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Research on a New Type of Electric Flap Mechanism

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Abstract: Aiming at the technical requirement of shelter panel overturning, this paper designs and develops a new type of panel overturning mechanism. Starting from the principle of the overall panel overturning mechanism, the overall structure and components of the electric panel overturning mechanism are proposed. The working principle and structural characteristics of each component are analyzed in detail, and finally a panel motion control system based on electric capstan control is realized. Practical engineering applications have verified that the electric panel overturning mechanism operates stably and has high reliability.

Keywords: Panel Overturning Mechanism; Working Principle; Electric Capstan; Motion Control System; Stable Operation; High Reliability

1. Introduction

In recent years, shelter systems have been increasingly widely used in various fields. As a load-bearing platform, the functional requirements of shelters have also been continuously improved. This paper describes an electric hatch panel flipping mechanism, which realizes the up-and-down flipping motion of the hatch panel through a control mechanism, featuring convenient and flexible operation. For operators, no professional technical training is required; all actions of hatch panel flipping can be completed with one-key operation via a single control box. The electric flap mechanism features convenient operation and adapts to the characteristic of rapid deployment of control equipment [1].

2. Application Background

As a mainstream transport carrier, shelters are equipped with various high-precision communication devices, and the normal operation of these devices must be guaranteed during communication. In some communication shelters, the communication host can be installed inside the shelter and the antenna outside to realize external communication functions. However, when the equipment in some other communication shelters is in operation, it is necessary to directly perform environmental scanning of the outside world, in which case the hatch panel undoubtedly becomes the main obstacle to signal transmission. If the hatch panel is not installed, the signal transmitting part of the equipment will be directly exposed to the outside, and the sealing, rainproof and even anti-theft performance of the equipment will become important issues.

In summary, the functions of such shelters are summarized as follows: when the equipment is in operation, the hatch panel must be fully open; after the equipment stops working or during vehicle transportation, the hatch panel must serve as a protective layer for the equipment and is indispensable. Against this background, the hatch panel must realize an automatic retraction function. In this case, the external communication scanning area of the equipment is: length × width = 6000mm × 2050mm . According to this range, in accordance with General Specification for Shelters of Military Electronic Equipment GJB870-90, the weight density ρ of the hatch panel is 25kg/m², and the weight of the flipping panel can be calculated as follows [2]:

$$m=\rho\times S=6\times 2.05\times 25=307kg \quad (1)$$

For a hatch panel of such weight and size, frequent manual disassembly or pushing up and down is relatively difficult to achieve. A new type of electric control flipping mechanism is studied to realize the flexible up-and-down flipping movement of the entire hatch panel. This technology has been successfully applied in products and has met the requirements after user testing.

3. Research on Key Technologies

To realize the opening and closing actions of the flap panel, the research focuses on the flipping control mechanism and analyzes the key technologies and technical performances of

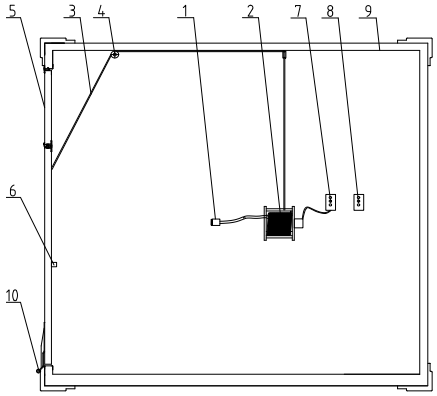
the entire mechanism, which must meet the following requirements:
1. Realize a fully automatic operation process with dual electric and manual functions, featuring simple and flexible operation;
2. Ensure safe and reliable operation with self-locking capability at any position;
3. Have no restrictions on installation space and allow flexible installation according to actual conditions;
4. Possess high load-bearing capacity and a high safety factor;
5. Impose no special requirements on operators and enable easy and simple operation;
6. Be economical, practical, and reasonably priced.
Combined with the above key technologies and the structural characteristics of the flipping side panel, the electric winch mechanism is selected as the power control device of the entire system, pioneering its application in the field of shelter technology.

4. Electric Flap Mechanism

4.1 Principle of the Flap Transmission Device

The electric flipping mechanism is mainly driven by the vehicle's own power system to actuate the winch mechanism, which in turn drives the up-and-down flipping motion of the flap panel. The core of the flap transmission device is the electric winch mechanism, which is composed of a motor, clutch, controller, winch drum, remote controller, steel cable guide, etc.
1. Motor: Also known as the electric machine, this component is a DC motor.
2. Clutch: Responsible for engaging and disengaging the winch drum, controlled by a simple handle.
3. Controller: The electrical control unit of the winch, which receives signals from the remote controller. Its internal structure is the complete machine circuit system, capable of reversing the rotation direction of the motor.
4. Winch drum: The steel cable is wound around the drum, which is driven to rotate by the motor. The rotation direction can be changed via buttons on the remote controller.
5. Remote controller: Also referred to as the handle, it allows remote control of the winch operation, available in both wired and wireless types.
6. Steel cable guide: Also known as the guide pulley or direction-changing pulley. It directs the steel cable to the target at a specific angle when required.
The working process of the flap transmission device is as follows: The vehicle battery supplies power to the motor, which drives the drum and the main shaft. The main shaft then drives the planetary gear set to achieve significant speed reduction, and the increased torque is transmitted back to the drum, which drives the steel cable. A clutch is directly connected between the motor and the reducer, controlled by a handle switch. The braking unit is integrated in the drum; when the motor stops and the steel cable is taut, the drum automatically locks. The end of the steel cable is connected to the flap panel, with a guide pulley installed between them to change direction. The retraction and release of the steel cable drive the movement of the flap panel [3].

4.2 Composition of the Flap Transmission Device



1 – Power input; 2 – Winch; 3 – Steel wire rope; 4 – Direction changing device; 5 – Flap panel; 6 – Detection head; 7 – Control box; 8 – Wireless control box; 9 – Shelter; 10 – Flap hinge

Figure 1. Overall Structure of the Flap Device

As shown in Figure 1, the electric flap mechanism consists of ten major components: power input (1), winch (2), steel wire rope (3), direction changing device (4), flap panel (5), detection head (6), control box (7), wireless control box (8), shelter (9), and flap hinge (10). The in-position control during the flap movement is realized by real-time detection via the detection head (6). Once the panel moves to the target position, a position signal is automatically sent to the winch (2) to cut off its operation, achieving the in-position stop function. The power input (1) supplies power to

the entire electric mechanism, meeting the power supply requirements. The winch (2) is connected to the flap panel (5) via the steel wire rope (3), and the winch (2) can automatically retract and release the steel wire rope (3), enabling the flap panel (5) to perform flipping motion around the flap hinge (10). The direction changing device (4) distributes the force on the steel wire rope (3) or changes its direction. The entire process is controlled by the control box (7) and the wireless control box (8) [4].

4.3 Winch Mechanism

In this case, considering overall performance, reliability, maintainability, and cost comprehensively, the electric winch is selected as the power unit of the entire electric mechanism. The advantages of the electric winch lie in its ability to be driven by the vehicle's own power, operating normally even when the vehicle is turned off. It features simple installation and allows multi-position mounting as well as rapid displacement. Its external structure is shown in Figure 2 [5].

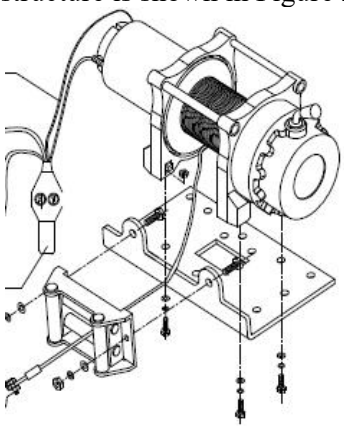


Figure 2. External Schematic of the Electric Mechanism

Based on the load capacity of the electric mechanism, the weight of the flap panel in this case is 307kg, so the electric winch model EWX4500 is selected. Its performance parameters are listed in Table 1.

Table 1. Parameters of the Electric Mechanism

Item Parameters	Rated pulling force 20.0kN (4500lbs)		
Motor (Permanent magnet DC)	nput power: 2.4kW (12V); 2.9kW (24V) Output power: 1.03kW (12V); 1.3kW (24V)		
Reduction ratio	172:1		
Steel wire rope (diameter × length)	Φ6.4mm × 14.5m		
Drum (diameter × length)	Φ45mm × 93mm		
Mounting dimensions & screw size	129mm × 96mm; 4-M8		
Model	EWX4500D	EWX4500A	EWX4500U
Overall dimensions (L×W×H)	378mm × 126mm × 165mm	378mm × 126mm × 165mm	378mm × 126mm × 165mm
Net weight (kg)	12.6	13.1	13.0

In Table 1, the rated pulling force is 20kN (equivalent to 2000kg). For a flap panel weighing 307kg, the rated pulling force is far greater than the panel weight under a 5-fold safety factor, meeting the operational requirements.

4.4 Reversing Device

The power output by the power unit must be distributed to each moving body (i.e., the flap panel) through a motion distributor. In the actual layout, the electric mechanism is far from the moving body, so the force output by the electric winch needs to be redirected to connect to the flap panel. The direction-changing device is divided into fixed pulleys and movable pulleys. Fixed pulleys mainly change the direction of force and are fixed in position and cannot be adjusted. Movable pulleys can distribute force according to actual conditions and act as a force distributor during movement. By reasonably arranging fixed and movable pulley mechanisms between the winch and the flap panel, the output force of the winch can be effectively transmitted to the flap panel [6].

The reasonable arrangement of the direction-changing device not only affects force transmission but also determines whether the entire force movement process is smooth. Unreasonable arrangement will increase the load of the entire movement mechanism, cause damage to the steel wire rope, wear of the direction-changing device, increase noise during transmission, and ultimately reduce the service life of the entire mechanism. The following analyzes the arrangement, structural theory, and actual use of the direction-changing device, as shown in the figures.

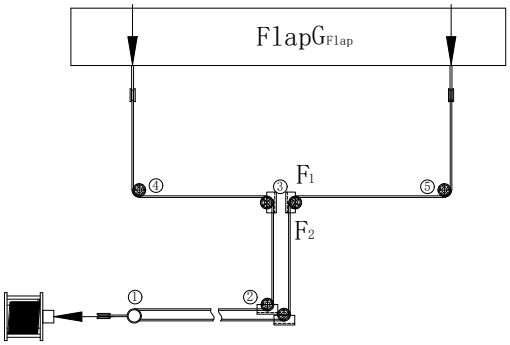


Figure 3. Direction-Changing Device Arrangement 1

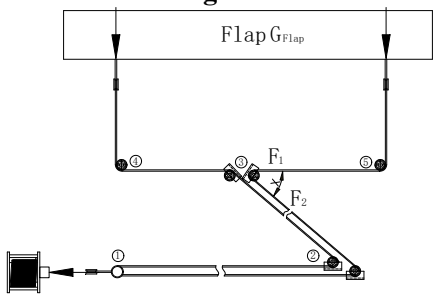


Figure 4. Direction-Changing Device Arrangement 2

In Figures 3 and 4, the electric mechanism realizes the flap panel movement through direction-changing mechanisms (1)(2)(3)(4)(5):Movable pulley is selected at position (1) for direction change, which can decompose and transmit force and move back and forth with the flap panel's movement. Fixed pulleys are used at positions (2)(3)(4)(5), which are fixed to the compartment wall and mainly change the direction of force. From Figure 1, movable pulleys exert pulling force on the front and rear ropes, while fixed pulleys only change the direction of force.

In Figure 4, fixed pulleys at positions (2) and (3) are obviously subjected to force [7].

In Figure 3: F1= F2= Gpanel/2, F1 and F2 have no component force at position (3).In Figure 4: F1 has no component force at position (3), and the force applied at position (3) by F2 is: F = F2*sinX .

From the above, in Figure 4 (fixed pulley arrangement), there are three positions with significant force during the entire flipping process. At the same time, the installation position of the fixed pulley on the compartment wall is subjected to large force. If the compartment wall does not have sufficient strength, the pulleys at positions (2) and (3) will fall off from the compartment wall, causing the entire mechanism to loosen and the flap panel to drop. This conclusion was verified during the actual project test. Therefore, for the entire mechanism design, a reasonable layout of the direction-changing device can significantly improve the performance of the entire mechanism [8].

4.5 Operation and Control

The electric mechanism is powered by the vehicle battery. Its operation control is divided into manual and electric modes, which are switched via the clutch operating handle on the electric mechanism.

Manual operation: Turn the clutch handle to the “disengaged” position to release the clutch. The length of the steel wire rope connected to the winch can be manually adjusted and fixed at any position. Note that a certain length of steel wire rope must be retained on the winch to ensure normal operation.

Electric control: Turn the clutch handle to the “engaged” position to re-engage the clutch. If necessary, rotate the drum until a clicking sound is heard to confirm full engagement.

Electric control includes wired switch control and wireless remote control. Wired switch control: Ensure the plug of the wired switch is connected to the socket of the electric control box. The operator only needs to press the “in” and “out” buttons on the wired switch to realize forward and reverse rotation of the electric mechanism, thereby controlling the lifting and lowering of the flap panel.

Wireless remote control: Different from wired control, the operator can stay away from the control mechanism and stand near the flap panel to directly observe its movement, enabling real-time adjustment of the panel motion as needed.

Both electric wired and wireless control modes support inching operation and stop-at-any-position function, ensuring a safe, stable and fast operation process.

4.6 Characteristics of the Flap Mechanism

The electric flap mechanism adopts a modular design with a high degree of automation, which is convenient for installation in the limited space of the shelter. It realizes the automatic opening and expansion of the flap, features strong operability, meets the working requirements of the cabin equipment in specific scenarios, and enables the rapid deployment of equipment in the command and control cabin

[9].

The electric flipping mechanism is driven by the vehicle's own power system to actuate the winch mechanism, which in turn drives the up-and-down flipping motion of the flap panel. Compared with other similar winch mechanisms, its main advantages are:

1. It can operate normally even when the vehicle is turned off, which is unmatched by other winch mechanisms.
2. No special requirements are imposed on the operating site or personnel; the operator can operate via the knob on the remote controller from any position.
3. There is no fixed installation position between the flap panel and the winch mechanism, which can be determined according to actual conditions, offering flexible direction conversion.
4. The flap panel can be self-locked at any position during the entire movement, ensuring safety and reliability.
5. The flap mechanism has a large unidirectional load-bearing capacity and a high safety factor.
6. The biggest advantage is that it can operate as long as the vehicle battery has power.

5. Application Examples

This flap flipping mechanism has been applied in a project, realizing the automatic opening and closing of the shelter's full-side panels with high automation and one-key retraction/extension. The actual application effects are shown in Figures 5, 6 and 7: Figure 5: The full-side panel is in the closed state, which must ensure the shelter's sealing and rainproof performance. Figure 6: The flipping mechanism is in operation, with the side panel opened to a certain angle. Figure 7: The side panel is fully opened and stopped in position, meeting the equipment's functional requirements. Throughout the process, the operator only needs to use a wireless remote control box, and the full opening of the flap panel can be completed in just 2 minutes, which is convenient and efficient.

In practical applications, the shelter underwent tests including road running, rain, lifting and flipping actions. The flipping test involved 20 consecutive opening and closing cycles without interruption, proving that the entire flipping mechanism operates smoothly, safely and reliably, with high self-locking performance. Compared with other transmission mechanisms, this mechanism has lower cost and broad application prospects [10].

Figure 5. Before Flap Actuation

Figure 6. During Flap Actuation

Figure 7. Flap Actuation Stopped

6. Conclusion

This paper describes a new type of flap flipping structure, focusing on the electric control mechanism for flap actuation. It elaborates on the structural composition, key component characteristics and optimized layout installation

of the mechanism, as well as its operation and control modes. Through this paper, a new idea and method for electric control mechanisms is provided.

After passing tests including rain tests and road running tests, this technology meets all requirements while achieving economic cost savings.

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