) simulation at 50 cycles; (b) simulation at 100 cycles

4. CONCLUSIONS

The purpose of this study is to simulate the curved excavation by the TBM steering system. Based on the mechanism of the curved excavation, the simulation of the curved excavation was conducted by Python. Further study will be focused on simulating the curved excavation in the TBM operating simulator.

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