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Structural Design of Multi Functional Underground Cable Laying Device

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Abstract. Urbanization construction is developing rapidly in various countries around the world, and the demand for underground cable laying construction is increasing year by year in multiple fields. In response to the many difficulties in traditional cable laying, this article designs a multifunctional cable laying device. On the premise of ensuring the construction requirements of cable laying, it quickly replenishes cables through a self-loading and unloading cable mechanism, excavates various laying trenches with different technical requirements, completes cable loading and laying, filler filling, and soil backfilling operations, and improves the construction efficiency of cable laying work. Reducing resource waste, lowering construction costs, and alleviating the degree of traffic congestion caused by the occupation of urban roads during the construction phase. Optimize the structure of the multifunctional cable laying device using UG software to ensure the effectiveness and safety of the structural design of the multifunctional underground cable laying device.

Keywords. Underground cable; Cable laying; Structural design; Trench excavation mechanism.

1. Introduction

Due to the shortage of urban land and high traffic pressure, underground cable transmission methods are becoming increasingly popular. Compared to overhead lines, cables have advantages such as small footprint, reliable transmission, and strong anti-interference ability. When laying cables, it is necessary to evenly lay fine sand on the top, bottom, left, and right sides, backfill the original soil, and cover the ground surface with hard protective layers such as bricks and concrete slabs. Faced with difficulties in excavating trenches, laying, filling with fillers, and backfilling with original soil during cable laying construction, many scholars have conducted research on underground cable laying devices.

As an important engineering project, the stability of cable laying is a particularly worthy research topic [1,2]. The effectiveness and sustainability of its construction projects are also crucial [3,4]. Professionals have utilized various advanced technologies to conduct online monitoring of different underground laying techniques and conducted comparative analysis of reliability characteristics [5-8]. There have also been successful attempts to use fuzzy logic to select the optimal non excavation pipeline laying technology [8,9]. The laying of superconducting feeder cables and stress relaxation

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methods for cooling, as well as the research and development of a down the hole drilling rig self-propelled vertical mining system, have all achieved success [10,11]. The progress management, construction costs, and core challenges of underground pipelines, as well as the risk orientation of occupational health and safety industrial control, have also attracted high attention from various countries [12-15].

In order to solve some of the difficulties faced in underground cable construction, techniques and improvement plans such as pulley mechanisms, cable reel loading vehicles, and soil backfilling have been constantly emerging [16-18]. The new type of climbing chain robot and long-distance cable pulley system have also effectively solved various problems in underground cable laying [19-21]. Some scholars have also used modeling to solve the efficiency problem of flexible cable pulley systems [22]. It can be seen that the laying of underground cables is of great importance and cannot be underestimated for the construction of new cities. It has attracted attention from various countries and sectors around the world.

Considering the above reasons, in order to efficiently carry out underground cable laying operations, a multifunctional underground cable laying device is designed to achieve independent walking function without laying operations; Capable of independent cable reel loading and unloading function; Can achieve the function of filling with fillers; Can achieve overall power driven by hydraulic pressure; Capable of achieving self backfilling function; The multifunctional underground cable laying device designed has wide promotion and application value in the field of cable construction operations.

2. Design Scheme for Multifunctional Underground Cable Laying Device

This paper proposes the overall design scheme of the Multi-Functional Underground Cable Laying Device (MFUBLD), which is designed with seven functional mechanisms on the body of the laying device. In addition to the walking mechanism that realizes the movement function, there are cable carrying and flipping mechanism, soil trench excavation mechanism, surface soil separation mechanism, cable anti twist damage and laying mechanism, filling mechanism, and soil landfill and backfilling mechanism.

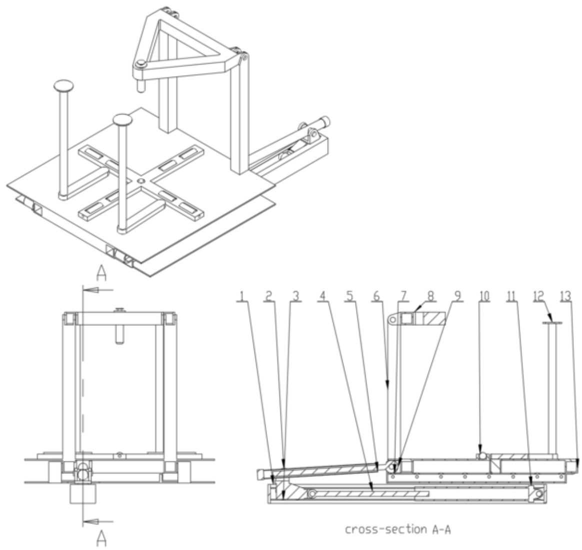
2.1. MFUBLD Cable Transport Flipping Mechanism

The MFUBLD is designed with a cable carrying and flipping mechanism, which can quickly supplement and solve the problem of unsafe transportation through a self-loading and unloading cable mechanism. It can also flexibly adjust the position for cable laying through the flipping mechanism. The frame of the cable carrying and flipping mechanism is constructed by welding 45 square steel, and is powered by two single head hydraulic cylinders to drive the mechanism during operation. The cable carrying and flipping mechanism of the multifunctional underground cable laying device is shown in Figure 1.

2.2. MFUBLD Soil Trench Excavation Mechanism

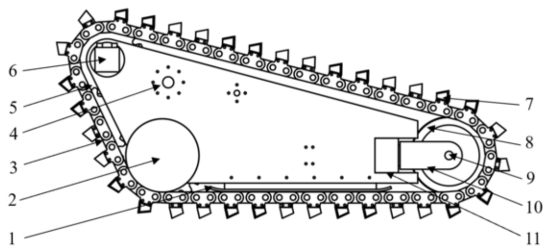
Multiple wear-resistant and high-strength excavation teeth are installed on the excavation chain of the soil trench excavation mechanism. Driven by a hydraulic motor, the sprocket rotates for excavation operations. In order to avoid the impact of excavated soil on subsequent cable laying operations, a surface soil separation mechanism was designed.

Two sets of hydraulic cylinders were used to control the angle and height of the excavator structure relative to the ground, thereby excavating laying trenches of different depths. The soil trench excavation mechanism is presented in Figure 2.



1-Hydraulic cylinder lower track; 2- Sliding frame of hydraulic cylinder and; 3-Hydraulic cylinder lower track V-wheel; 4-Hydraulic cylinder; 2 moving rods; 5-Hydraulic cylinder static rod; 6-Moving frame; 7-Base roller wheel; 8-Fix the A-frame with the movable cable reel; 9-Hydraulic cylinder rod; 10-Cable reel roller for moving frame; 11-Hydraulic cylinder 2 static rod; 12-Fixed adjustment rod for cable reel of moving frame, 13-Base.

Figure 1. MFUBLD cable transport flipping mechanism

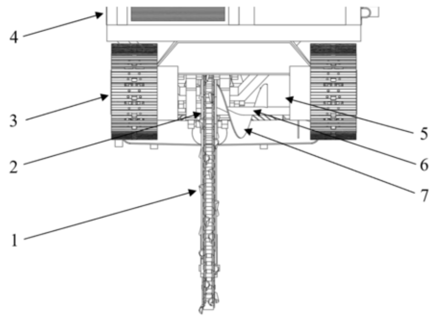


1-Excavator chain support skateboard; 2-Excavate the driven sprocket of the mechanism; 3-Excavator construction of excavation chain; 4-Installation holes for the main side panel of the rack; 5-Active chain wheel for soil trench excavation; 6-Hydraulic motor for excavation mechanism; 7-Excavate the cup teeth of the digging mechanism; 8-Excavator structure tension wheel; 9-The excavator structure tightens the wheel axle; 10-Tighten the wheel frame of the excavation mechanism; 11-The excavator structure tightens the wheel frame seat.

Figure 2. MFUBLD soil trench excavation mechanism

2.3. Surface Soil Classification Mechanism of MFUBLD

The soil used for cable laying trenches is generally sandy soil, loamy soil, slightly cemented gravel, gravel, and blasted stones. A study will be conducted on soil grade III, which is widely applicable for cable laying. The soil excavated by the trench excavation mechanism is in a loose state. The surface soil sorting mechanism is made of Q235B alloy steel and mainly consists of spiral blades and a middle rod. The blade has a spiral angle of 31 °, a pitch of P=500mm, and a radius of R=265mm. The main function is to push the excavated soil to both sides of the cable laying trench, avoiding any impact on subsequent cable laying operations and creating conditions for subsequent trench soil backfilling. The surface soil separation mechanism of the multifunctional underground cable laying device is described in Figure 3.



1-Excavate the cup teeth of the digging mechanism; 2-Excavator construction of excavation chain; 3-Lay the walking chain plate of the device; 4-Lay the device mainframe; 5-Soil sorting institutions separate soil outlets; 6-Soil separation mechanism mixing shaft; 7-Soil separation mechanism separates soil blades

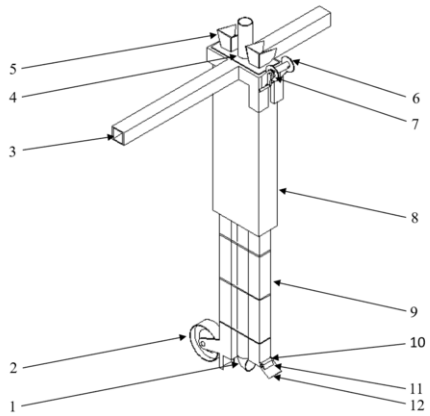
Figure 3. MFUBLD Surface Soil Classification Mechanism

2.4. MFUBLD Cable Anti Twist Damage and Laying Mechanism

The cable laying mechanism has a telescopic function to ensure that there is no interference during rapid operation. The square guide system at the front and bottom of the cable laying mechanism guides the filler into the laying trench, and at the same time, slides the cable that meets the laying diameter down from the feeding port to complete the cable laying layout. The back-end high-level square guide system guides the filler into the laying trench, completely covering the bottom and top of the cable with the filler, completing the laying operation. The mechanism is shown in Figure 4.

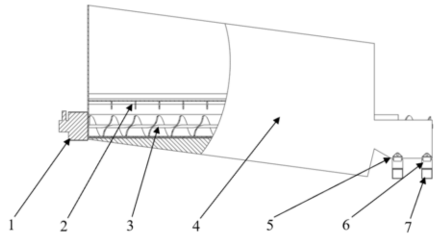
2.5. Filler Filling Mechanism of MFUBLD

The cable laying mechanism is installed on the multifunctional underground cable laying device rack, with extension and retraction functions. When moving quickly, the cable laying mechanism can retract to avoid interference. When it is necessary to lay cables, the load-bearing wheel of the laying device touches the bottom of the laying trench, and the shovel plate at the front end can scrape off the floating soil in the trench and on the side walls during excavation, and move the floating soil to the front for stacking. When a certain amount is reached, the soil trench excavation mechanism can bring out the trench to ensure that there is no soil or stones in the trench, avoiding the waste of length caused by cable twisting during laying, and at the same time, avoiding sharp stones in the trench from damaging the cables.



1-The cable passes through the lower port; 2-Install load-bearing wheels in the laying mechanism; 3-Lay the main support of the mechanism; 4-Cable passes through the upper port. 5-Laying filling material inlet; 6-Lay the winch trench for the mechanism; 7- Laying winch; 8-Lay the casing of the mechanism; 9-Depth extension end of the laying mechanism; 10-Expansion joint at the feeding port of the paver; 11- Laying mechanism feed inlet; 12-Laying device push shovel

Figure 4. MFUBLD cable anti twist damage and laying mechanism



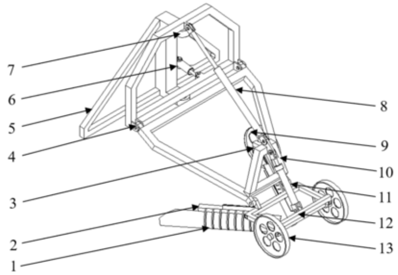
1-Fill storage compartment hydraulic motor; 2-Packing storage compartment; 3-Packing storage compartment winch; 4-Protective cover for filling mechanism; 5-Flip cover baffle for filling conduit; 6-Packing conduit; 7-Packing conduit flip tube

Figure 5. MFUBLD filler filling mechanism

When laying, open the winch trench to release the winch cable. The multifunctional cable laying device moves forward according to the construction route. The square guide system at the bottom of the front end of the cable laying mechanism guides the filler into the laying trench. At the same time, the cable laying mechanism can slide the cable that meets the laying diameter from the feeding port to complete the cable laying layout. The high-level square guide system at the back end guides the filler into the laying trench to ensure that the filler completely covers the bottom and top of the cable, completing the laying operation. The cable anti twisting and damage and laying mechanism of the multifunctional underground cable laying device are shown in Figure 5.

2.6. MFUBLD's Soil Landfill and Backfilling Mechanism

After the cable laying is completed, the ground surface needs to be restored to its original state. The soil landfill and backfilling mechanism completes the land leveling operation after soil excavation and cable laying through a series of mechanical and hydraulic mechanisms in an orderly manner. The soil landfill and backfilling mechanism is revealed in Figure 6.



1- Soil backfilling shovel; 2-Backfill the shovel seat; 3-Push shovel front axle seat; 4- Push shovel longitudinal swing frame; 5- Horizontal pivot frame seat; 6-Horizontal rotating frame hydraulic cylinder body; 7-Horizontal rotation frame; 8- Longitudinal swing hydraulic cylinder rod; 9-Push shovel seat front wheel; 10-Longitudinal swing support frame; 11-Longitudinal swing hydraulic cylinder body; 12-Vertical swing frame; 13-Pushing shovel seat rear wheel

Figure 6. MFUBLD Soil Landfill Backfilling Mechanism

3. Working Principle of Multifunctional Underground Cable Laying Device

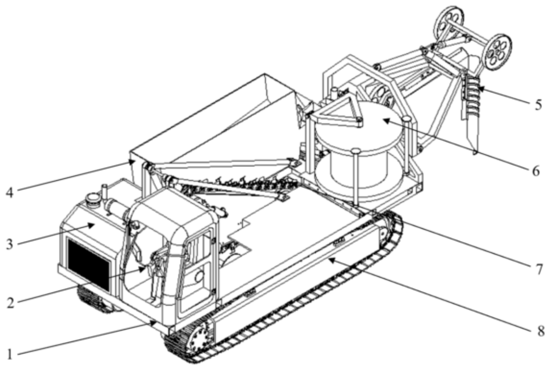
After the multi-functional underground cable laying device is started, the vehicle moves forward at a predetermined speed, and the chain excavation mechanism starts to the specified speed. According to the construction requirements, the cable is excavated to the specified depth from the inlet pipe. The cable is placed into the excavated trench, and the vehicle moves forward while the filling conduit is laid with filling material at the bottom of the cable trench. The pipeline is then laid, and the filling material is introduced into the buried cable wire through the filling inlet pipe, and the excavated floating soil is shoveled into the trench. Implement the functions of cable transportation, soil excavation, cable laying, filler filling, and soil backfilling in sequence to ensure that the laid cables meet the requirements of construction operation standards.

4. Overall Structural Design of Multifunctional Underground Cable Laying Device

According to the design plan, the multifunctional underground cable laying device is designed to sequentially carry cables, excavate soil, lay cables, fill materials, and backfill soil during the completion of cable laying operations. Ensure that the laid cables meet the requirements of construction operation standards. The overall structural design of the system is presented in Figure 7.

In the overall design scheme of the multifunctional underground cable laying device, the three-dimensional design rendering of the multifunctional underground cable laying device is shown in Figure 8.

According to the design scheme of the multifunctional underground cable laying device, Figure 9 shows the three-dimensional design effect of the cable laying construction operation.



1-Vehicle chassis; 2-Cockpit; 3-Power mechanism; 4-Packing mechanism; 5-Backfilling mechanism; 6-Cable reel loading mechanism; 7- Mining institutions; 8-Walking mechanism

Figure 7. Overall structural design of MFUBLD

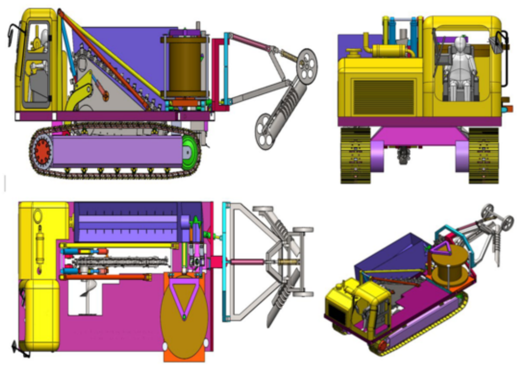


Figure 8. 3D design rendering of multifunctional underground cable laying device

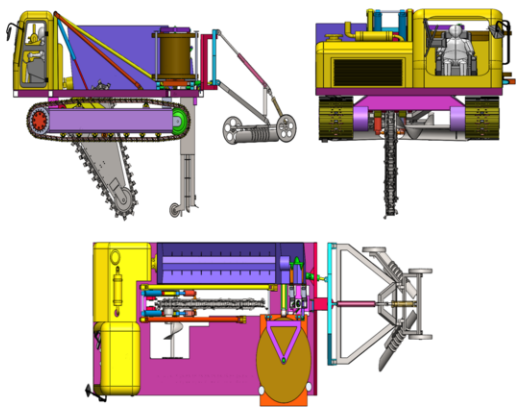


Figure 9. Three-dimensional design rendering of the MFUBLD in operation state

5. Conclusion

Based on the study of the advantages and disadvantages of traditional underground cable laying products, a comprehensive analysis was conducted on the difficulties of underground cable laying. A multifunctional underground cable laying device was designed, which has the following characteristics:

(1) The multifunctional underground cable laying device can adapt to various construction environments and working conditions.

(2) The multifunctional underground cable laying device can quickly replenish cables through a self-loading and unloading cable mechanism when the size of the cable reel is limited and the cable length is insufficient.

(3) The multifunctional underground cable laying device can sequentially carry cables, excavate soil, lay cables, fill materials, and backfill soil when completing cable laying operations.

(4) The multifunctional underground cable laying device can ensure that the laid cables are not damaged and can efficiently complete the laying construction tasks according to the requirements of underground cable construction.

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