Design and Experimental Research of Rope Missle

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Abstract. The UAV (unmanned aerial vehicle) unfolding guide rope is the construction process adopted in the tension stringing of overhead power transmission line. At present, due to the limit of UAV control precision, the function of threading the guide rope into the paying-off sheave groove directly cannot be realized, and we can only unfold the guide rope of UAV to the cross arm of iron tower, and then, make the operation personnel at height transfer the guide rope into the steel wire groove of paying-off sheave. Therefore, the construction efficiency of this process is relatively, and there is operation at height, with a certain safety risk. In this project, it is planned to develop a launching device carried by UAV, and this device uses the compressed carbon dioxide (CO₂) which is relatively safe as power source, which realizes the instantaneous release of compressed air through electromechanical servo control, and then generate the power which promotes the “rope missle” to fly. The tail of “rope missle” is connected with guide rope, and when it flies forward, the traction guide rope will move forward synchronously. After the “rope missle” threads into the sheave, the compressed air will be released completely, and then, the “rope missle” will transfer into the motion of a free falling body, thus further driving the falling of guide rope, so as to realize the function of “rope missle” tracts the guide rope to realize threading into the paying-off sheave.

Key words: guide rope; compressed air; UAV; launching device

1. Introduction

With the continuous development of our country’s economy, and as the foundation of social production, the demand of the society for power supply is increasing day by day, and the matched power grid construction tasks are also more and more arduous. However, during the process of power grid erection construction, the power grid erection is a decisive part, which directly influences the construction progress of power grid erection and completion quality of engineering. [1-3] During the construction, to erect the power transmission line to the power transmission iron tower, workers are usually required to thread the guide rope into the paying-off sheave. On one hand, this limits the construction efficiency severely, and on the other hand, this also increases the hazards during the construction severely. [4-9]
To avoid the operation risks of power workers and enhance the working efficiency, the research reported in this paper focuses on the operations including utilizing rope missile to carry the guide rope, and then substitute the power workers to complete the erection of guide rope. Take the rope missile as the actuator of stringing operation, so as to substitute the power workers to complete the action of threading guide rope into the paying-off sheave.

2. System Structure
The rope missile system mainly refers to dedicated “rope missile” subsystem, which consists of missile body case, CO₂ air cylinder, striker, release system, control circuit and other main parts. The details of the rope missile are shown in Figure 1.

(a) Appearance Diagram of Rope Missile

(b) Internal Structure of Rope Missile

(c) Side View of Rope Missile
3. Working Principle of “Rope Missile” System

The rope missile is protected with external case, and the appearance diagram of rope missile is shown in Figure 1(a). The external case includes front cover and missile body, and the thread mode is adopted for rotary joint between front cover and missile body. Screwing off the front cover, as shown in Figure 1(b) and Figure 1(c), insert the compressed air cylinder, and the rear part of air cylinder is fixed with air cylinder washer, and the air cylinder washer is fixed with screw and missile body.

The tail of striker is thread, fixed on the striker base via rotary joint, and a spring is installed between striker base and spring limit base. There is a hole in the middle of spring limit base, the screw rod at the tail of striker base threads into the hole, which is to be fixed with locking nut. The spring limit base is fixed with missile body via screw.

The tail of locking nut is connected with the output shaft of speed reduction motor, and the jackscrew is adopted for fixing. The speed reduction motor is installed in the motor base, and the motor base is fixed with the missile body via screw. The main control circuit board is installed on the motor base, connected with the tail flow electrical combination via wire arranging. The tail flow electrical combination, as shown in Figure 1(d) has four electronic contacts, with holes on both sides, used to release gas. There is a connection hole in the middle, which is used to install fixed guide rope.

In case of launching, the rope missile is connected with the control system via four contacts on the tail flow electrical combination, so as to obtain electric energy and control command. The control interface adopts RS-232 serial port connection to receive the control command issued from upper computer, and then give feedback information to the upper computer.

If the rope missile receives the effective launching commands (including unlocking of authority, command launching, etc.) issued by the upper computer, the main control circuit board will drive the speed direction motor for rotation. When the motor is rotating, the output shaft will drive the locking nut for rotation, and the tail thread of striker base will be screwed off from locking nut gradually till that it is released.

At this time, the spring will promote the striker base to move towards the air cylinder mouth rapidly, and the striker which moves at a high speed will pierce the sealing aluminium foil at the air cylinder mouth, and then the high pressure gas will be released and exhausted from the air exhaust outlet, so as to promote the rope missile move forward in the launching tube, thus realizing the function of rope missile launching.
4. Design Thought of Structure of “Rope Missle” System
To solve the problem of personnel at height threading guide rope into sheave during the stringing, the function of UAV carrying rope missle to tract the guide rope to thread into the sheave is taken into consideration, and there has been no example of this technology at home and abroad at present.

4.1. Model Selection of Power
With regard to the design of rope missle, it is necessary to consider the model selection of launching power source firstly, which shall not only launch the rope missle, but conform to relevant national rules, and the specific kinetic energy of rope missle shall be smaller than 1.8J/cm²; the management and using of gunpowder are strict, and the spring rubber band is too powerful, so these two power sources are excluded. Through referring to the power source of net gun in the public security system, finally, the compressed CO₂ gas is adopted as the power source of rope missle, and this kind of power is safe and controllable, with convenient storage. There are two modes of steel-type air cylinder of CO₂ compression: 12g and 45g; the weight and external diameter of 12g air bottle are more convenient for UAV in installation and carrying.

The internal diameter of missle body is 18.7mm, with external diameter of about 22mm, length of about 198mm, and weight of missle body of about 140g.

Through analysis and calculation of above parameters, when the launching tube is 30cm in length, the missle body can obtain the initial speed of about 10-15m/s, which basically conforms to the system design requirements.

4.2. Structure of Striker Device
The compressed air cylinder refers to steel structure, and the mouth of air cylinder has a layer of aluminium film, and only after the aluminium film is pierced can the gas be released. In this case, it is necessary to research a kind of electronic and mechanical structure to pierce the aluminium film via the numerical control device.

1. Confirm that the striker is to be adopted to pierce the aluminium film.
2. After testing, it is known that only the striker of 50N can be used to pierce the aluminium film, and through calculation with Hooke’s law, we can select the spring which can generate thrust required by striker.
3. The release structure adopts thread unlocking device, and the striker and thread unlocking device adopts top-quality steel material, which not only guarantees that the thread of striker structure will have no thread slipping during the using process; in the static status, the thread device is used to stick the spring; in the working status, the spring is to be released via controlling the rotation of thread shaft.
4. The thread shaft is to be driven via motor, and after adopting the motor of n20 which is provided with reduction gearbox, the speed reduction ratio of thread shaft to motor is 1:60, and the power supply voltage of motor is 5V.

4.3. Control Circuit
The control circuit can store the secrete key of launching of “rope missle”, and it can drive the striker release mechanism to complete the execution of launching command;

Considering safety, each main board of the circuit part which is driven by the striker has sole ID No. and secrete key for launching unlocking, and the tail of missle body of circuit is reserved with power supply and data interface; the launching system must very the secrete key of launching via dedicated protocol, so as to drive the striker, thus ensuring safety and reliability of missle body launching.

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The design diagram of control circuit is shown in Figure 2.

![Control Circuit Diagram](image)

**Figure 2** The design diagram of control circuit

The inner of missile body has driving circuit for micro-processor and electro-mechanical system, and the power supply and data connection of rope missile and launching system are realized via four electrical contacts at the tail of missile body. The micro-compressor is mainly used to complete the logic function control and control of secret key of launching, which can avoid risks brought by wrong operation and unauthorized launching.

### 4.4. External Case of Missile Body

Through survey and testing, the external case adopts aerial composite material, featured by light weight and solid structure; the external case is used to package and fix all internal components; the surface electroplating technology of all aluminium alloys is adopted to reduce the friction with launching tube to the greatest extent.

The external case tail is designed with a washer, and the washer is designed with an open hole for gas exhaust; the electronic contact is used for power supply and data connection; the middle connection hole is used to carry the guide rope.

### 5. Key Points of the System

1. Adopt compressed air as power, and adopt the electronic circuit to control mechanical servo device, so as to release the striker; the striker which moves at a high speed is adopted to pierce the sealed aluminium foil of air cylinder, so as to realize the gas release, thus completing the launching of rope missile and traction of guide rope.

2. Adopt the thread at the tail of striker base, and connect it with the locking nut driven by speed reduction motor, so as to realize the locking and release of striker.
6. System Test

6.1. Function Testing

6.1.1 Force Required by Striker to Pierce Aluminium Film of Compressed Air Cylinder Connect the striker and the common spring, and place them into a sleeve tube. Adopt 8 pieces of thin rope to connect at the edge of striker, and connect the other end of thin rope with dynamometer. In case of testing, fix the compressed air cylinder in front of the sleeve tube mouth, and pull the dynamometer towards the back of sleeve tube. After pulling to a certain value, shear the thin rope at the dynamometer end, and then the spring will promote the striker to pierce the aluminium film.

Conduct testing repeatedly, and then test the force required by striker for piercing the aluminium film of compressed air cylinder.

6.1.2 Testing of Spring inside Rope Missle Select the spring radius according to air cylinder size; calculate the elasticity modulus and length of spring as required according to the data obtained from the test in 5.1.

6.1.3 Testing of Thread Locking Device Rotate the thread column, make the thread column separate away from the thread cap, release the spring, and during the testing, it is found that the thread has been polished gradually after the thread column and thread cap made of aluminium have been used for many times, so there is safety hazard. Later, after the thread locking device is changed into that made of steel, and after multiple times of testing, it is proved to be reliable and stable.

6.2 Performance Testing

Install an instrument for speed measurement in front of the rope missle device. The speed measurement instrument consists of two optoelectronic switches, one of which emitting infrared light, and the other receiving infrared light. When there is an object in the middle of two switches, there will be a signal, and the distance between two optoelectronic switches is 5cm.

When the rope missle is launched out of the tube, the head of shell will successively shut out the first optoelectronic switch and the second optoelectronic switch, and these two optoelectronic switches will generate two signals; through the time points recorded by two signals, the initial speed of rope missle can be worked out, and through the diameter and weight of rope missle, we can work out the specific kinetic energy of missle.

It is worked out that the specific kinetic energy of rope missle leaving the shell is smaller than 1.8J/cm², which conforms to relevant legal rules of the State.

7. Conclusions

The using of UAV with the view of threading by carrying rope missle provides technical guarantee for automation of guide rope unfolding in the power stringing engineering, and targeting the problems including low automation degree of guide rope unfolding, labor force and time waste and that there is a certain danger, this paper analyzes the actual task demand of unfolding of guide rope, researches the mechanism design of a kind of rope missle, designs and realizes the rope missle for realizing automatic unfolding of guide rope, and verifies the method correctness under the simulation environment. This method supplements the insufficiency of existing construction method of guide rope unfolding, which has significant meaning for enhancing construction efficiency of power stringing and reducing construction cost.

Main research achievements of this paper are shown as below: according to actual demands of stringing tasks, it has been proved that when the rope missle is launched, a sufficient initial speed will be obtained in the launching tube, and after the rope missle leaves the launching tube, there will still be a certain power, which makes the rope missle fly forward, thus driving the guide rope to fly effectively, and then the paying-off operation function by threading the guide rope into the sheave is
realized. It can be used to substitute the construction technology of manual operation of artificial tower climbing. Targeting demand, the traditional method of threading guide rope into sheave is improved by combining actual situation. A corresponding experimental platform is set up, and under the laboratory environment, the experimental verification is conducted to the feasibility of “rope missle” guide; in addition, the method correctness is verified, the stringing process is simulated, and the result shows that the “rope missle” meets the stringing requirements.

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